David Axon/Rochester Institute of Technology  
The Inner Structure of OH Megamaser Galaxies: The Genesis of the Unified Scheme of Active Galactic Nuclei

OH megamaser galaxies (OHMG) represent a key post-merger phase in the evolution of the Ultra-Luminous Infrared Galaxies (ULIRGs) population, in which an edge-on circum-nuclear gas disk (proto-torus) has already formed. Detailed interferometric mapping of maser sources implies that they originate in dense edge-on rotating molecular gas within a few tens of parsecs of the AGN. In addition, the OH lines are often broad (Doppler widths ~ 1000 km/s), implying large dynamical masses in the central few parsecs. In many systems the OH lines also show high velocity asymmetric tails suggesting large-scale outflows that could be clearing away enshrouding dense molecular material. Taken together this evidence points to a picture in which an OHMG hosts a nascent QSO surrounded by a flattened distribution of dense molecular gas that is in the process of being cleared away along the rotation axis of the maser disk. A great advantage of studying OHMG systems over the general ULIRG population is that the circum-nuclear disks are effectively “fixed” at an edge on orientation, thereby breaking the degeneracy between the number of clumps and inclination in state of the art clumpy torus models.

We have been awarded HST time in cycle 17 to conduct a comprehensive study of structure of the circum-nuclear gas, and its relationship to the radio structure and that of the maser disk, of large sample (80) of OHMG. This work is supported by ground-based spectropolarimetry, integral field spectroscopy and new radio continuum observations. Our overall objective is to probe the final stages of evolution immediately before the full-emergence of an enshrouded AGN as the circum-nuclear dust is dispersed by starburst and AGN-induced outflows.

The specific scientific goals of this ADP proposal are to retrieve and analyze the Spitzer thermal-IR 5-70 micron imaging and IRS spectra of the subset of 72 of our targets for which Spitzer observations are available in the archive. We aim to establish the relationship between host and circum-nuclear ionized gas and dust structures in different OHMG spectroscopic types (AGN, Starburst, Composite) and model the AGN and starburst contributions to the mid-IR SED. Combining these with our other data we will address a number of important questions: is the mid-IR SED consistent with an edge-on circum-nuclear dust structure, as expected from the maser observations? What is the relative orientation of the Maser molecular structure and the ionized gas? Is there a connection between AGN heating of the circum-nuclear dust and wind or radiation driven
outflows from the nucleus? How does the bolometric luminosity of the AGN relate to the OH line luminosity, FWHM and line shape? In turn these will relate the ionizing luminosity to the covering factor of the torus and the enclosed dynamical mass. When complete, this study should provide new insights on the relationships between the fundamental physical parameters of the AGN, including black hole mass, accretion and mass outflow rates, and the large scale properties of the host galaxy.

Kazimierz Borkowski/North Carolina State University
Galactic Supernova Remnants in the Infrared: An Archival Survey with Spitzer's MIPS and IRS

Supernova remnants provide information on the nature of the progenitor supernova, the dispersal of elements both previously formed and newly synthesized, and the interaction of this material with the surrounding medium. Shock waves from supernovae compress and heat interstellar material, and are likely sources of acceleration for Galactic cosmic rays. They are sources for at least some of the dust observed in both the early and current universe. However, there are still holes in our understanding of the dynamics of the ejecta and the interaction of the forward shock with the ISM. Their efficiency at accelerating particles, ability to synthesize large amounts of freshly formed dust from refractory elements, and role in the evolution of the dust and gas in the ISM are still unresolved questions.

We propose an archival study of Galactic SNRs observed in the mid- and far-infrared with the Spitzer Space Telescope. Of the 274 known SNRs in the Galaxy, about 200 of them have been observed at 24 and 70 microns by either the MIPSGAL survey of 300 square degrees of the inner galactic plane or a pointed observation. Previous IR surveys at similar wavelengths done with IRAS have confirmed that many SNRs are visible at IR wavelengths, primarily due to continuum emission from warm dust collisionally heated by energetic electrons behind the blast wave. We expect to see emission at 24 microns in particular from dozens, perhaps up to 50%, of the SNRs in the Galaxy observed with Spitzer. Younger remnants in their non-radiative phase show a tight morphological resemblance in emission seen at IR and X-ray energies. We have identified more than 30 Galactic SNRs observed by Spitzer that have full- or partial-shell detections in both 24 microns and Chandra or XMM-Newton X-ray images. This tight IR/X-ray correlation is driven by the physics of the interaction of the forward shock with the ISM; the same hot gas that radiates in X-rays collisionally heats dust grains to IR emitting temperatures.

We have developed models of collisionally-heated dust that allow us to learn about both dust and gas properties in the shocked ISM. In conjunction with X-ray observations, which give information about the plasma temperature, modeling dust continuum can allow the inferences of the shocked dust mass, fraction of dust destroyed in the shock, and the plasma density - information not obtainable in any other way. The specific goals of our proposal are as follows: 1) Determine post-shock gas densities in SNRs - This will be done in conjunction with analysis of archival X-ray observations, using our shock codes calculating the collisional heating and destruction of grains behind a shock. 2) Measure dust-to-gas ratios outside those SNRs - making use of our calculated densities.
3) Test and refine models of dust heating and destruction - Our shock models now include various important physical effects bearing on grain properties, such as porosity, which can be tested against these observations. 4) Produce a uniform catalog of Spitzer observations of SNRs - An important byproduct of our project will be the creation of a catalog of remnants observed by Spitzer, uniformly reduced and characterized, which should be a valuable resource for current and upcoming IR missions such as WISE, Herschel, and JWST. 5) Measure or place limits on amount of ejecta dust produced in SNe. - Flux measurements or upper limits at 70 microns will place constraints on the amount of ejecta dust produced in both core-collapse and type Ia SNe.

William Brandt/Penn State University
X-ray Investigations of Quasars with XMM-Newton: Outflow Energetics and High-Redshift Intrinsic Absorption

Active Galactic Nuclei (AGNs) are among the most extreme physical environments in the Universe, and it now appears that feedback from AGN winds and jets plays a critical role in the evolution of typical massive galaxies and larger-scale structures. This proposal requests funding to support work on two XMM-Newton guest investigator projects that have already won competitive observing time to study quasars, the most luminous examples of AGNs.

The first project is an approved XMM-Newton Large Program that won 350 ks of priority A observation time in AO-9. This project involves an ambitious long-look observation that will obtain the first high-quality grating spectroscopy of a mini-Broad Absorption Line (mini-BAL) quasar, with the aim of assessing the kinetic luminosity of its outflow (the target is PG 1114+445). Grating spectroscopy of a small sample of local Seyfert galaxies has led to highly regarded accurate determinations of their wind properties. The planned extension of grating spectroscopy to the first mini-BAL quasar level AGN will determine if the outflow becomes as powerful as proposed in current AGN feedback scenarios. The 375,000 count EPIC CCD spectra from this long-look will enable unprecedented complementary studies of high-energy absorption features and iron K emission. The data for this project will be gathered over the coming year starting in 2010 May.

The second project is an investigation of X-ray absorption in the most-distant radio-loud quasars. Here we are extending our systematic X-ray studies of the most-distant known quasars with XMM-Newton spectroscopy of typical radio-loud quasars (RLQs) at z ~ 4-5. Our targets are more representative of the overall RLQ population than the small number of highly radio-loud blazars studied at these redshifts. We will search for X-ray absorption in the quasars’ environments to determine if it is common among typical RLQs at the highest redshifts. We will also measure X-ray continuum shapes and search for variability and clustered AGNs. Two priority C targets from this project, SDSS J0011+1446 and PMN J0214-0518, were successfully observed as part of XMM-Newton AO-8 (with exposure times of 28 ks and 59 ks, respectively).
This proposal is directly relevant to NASA strategic subgoal 3D. It will provide insight into phenomena near black holes (objective 3D.1), and it will address the formation and evolution of galaxies and cosmic structures (objective 3D.2).

Joel Bregman/University of Michigan
Missing Hot Baryons Around Galaxies

If galaxies had the cosmological baryon-to-dark matter ratio, they would have 3-30 times their observed baryon mass. These missing baryons are undetected, but a cosmologically significant fraction may surround galaxies with a hot diffuse halo of gas that extends to the virial radius (250 kpc for the Milky Way). Theory predicts that this hot halo has a flatter distribution than even the NFW distribution of the dark matter. A loosely bound gaseous halo could be stripped in a cluster or group environment, but should be relatively undisturbed around spirals not in rich environments. A large extended hot halo would have gone unnoticed in most pointed XMM and Chandra observations, which are mainly of nearby systems where only the inner parts fit in the field of view ($r < 0.1 r_{\text{virial}}$).

Three programs are proposed to measure the mass of hot extended halos: an approved deep XMM observation of a massive isolated spiral at a distance where $r_{\text{virial}}$ fits in the field of view; a stacking of many field spiral galaxies that were observed with the ROSAT All-Sky Survey; and a stacking of moderately distant (70-150 Mpc) spirals that were serendipitously observed with XMM. These observations will either determine the fraction of missing baryons in a hot halo or show that they are not significant and were truly lost during early galaxy formation. In a related project, we consider whether cooling of gas from a hot halo leads to a detectable UV signature. HI observations imply a time-averaged accretion rate onto spirals of 0.2 Msun/yr, yet there is no HI reservoir, so the gas must have cooled from a hotter phase. Absorption line studies indicate that warm ionized intergalactic gas has a metallicity of about 0.2 solar, so dust may be present. UV light, scattered off of halo dust is already detected with Galex toward an edge-on galaxy, but this may be due to a galactic fountain rather than inflow. The proposed stacking observations of a few dozen edge-on galaxies with Galex data will improve sensitivity and reveal if this material extends significantly further out.

Jean Chiar/SETI Institute
The Role of Polycyclic Aromatic Hydrocarbons in Dense Cloud Absorption Features: The Last Major Unanswered Question in Interstellar Ice Spectroscopy

Interstellar dust plays a vital role in the star formation process and the eventual formation of planetary systems including our own. Ice mantles are an important component of the dust: reactions involving simple ices can create more complex (and astrobiologically interesting) molecules, and ices sublimated back into the gas phase influence the gas-phase chemistry. Although polycyclic aromatic hydrocarbons (PAHs) are commonly thought to be very abundant interstellar species and, as such, are likely to be important components of interstellar ices, their contribution to the infrared spectra and chemistry of ices in dense molecular clouds is an open question. This program makes extensive use of three major NASA-funded databases: the Spitzer archive, the 2MASS archive, and the NASA Ames PAH database in order to answer the last major unanswered question in
interstellar ice spectroscopy: what role do PAHs play in contributing to unidentified absorption features observed in dense cloud spectra.

PAHs are observed to be present and abundant in nearly all phases of the galactic and extragalactic interstellar medium. The evidence for the ubiquity of interstellar PAHs is the widespread well-known family of prominent emission bands at 3.28, 6.2, 7.7, 8.6, and 11.2 micron. To date, these PAH bands have been most easily detected in regions where individual gas phase PAH molecules (neutrals and ions) become highly vibrationally excited by the ambient radiation field. While PAHs and closely related aromatic materials should be present throughout dense interstellar regions, PAH emission is quenched in cold dark dense clouds. Also, in these regions, most PAHs should efficiently condense out onto dust grains, either as “pure” solids or as “guest molecules” in icy grain mantles, much as is the case for most other interstellar molecules. Thus, in dense molecular clouds, condensed PAHs will give rise to IR absorption bands rather than emission features.

While PAH absorption has been identified in a small handful of dense cloud sources (solely high-mass YSOs), there have been no comprehensive comparisons of experimental or computational spectra to the observed “unidentified” dense cloud absorption features, centered at 6.0 and 6.8 micron, which fall in the range of fundamental PAH vibrational modes. From the Spitzer IRS archive, we have selected 42 lines of sight through dense clouds and 34 lines of sight through colder less turbulent dense cores in order to best characterize PAHs in the most quiescent regions of the dense ISM. Since the 6.0 and 6.8 micron features in these sources show profiles which are different than those observed for YSOs, we have also selected 35 low-mass YSO spectra in order to assess the role the physical and/or chemical characteristics of the PAHs play in the observed features. For all our targets, ground-based 2 to 5 micron spectroscopy has been acquired by us or is available in the literature to aid in the analysis. We have at our disposal the NASA Ames Astrochemistry PAH database and proven techniques for determining continua to extract the dust and ice absorption features. The Ames PAH database is the largest of its kind and includes the spectra of theoretically calculated and experimentally measured IR absorption spectra of both neutral and ionized PAHs and nitrogen-substituted PAHs in inert gas matrices and water-ice.

Our team includes the expertise of astronomers with over 2 decades of combined experience in observations of dust and ice in dense clouds and the properties of PAH emission in star-forming regions with the expertise of experimental and computational chemists whose specialty is the study of PAHs. Our proposed research will place tight constraints on the PAH concentrations and forms that could be present in interstellar ices which will, in turn, guide future astrochemistry model development and fuel new observations with future NASA facilities such as SOFIA and JWST.
Wolf-Rayet (WR) stars are rare high-mass stars with potent winds which disturb and chemically enrich their surroundings, often creating optical nebulae as their ejecta sweep up the local interstellar medium. The intriguing dusty late-type carbon WRs) have generated thick circumstellar shells. Many WCs often have variable dust production, some periodic, others random. Only by studying all these highly energetic stars in depth will we decipher the nature of the dust condensation process and the pathway to grains in these hydrogen-poor atmospheres. This promises an accurate assessment of the quantitative contribution of WRs to the cosmic carbon budget. Such stars are few in number, but play a key role in generating the chemical elements and recycling stellar material. In 2001 we knew 227 Galactic WRs and 99% of the WC9s were dusty. Today we list close to 400 WR including the the WN and WO types. But only 56% of the WC9s are known to be dusty, dominated by those with persistent dust. Those for which we have determined both the existence of dust variability and know its temporal character is still of order 10. Much work remains to characterize the nature and variability of IR emission for many newly discovered WCs which have only optical classifications. Every new IR survey of the Galactic plane has the potential to offer crucial data on dusty WR stars, by finding new examples or providing another epoch of photometry for previously known WCs, to compare with earlier IR data to study the individual mass loss history for each. This is the method by which these variable stars were found to undergo episodes of dust making and it maximizes the value of old data sets, particularly when the effort is made to maintain a consistent absolute calibration for new missions. It is not enough merely to uncover new WCs, nor even to assign spectral classes to them. It is also essential to archive their spectral energy distributions (SEDs) as fiducial references for the future. Spitzer offers a wealth of new measurements of known WRs and it has already contributed substantially to the increase in the current census of Galactic WRs. WRs are often associated with optical so-called “ring nebulae” which are essentially fossil records of stellar mass loss. Spitzer has observed, and is currently still observing, large areas of the Galactic plane. It is timely to undertake an unbiased survey of WRs looking for new, small, faint 5-20 micron counterparts, particularly for the WC and WO stars which, combined, are a factor of two less frequently allied with ring nebulae than are WN stars.

My specific objectives are to: (i) develop IR SEDs for as many as possible of the known WR stars in the Galaxy and in the Magellanic Clouds; (ii) quantify any IR excess over the combination of photosphere, wind, and free-free emission; (iii) determine whether each excess is due to free-free or thermal emission of warm dust grains and, for dust, measure the temperature; (iv) decide from all available IR photometry of a WC star at different epochs whether this dust emission is variable or constant; (v) create a repository of reference SEDs of all dusty WC stars, in particular, so that future observations may be compared with these benchmarks; (vi) seek new dusty WRs in those regions of the Galactic plane that are still being surveyed by Spitzer; (vii) examine Spitzer images of all known Galactic and Magellanic WRs seeking unknown, potentially associated, MIR
nebulae; (viii) measure spatially integrated nebular SEDs; (ix) test whether these nebulae are thermal radio emitters and, if so, determine their IRAC/MIPS color indices, false colors and MIR/radio flux ratios as potential discriminants for WR nebulae among the many kinds of bubble in the ISM.

David Cohen/Swarthmore College
O Star Wind Mass-Loss Rates and Shock Physics from X-ray Line Profiles in Archival XMM RGS Data

O stars are characterized by their dense, supersonic stellar winds. These winds are the site of X-ray emission from shock-heated plasma. By analyzing high-resolution X-ray spectra of these O stars, we can learn about the wind-shock heating and X-ray production mechanism. But in addition, the X-rays can also be used to measure the mass-loss rate of the stellar wind, which is a key observational quantity whose value affects stellar evolution and energy, momentum, and mass input to the Galactic interstellar medium.

We make this X-ray based mass-loss measurement by analyzing the profile shapes of the X-ray emission lines observed at high resolution with the Chandra and XMM-Newton grating spectrometers. One advantage of our method is that it is insensitive to small-scale clumping that affects density-squared diagnostics. We are applying this analysis technique to O stars in the Chandra archive, and are finding mass-loss rates lower than those traditionally assumed for these O stars, and in line with more recent independent determinations that do account for clumping.

By extending this analysis to the XMM RGS data archive, we will make significant contributions to the understanding of both X-ray production in O stars and to addressing the issue of the actual mass-loss rates of O stars. The XMM RGS data archive provides several extensions and advantages over the smaller Chandra HETGS archive: (1) there are roughly twice as many O and early B stars in the XMM archive; (2) the longer wavelength response of the RGS provides access to diagnostically important lines of nitrogen and carbon; (3) the very long, multiple exposures of zeta Pup provide the opportunity to study this canonical O supergiant's X-ray spectrum in unprecedented detail, including looking at the time variability of X-ray line profiles.

Our research team has developed a sophisticated empirical line profile model as well as a computational infrastructure for fitting the model to high-resolution X-ray spectra in order to determine the values of physically meaningful model parameters, and to place confidence limits on them. We have incorporated second-order effects into our models, including resonance scattering. We have also developed tools for modeling the X-ray opacity of the cold, X-ray absorbing wind component, which is a crucial ingredient of the technique we have developed for determining wind mass-loss rates from analyzing the ensemble of emission lines from a given star's X-ray spectrum.

In addition to testing state-of-the-art wind shock models and measuring O star mass-loss rates, an important component of our proposed research program is the education of talented undergraduates. Swarthmore undergraduates have made significant
contributions to the development of our line profile modeling, the wind opacity modeling, and related research topics such as laboratory astrophysics before going on to PhD programs. Two have been named as finalists for the APS's Apker prize. The research we propose here will involve two undergraduates and will likely lead to honors theses, refereed papers, and the opportunity to present their research results at national and international meetings.

By measuring mass-loss rates for all the O stars for which high-resolution X-ray spectra exist and by constraining X-ray production mechanisms, we will address issues important to our understanding of stellar and galactic evolution: including the frequency of core collapse supernovae, the energetics of the Galactic interstellar medium, and the radiation conditions in star formation regions where not only new, solar-type stars form, but also where their planetary systems form and are subject to effects of high-energy emission from nearby stars. In this way, the work we are proposing in this project will make a contribution to NASA's mission to understand cosmic evolution and the conditions for generating and sustaining life in the Universe.

Xinyu Dai/University of Oklahoma
The Swift Soft X-ray Serendipitous Survey

Since the launch in November 2004, Swift has observed over 500 gamma-ray bursts (GRBs). These GRB fields are uniformly distributed on the sky and not correlated with other known X-ray sources. Therefore, these XRT observations form an excellent soft X-ray serendipitous survey with a sky area of ~75 square degrees and a median flux limit of 4e-15 erg/cm^2/s. This survey is about an order of magnitude deeper than previous surveys of similar area, and an order of magnitude wider than previous surveys of similar depth. The unique combination of the survey area and depth enables it to fill in the gap between the deep, pencil beam surveys (such as the Chandra Deep Fields) and the shallow, wide area surveys measured with ROSAT. With it, we will place independent and complementary measurements on the number counts and luminosity functions of X-ray sources, with a focus on galaxy clusters. The highest priority goal is to produce the largest X-ray selected cluster catalog and increase the sample of high redshift clusters ($z > 0.9$) by an order of magnitude, from which we will study the evolution of cluster number counts, luminosity function, scaling relations, and eventually the mass function. This is a crucial step in mapping cluster evolution and constraining cosmological models.

First, we propose to extract the complete serendipitous point source and extended source lists for the existing ~500 GRB fields. We plan to analyze ~800 fields (~120 square degrees) at the late stage of the project. Second, we will use optical observations to further identify galaxy clusters. These optical observations include existing data from SDSS, UKIDSS, and deep optical follow-up observations of GRB fields, and new data obtained with MDM, Magellan, LBT, or NOAO telescopes. We expect to detect 460 and 60 clusters in the redshift bin of 0.5<z<0.9 and 0.9 < z < 1.3, respectively, 12 and 10 times larger than the current sample. Deep X-ray follow-up observations of the 60 high redshift clusters will constrain the equation of state of dark energy with \Delta w < 0.07
by this method alone, reducing the uncertainty of the current measurement using X-ray selected clusters by a factor of 2.5.

Megan Donahue/Michigan State University
Virgo Clusters of Galaxies at Redshift 0.35: Probing the Cluster-Group Transition

The cluster X-ray luminosity-temperature (L-T) relationship is sensitive to feedback processes of galaxies. Because L and T are used as surrogates for the cluster virial mass M in cosmological studies, understanding the L-T and the L-T-M relations, including scatter, evolution of scatter, is critical for cluster constraints on cosmological models, as well as models of galaxy and cluster evolution. We propose to measure Tx and Lx for a representative sample of more than 8 low-luminosity, low-T (2-2.6 keV) clusters of galaxies at moderate redshift (z=0.32-0.37) from the ROSAT 160SD survey. We also will study the L-T-M relation for 6 clusters with weak lensing masses obtained with HST. This sample spans the mass range between rich clusters and groups, the range where feedback processes become important.

Harald Ebeling/University of Hawaii
Beyond MACS: An All-Sky Search for the Most X-ray Luminous Clusters of Galaxies Out to z~1

Galaxy clusters are seeing a dramatic renaissance as cosmological tools and astrophysical laboratories. In the local Universe (z<0.3), extensive statistical and in-depth studies of the most extreme clusters have greatly advanced our understanding of the interplay of gas, galaxies, and dark matter in these largest building blocks of the Universe. The high-redshift counterparts and predecessors of the most famous and best studied local systems have, however, remained elusive until recently.

In 2009, the completion of the Massive Cluster Survey (MACS) yielded the definitive sample of very X-ray luminous clusters at 0.3 < z < 0.6. Thanks to its huge sky coverage of almost 23,000 square degrees, MACS was able to increase the number of such systems known by a factor of 30 over previous surveys, thereby dramatically extending the redshift baseline for studies of cluster and galaxy evolution, and establishing massive clusters as independent cosmological probes. MACS clusters have been used extensively by the extragalactic community in many high-profile investigations, demonstrating the legacy character and broad applicability of MACS for astrophysical and cosmological research. The importance and value of this sample was underlined again very recently by the award of an HST Multi-Cycle Treasury program which will use 524 orbits to observe 25 massive galaxy clusters, 16 of which are MACS discoveries.

We here propose a new all-sky X-ray cluster survey, eMACS, to take the process to its logical and ultimate conclusion. Using again data from the ROSAT All-Sky Survey and lowering the flux limit to half that used for MACS, we will extend MACS in a quest to discover extremely X-ray luminous clusters at 0.5 < z < 1, a nearly unexplored mass/redshift range.
Expected to find more than 80 of these extremely rare systems at $z>0.5$, an increase of nearly an order of magnitude over the number of such systems presently known, eMACS will create a sample of unprecedented power for cosmological and astrophysical research. Reflecting the importance of galaxy clusters for a wide range of extragalactic research topics, the science goals addressed by this project are numerous, from the physical mechanisms governing galaxy evolution, through the formation and dynamics of structure on Mpc scales, to investigations into the nature and properties of dark matter and dark energy.

Moshe Elitzur/University of Kentucky
**DUSTY-PHOTZ: Dusty Starbursts, Photometric Redshifts, and Star Formation in the Distant Universe**

Many cosmologically-distant galaxies are too faint for the acquisition of spectra. For these, a powerful, though somewhat indirect, method for distance estimates relies on photometric redshifts, in which multiband photometry is compared with templates covering ranges of age and metallicity found in the local universe. However, in the case of IR-luminous galaxies, ultra-luminous IR galaxies (ULIRGs), and sub-millimeter galaxies (SMGs), in which most of the star-formation activity occurs at high redshift, these methods can be futile because the UV/optical features are highly obscured by dust. To date, no publicly available facility provides a photometric redshift estimator incorporating IR spectral energy distributions (SEDs). We propose to fill this gap through a two-pronged approach: (a) creation of a vast library of UV+optical+IR SEDs applicable to data for starbursts in the local universe and at high redshift; (b) development of an efficient method to derive the best-fit model SED at redshift zero, and derive the best-fit SED model together with an estimate of a photometric redshift for objects at cosmological distances.

Taotao Fang/University of California, Irvine
**Detecting the Warm-Hot Intergalactic Medium in the Hercules Supercluster**

The "Missing Baryons", in the form of the Warm-Hot Intergalactic Medium (WHIM), represent a fundamental challenge to the current theory of cosmological structure formation and evolution and has remained elusive. Recently, as part of Chandra and XMM ToO programs, we detected a WHIM absorption produced by a known large-scale structure (Sculptor Wall) at the 3 sigma level, demonstrating that superstructures are probably the best locations to detect the WHIM. To assess whether the result for the Sculptor Wall is typical, we propose a non-ToO observation of Mkn 501, a blazar located behind the Hercules Supercluster. The combination of the strong flux and the foreground superstructure make Mkn 501 the most promising target for a new WHIM detection, with a relatively low expense of telescope time (150 ks).
Edward Fitzpatrick/Villanova University  
The UV Through IR Extinction in the Local Interstellar Medium

By extending our recently developed techniques for determining extinction curves to cooler stars and longer wavelengths, we intend to characterize the properties of local dust. This includes dust in the diffuse interstellar medium and in local star forming regions such as the Taurus and rho Oph dark clouds and star forming regions. By using Hipparcos data for many of the program stars, we will be able to map the extinction in all three spatial dimensions and determine the total line of sight extinction. In this way, we will be able to examine how dust properties depend upon their proximity to molecular material.

Understanding the properties of the dust will not only be useful for studying how the properties of dust respond to different environmental influences, but also for dereddening the spectral energy distributions of the active young stars which inhabit the clouds -- an essential step toward understanding the physical properties which regulate the evolution of these objects.

William Forman/Smithsonian Astrophysical Observatory  
Insights into Cluster Formation: Merging and Substructure in the Nearby, Massive Coma Cluster

We propose an investigation of merging and substructure in the nearby, X-ray bright Coma cluster by combining our approved deep AO9 XMM-Newton observation with archival XMM-Newton data. X-ray observations are ideal for this study since X-ray emission arises from the hot intracluster medium, the dominant baryonic component in rich clusters, and this gas reflects the hydrodynamic processes of cluster formation. Our new XMM-Newton observation is centered on the cD galaxy NGC4839 at the core of a massive group that is falling into the Coma cluster. The combined XMM-Newton data set, archival and newly approved observations (from 2009), will provide the first high angular resolution map of the merging subcluster and allow the physics and dynamics of this nearest major cluster merger to be studied with unprecedented detail. We will measure the total (3D) velocity of the merging group and the properties of the shock/sheath region at the interface between the Coma ICM and the group gas. We also will derive the gas mass in NGC4839's 400 kpc tail to determine the importance of cluster gas mixing with the stripped group gas. Studies of the heavy element abundances (iron) will provide insights into the enrichment processes of the intracluster medium, the dominant baryonic component in clusters. These observations also will determine the nature of the hot core in NGC4839, including the outburst power of the low luminosity supermassive black hole that lies at the nucleus of NGC4839.

A natural outgrowth of our analysis will be a comprehensive study of the formation and growth of the Coma cluster. Although Coma was studied during the early phases of the XMM-Newton mission, the accumulated XMM-Newton data (1.3 Ms, four times the exposure in previous work) for this nearby massive cluster has not been analyzed in detail. We will study the structure around the two central cD galaxies and structures
reported from gravitational lensing and dynamical studies. In addition, we will study X-ray only substructure. We will generate pseudo pressure and entropy maps, as well as projected gas temperature and heavy element abundance maps. These maps will enable us to differentiate among the origins for substructure in the gas, including the effects of perturbations in the gravitational potential and the hydrodynamic effects of mergers. With our large scale X-ray maps, we will evaluate the influence of mass structures detected from dynamical and lensing studies. This investigation of merging and substructure in Coma will provide a detailed view of the processes that drive the formation and growth of galaxy clusters, the most massive collapsed systems in the Universe.

William Forrest/University of Rochester
Dust Processing in T Tauri Disks

Spectroscopic surveys with the Spitzer Infrared Spectrograph show that dust with a range of mineralization and particle size is present in the protoplanetary disks around T Tauri stars. To be sure, there is ubiquitous evidence in protoplanetary dust for submicron amorphous grains which probably represent primordial interstellar-like dust. But even in young disks, the spectra indicate that significant dust processing has occurred. Grain growth, from submicron to several microns, is detected in most cases. Crystalline grains, which require high temperature processing, are usually present. Dust features at different wavelengths indicate that such processed grains are widespread in the disks. The surprisingly large abundance of these processed grains indicates disk-wide processes at work. For silica (solid SiO$_2$) we have identified the major component with annealed silica. Significantly, all of the the silica grains returned from Comet Wild-2 by the NASA Stardust mission have been identified as tridymite and/or cristobalite, the high temperature polymorphs which comprise annealed silica. Thus we are detecting processing in the first 3 My of these T Tauri disks, and have within our grasp a concordance of dust properties in current protoplanetary disks with the fossil record of solids in our solar system.

We request support from the NASA Astrophysics Data Analysis program for modeling to determine the dust composition in nearby protoplanetary disks using all the available T Tauri spectra from the IRS on Spitzer, and using the methods we developed in the modeling of the 65 T Tauri stars from the Taurus/Auriga dark clouds (Sargent et al. 2006, 2009a, 2009b). In the Spitzer archive there are observations of some 2000 of these objects within 500 parsecs of the solar system, of which we observed some 1400 in our own Spitzer guaranteed-time or general observations. We will analyze correlations of the mineralogy (grain growth and crystalline silicate abundances) with other system properties (SED shape, star and disk masses, stellar accretion rates, age, and X-ray luminosity) to illuminate the processes responsible for the dust processing. Much of the mineralogical information is borne by the longer-wavelength (20-40 micron) IRS spectrum, for which Spitzer has no identified successor. Therefore this analysis of Spitzer spectra of T Tauri stars will be the fundamental reference for protoplanetary dust evolution for a very long time.
Solar Wind Charge Exchange (SWCX) emission from interplanetary space and Earth's magnetosheath contributes a significant background to X-ray observations of extended astrophysical objects, which is often inseparable from the signal of interest. Many of the emission lines from SWCX are the same used as plasma diagnostics of thermal emission (e.g. CVI, OVII, and OVII). For observations of objects covering the field-of-view separate observations of the background may produce incorrect results, as the strength and spectrum of the SWCX emission is temporally variable.

Modeling the SWCX emission requires understanding the distribution of neutral material in the magnetosheath and heliosphere, the properties and distribution of the solar wind, and the interaction cross-sections. We will use the time variability of the SWCX emission to verify our models of the neutral distribution and measure the interaction cross-sections. As part of XMM-Newton AO-9 we requested, and received, 480 ks for the SWCX characterization. The "Large Program" consists of a monitoring campaign based on 4 observations, 120 ks each, spread over two years, in the direction of the high latitude molecular cloud MBM12 to study the temporal variation of the SWCX emission. By choosing a molecular cloud we remove the non-local X-ray background and maximize the SWCX signal.

The proposed investigation was approved with observing priority B. In this proposal we request financial support for a graduate student and the PI for data reduction and analysis.

We propose a systematic, simultaneous study of all components of the DXB below 1 keV to determine the properties of the Astrophysical objects responsible for the emission. XMM-Newton, Chandra and Suzaku have a sufficiently mature archive and will be used for this investigation. A multi-wavelength approach will also be used where necessary, in particular for the study of the WHIM. We identified 55 targets in the public archives of the three missions to use in this analysis, some of them observed by multiple missions. For all three satellites we constrained our selection to observations with observing time longer than 50,000 s, and without bright sources in the field of view.

The investigation will be organized in three main subjects:

**GALACTIC EMISSION:** we will analyze the spectra of the soft X-ray diffuse emission to characterize the temperature, pressure, and density of Local Bubble and Galactic Halo and the fluxes in oxygen emission lines as function of position (in particular latitude). We will also use our models of the SWCX, based on real time solar data, to characterize and remove its contribution.

**WHIM:** our previous work with XMM-Newton has detected the WHIM signature in the angular correlation of soft X-ray images. In this investigation we plan to move from detecting to characterizing the WHIM. By significantly increasing the number of targets
we will investigate the cosmic variation of the WHIM emission. Moreover, by using the
good angular resolution of Chandra we will also be able to investigate the spatial
distribution of the WHIM as a function of its distance from point sources.
We will also study the WHIM properties by looking at the cross correlations between X-
ray data and Microwave background data from the Atacama Cosmic Telescope (ACT)
due to the Sunyaev-Zel'dovich (SZ) effect. We will use our existing simulation of the X-
ray emission from the WHIM to investigate the expected cross correlation between ACT
and XMM-Newton signals and then use the common fields between XMM-Newton
archive and the ACT field to look for the correlation and extract the WHIM properties. In
particular, the different dependence on electron density between X-ray emission and SZ
effect will be an invaluable tool to understand the density distribution of the WHIM.

POINT SOURCES: The X-ray emission from unresolved point sources has been studied
extensively above 1 keV, however, very little data are available below 1 keV. For
example, we recently used 5 XMM-Newton targets and found the presence, in addition to
the typical power law spectrum attributed to Active Galacti Nuclei (AGN), of a thermal
component around 0.5 keV that we attribute to galaxy clusters and groups, but is also
somewhat consistent with stellar emission from the Milky Way. The much larger set of
data that will be used in this investigation and the higher angular resolution of Chandra
will allow a much better characterization of both the AGN contribution and the thermal
component, including its origin.

Fotis Gavriil/NASA Goddard Space Flight Center
A Comprehensive Study of the Most Magnetic Objects in the Universe - Magnetars

Neutron stars possess the strongest magnetic fields found in nature. How they obtain such
fields, and how these fields evolve is an open question. Neutron stars are the compact
cores of collapsed massive stars, and have ~1.4 solar masses in only 10 km radii.
Rotation-powered pulsars (RPPs) are isolated neutron stars powered by their loss of
rotational kinetic energy. Magnetars, on the other hand, are young isolated neutron stars
that are powered by their enormous magnetic fields. Magnetars exhibit flares, bursts, and
bright X-ray pulsations that are all too bright to be powered by rotation. An open question
in pulsar astrophysics has been why does there exist RPPs with magnetic fields
comparable to those of magnetars that do not show any magnetar-like emission. The
connection between these highly magnetized rotation-powered pulsars (high-B RPPs) and
magnetars was established with the discovery of magnetar-like emission from the young
pulsar PSR J1846-0258 in Kes 75. Although the magnetic field of this source is high
when compared to other RPPs, it is still less than those of the magnetars, and prior to its
magnetar-like outburst, displayed all the signs of being powered exclusively by rotation.
The detection of magnetar behavior from PSR J1846-0258 has helped bridge the gap
between the high-B RPPs and magnetars, however, it has raised some important
astrophysical questions:
- Do other high-B RPPs exhibit magnetar-like behavior?
- Do high-B RPPs evolve into magnetars?
- Is magnetar-like emission just a phase that some neutrons stars go through?
- Do some RPPs have magnetic energy stored in higher multipoles as is suggested for the magnetars?

To tackle these issues we will make use of archival data primarily from, but not limited to, the Rossi X-ray Timing Explorer (RXTE), XMM-Newton, Swift, and the Chandra X-ray Observatory. Specifically, we will:
- Search for magnetar-like emission, such as bursts and X-ray pulsed flux enhancements, from young highly magnetized rotation-powered pulsars. We will search archival observations in the vicinity of the Galactic Plane for possible high-B RPP transients.
- Perform spectroscopic measurements of high-B RPPs in order to determine if we can see the effects of a magnetic field that is not purely dipolar. We will fit physically motivated models to high-B RPP spectra in order to measure the properties of the plasma in their magnetospheres.
- Revisit the bursts from magnetar candidates in order to determine whether their spectra can be used to provide magnetic field measurements that are independent of the spin-inferred method which is only sensitive to the dipolar component.

This work will lead us closer to understating how magnetars acquire such strong magnetic fields, and how these fields evolve in magnetars and in neutron stars in general. Our study will also elucidate important issues which will be addressed by upcoming NASA missions, such as the focusing high-energy X-ray instrument Nuclear Spectroscopic Telescope Array (NuSTAR), and the X-ray polarimeter Gravity and Extreme Magnetism SMEX (GEMS). We are studying the end products of stellar evolution at the highest magnetic fields and highest densities, thereby directly addressing NASA's Strategic Goals and Research Objectives, specifically Strategic Subgoal 3D: "Discover the origin, structure, evolution, and density of the universe".

Kenneth Gayley/University of Iowa

Why Evolved Massive Single Stars Create X-rays: Analysis of XMM Observations of WR 6 (EZ CMa)

The proposers are US Co-Is on an XMM-Newton proposal that has been awarded a 400 ksec exposure of the Wolf-Rayet star EZ CMa (WR 6). The XMM observations do not currently come with funding for data analysis, so the US Co-Is need separate funding from NASA to be able to carry out the analysis of this important and unique dataset. The reason the data is so important is that it is the longest and highest-resolution X-ray spectrum that has ever been taken of a single Wolf-Rayet star, and it will provide large photon counts as a function of time (to study variability), as a function of phase within the rotation period (to study longitudinal structure), and within each spectral line (to study line shapes and f/i/r ratios). Thus the dataset represents a treasure trove of information about how X-rays are formed in the winds of single Wolf-Rayet stars, which is important to understand because the winds of these stars so completely shroud the underlying hydrostatic object that the only way to study the characteristics and evolution of this important class of supernova and GRB progenitor is by studying its winds.

X-rays provide a window into the processes that generate shocks and hot gas in these winds, which in turn may couple to the stellar rotation, pulsations, magnetic fields, and wind acceleration mechanisms, all currently poorly understood for this type of star. Our
data analysis will focus on identifying the basic physical processes most likely to be responsible for the X-ray emission. Starting from issues like the total fluxes in lines and continua, we will constrain the energetics involved, and then by considering the details of the line shapes, we can use the line widths, asymmetries, and f/i/r ratios (where applicable) to obtain robust constraints on the location of the hot gas in the wind. Then by considering the temporal variability of the emission, we can distinguish the emission from numerous stochastically distributed shocks, such as from the line-driven instability, from a smaller number of largely coherent structures, perhaps due to magnetic loops or other magnetically induced phenomena. Also, by binning the data by phase over the 3.77 day rotational period of the star, we can probe quasiperiodic longitudinal structure, reminiscent of corotating interaction regions (CIRs) on our own Sun.

We will also be able to conclusively verify expectations from previous lower-resolution and lower-photon-count observations, such as that the X-rays will exhibit lines and a thermal continuum suggestive of local shock heating more so than a predominantly nonthermal spectrum. Less certain are the degree of rotational modulation, as opposed to a more constant stochastic background, and whether there will be temporal variability suggestive of features that either come and go on the several-day flow time in the wind, or persist longer over multiple rotations. We need a sustained year-long analysis effort to obtain answers to these questions.

The Co-Investigators of this proposal have significant experience analyzing radiative processes in hot-star winds, including Wolf-Rayet winds, and the hydrodynamical and magnetic phenomena that can give rise to shocked X-ray plasma. This was their expected role as Co-Is for the XMM observation, so NASA funding will help make the most of the observing resources already committed.

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Sunil Golwala/California Institute of Technology
Joint X-ray/Sunyaev-Zeldovich Effect Studies of Massive Clusters

Galaxy clusters are the largest collapsed objects in the universe, and as such provide excellent laboratories for studying the astrophysics of gravitational collapse in detail, including the effects of radiative cooling, star formation, turbulence, magnetic field support, and cosmic ray pressure. One of the best ways to quantitatively test for these effects is to measure scaling relations for clusters, which are relations between cluster-integrated observables. The intracluster medium (ICM) provides a number of such observables: X-ray luminosity, X-ray-derived gas mass, X-ray-spectroscopic gas temperature, thermal Sunyaev-Zeldovich effect gas pressure, etc. Systematic deviations of scaling relations from the expectations of self-similar collapse in power-law slope and normalization, as well as the size of scatter about the mean behavior, measure the effect of the above non-self-similar processes on the ICM. The importance of such processes can be tested quantitatively via comparison to simulations that incorporate them.

Beyond the study of scaling relations to understand cluster formation and evolution, such work is necessary in order to use clusters as a cosmological tool: cosmological measurements of the cluster number abundance and mass function, today and as a
function of redshift, require that such global observables be calibrated to underlying mass using simulations or parameterized relations fitted to data. Successful prediction of observed scaling relations would provide confidence in such calibrations.

We propose to undertake a new set of model-independent tests of scaling relations between X-ray and thermal Sunyaev-Zeldovich effect (tSZ) observables. Our proposal is novel in the following ways:

* it uses high signal-to-noise 150–GHz bolometric tSZ imaging data, which provides almost model-independent estimates of tSZ parameters and suffers minimal contamination from point sources;

* it has the highest median redshift of any sample (median \( z = 0.5 \)), testing X-ray/tSZ scaling relations at a higher redshift than has been possible before and also reducing the impact of confusion of tSZ with primary CMB anisotropy; and,

* the data extend out to \( r_{500} \) to \( r_{200} \), larger than any sample with a comparable redshift distribution.

Additionally, we propose to recover novel, model-independent gas-mass-weighted temperature estimates by direct comparison of the gas density radial profile recovered from X-ray data to the tSZ radial pressure profile. Conventional X-ray-based temperature estimates are obtained by X-ray spectroscopy, which provides a luminosity-weighted temperature and is thus substantially more sensitive to the behavior at small radius (even in core-excised measurements) and also suffers systematic errors due to spectral modeling of the X-ray background. Since the tSZ flux is linear in gas density, tSZ-based estimates are gas-mass weighted. Additionally, with deprojected density and pressure profiles, it will be possible to reconstruct the ICM entropy and \( f_{\text{gas}} \), the gas mass fraction, as a function of enclosed radius.

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**Eric Gotthelf/Columbia University**

**Anti-magnetars: Revealing the Pulsar Properties of Central Compact Objects in Supernova Remnants**

This proposal is to fund the analysis of large data sets that we were awarded in XMM-Newton AO9 to search for the pulsation periods and measure the spin-down rates of Central Compact Objects (CCOs) in supernova remnants (SNRs). These observations include a Large Program (350 ks) to search for the pulsar in Cas A, and a multi-epoch timing program (200 ks total) to measure the spin-down rate and dipole magnetic field strength of the newly discovered 0.112 s PSR J0821-4300 in Puppis A. These observations are motivated by growing evidence that the class of CCOs, which are detected only in X-rays and are the least conspicuous of young neutron stars, are characterized by weak dipole magnetic fields and relatively long initial spin periods. As such, they may comprise a large fraction of neutron star births. From upper limits that we established on their spin-down rates, as well as one measurement of P-dot in a CCO, we developed the "anti-magnetar" model, which describes CCOs as pulsars with even
weaker magnetic fields \((B_s = 1.10^{-11} \text{ G})\) than ordinary young pulsars. The approved observations will provide strong confirmation of this model if the expected slow spin-down rate of PSR J0821-4300 is measured, and if similar spin properties are discovered from the Cas A CCO.

The remaining mystery of CCOs is what maintains their small, hot regions of surface thermal X-ray emission. Spin-down power is insufficient; otherwise, only the effects of strong \((B_s > 1.13 \text{ G})\) magnetic fields are thought able to enforce nonuniform surface temperature, in apparent contradiction to the anti-magnetar hypothesis. We will apply a detailed ray-tracing code to model the energy-dependent light curves and phase-resolved spectra of PSR J0821-430 and other CCOs in order to determine the geometry of their surface hot spots with respect to the rotation axis and viewing direction. Evidence for cyclotron resonance lines in the spectra will also be modeled as a function of rotation phase, which will provide a local measurement of the B-field on the surface for comparison with the global dipole value determined from the spin-down rate. It may be possible to unify magnetars and anti-magnetars by invoking strong sub-surface or "sun-spot" B-fields that do not (yet) contribute to a significant external dipole in CCOs. A large part of the effort will be the pulsation search of the large data set on Cas A, for which a weak signal is expected, superposed on background from the bright SNR. Even though XMM-Newton is the most sensitive existing instrument for this search, the computing requirements for finding the signal using the best techniques are prohibitive on an ordinary desktop workstation. Therefore, we will exploit the latest advances in parallel computing technology to speed the execution time by at least a factor of 100. In the second year of the project, the same equipment will be used to facilitate the calculations of extensive sets of phase-dependent spectral models and pulsed light curves for comparison with the superb set of data that we will have accumulated on PSR J0821-4300 in Puppis A.

Robert Gruendl/University of Illinois at Urbana-Champaign

Massive and Intermediate Mass Star Formation in the Small Magellanic Cloud

Studies of star formation are fundamental to our understanding of the evolution of the universe. In the Milky Way, studies of the massive star formation are often limited by line-of-sight obscuration and confusion. Studies in the Magellanic Clouds offer some distinct advantages due to their low foreground extinction, nearly face-on orientations, and known small distances. With the advent of the Spitzer Space Telescope, the massive and intermediate-mass young stellar objects (YSOs) in the Magellanic Clouds can be resolved, inventoried, and studied to provide broad insights into the massive star formation process. This is particularly important because the Magellanic Clouds offer the chance to study star formation in an environment with much lower metallicities, similar to those in galaxies at earlier cosmic epochs.

We have already used Spitzer observations to search for massive and intermediate-mass YSOs in the Large Magellanic Cloud (LMC). The resulting multi-wavelength analysis identified a population of 1,172 YSOs in the LMC, which have been used in follow-up studies of the star formation process on scales ranging from individual HII regions to global processes on the kpc scale.
Unlike the LMC, the YSO population in the Small Magellanic Cloud (SMC) has not yet been as well-studied. We propose to perform a search, similar to that in the LMC, to identify the massive and intermediate-mass YSO population in the SMC. Based on preliminary color and magnitudes evaluations, we estimate that roughly 1,500 initial YSO candidates need to be considered, and we expect that 400-450 of these candidates will survive our multi-wavelength scrutiny to be confidently identified as massive and intermediate-mass YSOs. These results can be compared with the more limited studies that have already taken place in the SMC by other research groups, but more importantly can be directly compared to our LMC results to search for observational differences in the star formation process due to different metallicities (on local scales) tidal effects (on a global scale). This program requests funding for two years to carry out the search and to analyze the results.

**Dirk Grupe/Pennsylvania State University**

**The X-ray Absorber in the X-ray Transient NLS1 WPVS 007**

This proposal is for a funding request for an approved XMM-Newton observations of the X-ray transient Narrow-Line Seyfert 1 galaxy WPVS 007. The request is for 4 month of salary for the PI for one year in order to do the data analysis, publish the results, and attend an international AGN meeting. XMM will observe WPVS 007 in June 2010 simultaneously with HST, Chandra, and Swift. The goal is to establish a tight connection between the UV broad absorption line troughs found in FUSE observations and the strong partial covering absorber feature found by Swift. WPVS 007 showed a dramatic transformation into a Broad Absorption line QSO like AGN between a 1996 HST observation and a 2003 FUSE observation. Several Swift monitoring observations have suggested that the absorber may have started to disappear. Therefore it is crucial for our HST COS UV spectroscopy to know what the status of the X-ray absorber is. The XMM observation will provide a well-exposed X-ray spectrum even if WPVS 007 will be in a low flux state. This spectrum will enable us to put constraints on the absorption column density and covering fraction of the partial covering absorber.

**Hans Guenther/Smithsonian Astrophysical Observatory**

**Stellar X-ray Emission From Magnetically Funneled Shocks**

Stars and planets form in giant molecular clouds, so they are deeply embedded in their early stages. When they become optically visible, the young stars are still surrounded by a proto-planetary disk, where planets evolve. These stars are called classical T Tauri stars (CTTS). A key, yet poorly constrained, parameter for the disk evolution is the stellar high-energy emission. It can ionize the outer layers of the disk, change its chemistry and even drive photoevaporation of the disk. Thus the spectral shape and the temporal variability of the stellar X-ray and UV emission shapes the gas and dust properties in some regions of the disk. It sets the photoevaporation timescale which provides an upper limit for planet formation.
CTTS still actively accrete mass from their disk. The infalling matter is funneled by the stellar magnetic field and impacts on the star close to free fall velocity. A hot accretion shock develops, which emits X-rays which are distinct from any coronal X-rays. Eventually the disk disperses and bulk planet formation comes to an end.

X-ray emitting shocks can still occur at a later stage in stellar evolution, if e.g. the magnetic field is strong enough to funnel the stellar wind to collide in the disk midplane. This so-called magnetically confined wind shock model was originally developed for the A0p star IQ Aur. The magnetically funneled accretion model has been successfully tested for CTTS in a small mass range only; the magnetically confined wind shock model lacks a comparison for high-resolution X-ray grating spectra for all but the most massive stars.

In this proposal we request funding to analyze three XMM-Newton observations, which will probe X-ray emitting shocks in stars with magnetic fields: DN Tau (observed as category C target in cycle 8), a CTTS with much lower mass than previous CTTS with X-ray grating spectroscopy; MN Lup (to be observed in cycle 9), a prime candidate for simultaneous X-ray/Doppler-imaging studies; and IQ Aur (to be observed in cycle 9), a magnetic A0p star with an exceptionally soft X-ray spectrum.

We have an established and working code to simulate high-resolution X-ray spectra emitted by shocks. This code was originally developed for accretion shocks on CTTS. We will fit a grid of models from this code to the observed spectra to deduce the shock properties, such as infall velocity, mass accretion rate and elemental composition.

Specifically, we will 1) test for the existence of wind shocks in IQ Aur and, if confirmed, measure density, velocity, mass flow and distance to the stellar surface, 2) calculate the accretion density and rate on DN Tau (all previously modeled CTTS have higher masses, so a comparison shows how the accretion shock X-ray emission and thus the feedback on the disk depends on the stellar mass) and 3) analyze the X-ray properties of MN Lup, which has been Doppler-imaged in the past, to design a simultaneous X-ray/Doppler imaging campaign to pinpoint the accretion spots on the stellar surface.

Through an analysis of X-ray data, this research characterizes the (high-energy) environment of planet formation and the interaction of different components in stellar systems (magnetic fields and plasma flows), which are two aspects of NASA's strategic goals.

Robert Gutermuth/University of Massachusetts
A Uniform, Deep, Multi-epoch Spitzer Census of Clustered Star Forming Regions and Molecular Clouds from 400-1000 pc

We propose a Spitzer and 2MASS archival program to perform a uniform analysis of all of the known star forming regions that are 400-1000pc away, creating a Legacy-class photometric database of >9000 young stellar objects forming in a wide variety of
environments. The products of this program will be: uniform catalogs of Spitzer surveys including photometry from each individual epoch and photometry from data combined from all epochs; multi-epoch near-IR photometry for the Spitzer sources including 2MASS data and results from deep near-IR imaging, Spitzer and near-IR mosaics of each field; Av maps determined with the near-IR data. With these data we will search for eruptive outbursts over the timespan covered in these observations and estimate the frequency of such outbursts, we will extend our examination of the relationship between the surface density of young stars and protostars and the column density of gas, and we will perform a detailed analysis of the structure in the distribution of young stars and protostars, and the evolution of that structure with time.

John Hughes/Rutgers University
Mass Calibration of the ACT Cluster Sample Using XMM-Newton X-ray Observations

The Atacama Cosmology Telescope (ACT) is a custom-built 6-m telescope in Chile dedicated to mapping the temperature anisotropy of the Cosmic Microwave Background radiation at arcminute angular resolution. ACT has recently detected a sample of 23 galaxy clusters through the Sunyaev Zel'dovich (SZ) effect using maps constructed at an observing frequency of 148 GHz. The median redshift of the sample is 0.4 and the typical cluster mass is 7e14 solar masses. Most of the ACT-detected clusters are new, but there are six known clusters with archival XMM-Newton observations and another three that were awarded to us in the last XMM-Newton proposal round (cycle 9). Here we request funding to carry out a homogeneous analysis of these observations in order to obtain accurate hydrostatic mass estimates and thereby calibrate the relationship between cluster mass and SZ signal. Obtaining an accurate calibration of this relation is a crucial requirement for the use of SZ clusters to probe the growth of structure in the Universe. This proposal, therefore, forms a crucial element of our intensive program of mass estimation from X-ray, weak lensing, and galaxy velocity dispersions for this first sample of massive SZ-selected clusters from ACT.

Eiichiro Komatsu/The University of Texas at Austin
Sunyaev-Zel'dovich Effect in the WMAP 9-year Data

Clusters of galaxies have been used as an excellent probe of the growth of cosmic structures, which would help us elucidate the nature of dark energy. With the precision of data improved, we are required to have a better understanding of the physics of gas in clusters. We propose to use the WMAP 9-year data to measure the Sunyaev-Zel'dovich (SZ) effect of clusters of galaxies that are also observed by Chandra and/or XMM-Newton in X-ray. Using the 7-year data, we have found evidence that the SZ effect of nearby clusters measured by WMAP is less than expected from the existing models of galaxy clusters. If confirmed, it has important implications for galaxy clusters as a cosmological probe. We shall use the 9-year data to make a definitive measurement on this issue. In particular, (i) we shall extend our measurements to more distant clusters, and (ii) we examine the deficit of the SZ effect as a function of cluster properties such as
the cooling flow and mergers. Our analysis method can readily be used for the Planck satellite, which would further study our finding in the WMAP 9-year data.

Alan Levine/Massachusetts Institute of Technology
A Major Addition to the Number of Sources in the RXTE/ASM Light Curve Data Base

The All-Sky Monitor (ASM) on the Rossi X-ray Timing Explorer (RXTE) NASA X-ray astronomy mission has been used to follow the intensity variations of the few hundred brightest cosmic X-ray sources for more than 14 years. The results are made available to the public in the form of files containing light curves for individual sources or objects that are candidate sources. At present, the results include light curves for nearly 600 such objects, and are frequently used in investigations of the time variations of X-ray binaries and other types of X-ray sources. Certain aspects of the analysis software in present use limit the expansion of the list of candidate sources. For the most part, the limitations are practical rather than fundamental. We propose to revise the ASM data analysis software to enable the production of light curves for a significantly increased number of objects, and to then use it to produce light curves for 1000 additional objects. The additional objects would be selected from catalogs and reports in the literature that have been produced by various high energy astrophysics projects. The new light curves would be publically available from the same web sites that provide access to the currently available light curves and would be a major enhancement of a NASA astrophysics data archive.

Carey Lisse/JHU-APL
Mining the Spitzer & ISO Data Archives of Debris Disk Spectra for Warm Dust Tracers of Planetesimal and Planet Processes

Debris disks are optically thin, almost gas-free dusty disks observed around a significant fraction of main-sequence stars older than about 10 Myr. Since the circumstellar dust is short-lived, the very existence of these disks is considered as evidence that dust-producing planetesimals are still present in systems in which are forming - or have failed to form - a long time ago. Our work on this proposal will perform a unified search of the Spitzer and ISO data archives for good debris disk spectral candidates, attempting to place them into the general context of planetary systems, uncovering interrelations between the disks, dust parent bodies, and planets. We propose mining the Spitzer and ISO data archives to search for high SNR, high spectral feature contrast IRS 5-35 um spectra of dust disks around (mainly) young stars in the throws of building and evolving planets. Archival data spectra will be analyzed for the amount, size, location, & composition of the dust & any remnant gas. The remote sensing analysis is based on the results of the Deep Impact excavation experiment & the STARDUST sample return experiments, & is thus both novel & experimentally verifiable. Additional information on the behavior and effects of the primary on the disk will be gleaned from the IRAS, COBE, MSX, 2MASS, SDSS, PanSTARRs, and ROSAT, Chandra, and XMM archives.

We will especially target nearby young, bright stars with unusually high amounts of warm circumstellar dust & gas formed by high temperature processes like stellar flares,
nebular shocks, collisional grinding, & giant impacts. We will explore the implications of the derived composition for the formation of the dust in the proto-planetary disk and the subsequent effects of aggregation, thermalization, & planetesimal formation. Our studies to date have detected evidence of terrestrial planet building, catastrophic disruption of an asteroid yielding a dense zody cloud, & a giant hypervelocity impact event in nearby young star systems, showing that debris disks can serve as tracers of planetesimals and planets, providing clues to the planetesimal and planet formation processes that operated in these systems in the past.

Michael Loewenstein/NASA Goddard Space Flight Center
Mining the Suzaku Archive for Elliptical Galaxies

Despite significant progress, our understanding of the formation and evolution of giant elliptical galaxies is incomplete. Many unresolved details about the star formation and assembly history, dissipation and feedback processes, and how these are connected in space and time relate to complex gasdynamical processes that are not directly observable, but that leave clues in the form of the level and pattern of heavy element enrichment in the hot ISM. The low background and relatively sharp spectral resolution of the Suzaku X-ray Observatory XIS CCD detectors enable one to derive a particularly extensive abundance pattern in the hot ISM out to large galactic radii for bright elliptical galaxies. These encode important clues to the chemical and dynamical history of elliptical galaxies.

The Suzaku archive now includes data on many of the most suitable galaxies for these purposes. To date, these have been analyzed in a very heterogeneous manner -- some at an early stage in the mission using instrument calibration and analysis tools that have greatly evolved in the interim. Given the level of maturity of the data archive, analysis software, and calibration, the time is right to undertake a uniform analysis of this sample and interpret the results in the context of a coherent theoretical framework for the first time.

We propose to (1) carefully and thoroughly analyze the available X-ray luminous elliptical galaxies in the Suzaku database, employing the techniques we have established in our previous work to measure hot ISM abundance patterns. Their interpretation requires careful deconstruction within the context of physical gasdynamical and chemical evolutionary models. Since we have developed models for elliptical galaxy chemical evolution specifically constructed to place constraints on the history and development of these systems based on hot ISM abundances, we are uniquely positioned to interpret -- as well as to analyze -- X-ray spectra of these objects. (2) We will apply these models, tailored to each system, to constrain their enrichment histories. In this way we exploit X-ray spectroscopy to help deconstruct how elliptical galaxies, and the stellar populations that compose them, form and evolve.

The insights gained into galaxy formation and evolution, the nature of Type Ia supernova, and the origin of elements in the universe necessary for life to emerge will advance the
Michael Loewenstein/NASA Goddard Space Flight Center
Solving the Mystery of Dark Matter with XMM-Newton

The keV mass sterile neutrino is a plausible (warm) dark matter candidate that may resolve some of the discrepancies in cold dark matter models, while explaining pulsar kicks and facilitating primordial star formation. Their radiative decay produces a photon amenable to X-ray observation. We have initiated the first dedicated search for dark matter using X-ray telescopes to observe dwarf spheroidal galaxies, which are ideal targets. Our Suzaku observation of the Ursa Minor system placed new constraints on sterile neutrino mass and mixing angle. These have been bolstered by Chandra data on one of the recently discovered extreme dark-dominated dwarf spheroidals -- Willman 1 -- where we uncovered evidence of a 5 keV sterile neutrino emission line. This tentative detection is best confirmed (or refuted) by utilizing the large effective area of the XMM-Newton EPIC detectors; and, we proposed for and were awarded 100 ksec of observing time (including a 20 ksec offset pointing) of Willman 1 for this purpose. Here, we propose for funding support to conduct the data analysis and interpretation necessary to arrive at a robust and definitive conclusion to the question at hand. Confirmation of this tentative detection would be of incomparable astrophysical importance, pointing the way to physics beyond the Standard Model, and implying that future X-ray spectroscopic missions will directly map the dark matter distribution, including the redshift.

Barry Madore/Carnegie Institution of Washington
The Three-Dimensional Structure of the Large and Small Magellanic Clouds

We are proposing to use archival SPITZER/IRAC observations of several thousand Cepheids in each of the Magellanic Clouds to map out the detailed three-dimensional structure of the SMC and LMC. Using newly developed techniques to recover time-averaged magnitudes from sparsely-sampled light curves and applying the most recent absolute calibrations of the mid-infrared Period-Luminosity relations to these samples we are confident that we can measure and map the back-to-front geometry of the Magellanic Cloud themselves and with respect to one another, placing new and interesting constraints on their mutual interaction and plausibly their orbital relationship to the Milky Way itself.

Alex Markowitz/University of California, San Diego
A Spectral Variability Survey of X-ray Reflection and Absorption in Seyfert AGN using the Rossi X-ray Timing Explorer Database

The Rossi X-ray Timing Explorer (RXTE) is the current longest-running X-ray mission. It has collected data on over 130 Active Galactic Nuclei (AGN) over its 15-year lifetime. We plan to systematically analyze the broad X-ray spectra of all AGN observed with RXTE to produce the ultimate and complete spectral sample with which to solidify the
legacy of RXTE towards AGN science and towards understanding the nature of reprocessing and reflection processes in Seyferts. In many cases, RXTE conducted sustained monitoring spanning a baseline of many years, so our proposed time-averaged spectral analysis reduces the ambiguity inherent in individual snapshots due to source variability, thereby providing the community with long-term average X-ray spectral properties as well as identifying any state changes in sources. We will also perform time- and flux-resolved spectroscopy to search for variability in the Fe K alpha emission line in response to X-ray continuum flux variations to constrain its location via reverberation mapping, e.g., material commensurate with the optical Broad Line Region or a parsec-scale torus. Our proposed work will place important constraints on the location and homogeneity of the Compton-thick circumnuclear accreting gas. We will also search for variations in the line-of-sight column density of absorbing material in Seyferts to test classical Seyfert 1/2 unification schemes against newer models which rely on distributions of clumps of gas and for which X-ray absorption is a viewing-angle dependent probability, and provide observational constraints for these latter models. This research supports NASA Strategic Goal 2 by expanding scientific understanding of the universe in which we live, how the universe works, and how the observable universe came to be.

**Derck Massa/STScI**  
**IR Wind Excesses in Magellanic O Stars**

It is argued that the Magellanic Clouds provide a much cleaner laboratory for studying IR excesses in OB stars than the Galaxy. We then demonstrate that Spitzer and 2MASS data for LMC and SMC O stars reveal measurable mid-IR and NIR excesses due to the stellar winds in these stars. We propose to model these excesses to determine mass loss rates for hundreds of Magellanic Cloud O stars. These IR mass loss rates will be compared to theoretical predictions and to previous observational determinations. Differences will interpreted in terms of how strongly the winds are clumped, providing important input for resolving the current controversy over the actual and inferred mass loss rates of massive stars.

**Smita Mathur/The Ohio State University**  
**Identity of nuclear X-ray sources in nearby galaxies.**

This proposal has two distinct parts which are scientifically the same; the goal is to identify nuclear X-ray sources in what were thought to be normal galaxies.

1. An approved XMM-Newton AO9 program.

We initiated a Chandra program to search for low-level nuclear activity in a representative sample of late-type galaxies within 20 Mpc. This was a highly successful program; out of 56 galaxies surveyed, we found 17 nuclear X-ray sources which are highly likely to be AGNs. We proposed XMM-Newton observations of two late-type galaxies, Scd and Sd, in both of which a nuclear X-ray source was detected with Chandra.
X-ray spectra, lightcurves, and optical--X-ray spectral energy distributions obtained with XMM will secure the identification of X-ray sources as either AGNs, low-mass X-ray binaries or star clusters. Discovering secure AGNs in these bulge-less galaxies will be exciting as it will imply that bulges are not necessary for existence of black holes. This will have important consequences towards understanding the formation and co-evolution of black holes and galaxies.

The two proposed targets were accepted for observations with priorities B (62 ks) and C (73 ks). With this proposal, we request support for this approved XMM-Newton AO9 program (PI: Mathur).

2. An archival XMM-Newton program.

From the Chandra survey mentioned above, we found that nuclear X-ray sources are present in what were thought to be normal galaxies. Moreover, they span the entire range of Hubble types, and in each Hubble type, there is a wide range of luminosity. Thus the important unsolved problem is what triggers nuclear activity in a galaxy and what determines the accretion rate. In order to answer this fundamental question, we have selected a well defined sample of nearby galaxies for which multiwavelength data already exist, from the Spitzer Infrared Nearby Galaxy Survey (SINGS). We propose to perform spectral and timing analysis and obtain optical--X-ray spectral energy distributions of nuclear X-ray sources in SINGS galaxies with XMM and we request funding for the same. Similar to the new XMM observations mentioned above, the goal is to identify these sources as AGNs, binaries or star-clusters.

This proposal is to analyze XMM-Newton data, so is directly relevant to this ADAP solicitation.

Jeffrey McClintock/Smithsonian Astrophysical Observatory

Measuring the Spins of Stellar-Mass Holes in X-ray Binaries, Phase 2

Relativity theory firmly predicts that an astronomical black hole is the result of the complete gravitational collapse of tens, millions or billions of solar masses of matter to a point, a conclusion that is beyond comprehension. In our Milky Way, there are an estimated 100 million "stellar" black holes, the collapsed remnants of giant burned-out stars. The masses of 23 of these black holes, with typical masses of 10 suns, have been measured, most of them by our team during the past 25 years. These black holes are closely orbited by a normal star that trickles gas into an X-ray-hot disk of matter that encircles the black hole.

During these past five years, we have succeeded in measuring the spins (or rate of rotation) of six of these same black holes. This is of fundamental importance for two reasons. First, a black hole is *totally* described by just the two numbers that specify its mass and its spin. Second, this complete description allows one to build full models of relativistic jets, supernovae, gamma-ray burst sources, etc. Our method for measuring spin is based on Einstein's prediction that there exists a smallest radius for a particle orbiting a black hole, inside of which the particle suddenly plunges into the hole. As a
consequence, the inner edge of the disk of gas that encircles the black hole is truncated at this minimum radius, which depends only on the spin and the known mass of the black hole. We determine the inner radius of this disk and thereby the spin by fitting the continuous X-ray spectrum recorded by an X-ray detector to a model of the black-hole's disk that includes all relativistic effects.

We propose to double our sample of black holes with measured spins from six to twelve while continuing to improve the quality of all of our spin estimates. The bulk of the requested funding will provide continued support for a postdoctoral student who leads our X-ray data analysis effort. Our work represents a new and vital use of NASA's vast HEASARC data archive. To date, we have used data from a total of ten past and current missions: RXTE, Chandra, Swift, Suzaku, ASCA, BeppoSAX, Ginga, EXOSAT, XMM-Newton and OSO-8. Our work is important to such future missions as IXO and LISA and to attaining NASA's Strategic Goal of understanding "phenomena near black holes and the nature of gravity."

Stacy McGaugh/University of Maryland

The Relation between Mass and Light in Spiral Galaxies

The rotation curves of spiral galaxies provide some of the most compelling evidence for dark matter. These data also imply a close relationship between the luminous and dark components. One example is the Tully-Fisher (TF) relation between the luminosity of a galaxy and its rotation velocity. Another is the apparent correspondence between bumps and wiggles in photometry and rotation curves.

Now that the distance scale debate is largely settled, the role of the TF relation can be expanded to the physical properties of disk galaxies and their dark matter halos. The scatter in the TF relation is minimized in the near infrared, making it the best place to map between the two components. I propose to use archival data from 2MASS and Spitzer to exploit the relation between baryonic mass and rotation velocity to obtain precise measurements of the mass and mass-to-light ratios of spiral galaxies. This is fundamental information for understanding the properties of galaxies.

In addition to global properties, there is an empirical connection between the light and mass on local scales as well. Examples include the bumps and wiggles, the systematic change in rotation curve shape with luminosity, and the mass discrepancy-acceleration relation. To date, these have only been investigated with optical surface photometry. Since we expect the relation between stellar mass and light be closest in the near-infrared, a more meaningful set of relations will follow from near-infrared data. I therefore propose to combine archival 2MASS and Spitzer data with a large, extant sample of high quality rotation curves to calibrate these relations. The result will provide information on the detailed distribution of mass in galaxies that is not otherwise accessible. This treatment of the baryonic component of bright galaxies will enable the mapping of the density profile of the dark matter halo at small radii where it is most relevant to testing the predictions of structure formation simulations.
In summary, this project will calibrate known relations between light and mass in the near-infrared. The results will be applied to obtain accurate constraints on the stellar mass of spiral galaxies and the radial distribution of dark matter therein. These are fundamental to our understanding of the formation and evolution of galaxies.

**Margaret Meixner/Space Telescope Science Institute**

**Seeding the Interstellar Medium: Quantifying the Mass Return from Evolved Stars**

We request support from the NASA Astrophysics Data Analysis program to quantify the mass return from evolved stars in the Magellanic Clouds (MCs). At the end of their lives, stars lose mass by producing dust grains and expelling them into the surrounding interstellar medium (ISM). But how much dust do the different kinds of evolved stars contribute to the mass budget of their host galaxy, and how is this dust produced? How do the returned amounts of dust from these stars depend upon metallicity? We will answer these questions by studying mass loss from evolved stars in the Large Magellanic Cloud (LMC; $Z\approx 0.3-0.5 \times Z_{\odot}$) and the Small Magellanic Cloud (SMC; $Z\approx 0.2-0.3 \times Z_{\odot}$).

The LMC and SMC have been extensively surveyed with the Spitzer Space Telescope IRAC and MIPS instruments in the Surveying the Agents of Galaxy Evolution (SAGE) legacy projects. The wealth of infrared photometry from the SAGE surveys enables determination of the dust mass loss from evolved stars to the MCs. We propose to quantify the mass-loss rate from each red supergiant (RSG) and asymptotic giant branch (AGB) star in the Magellanic Clouds by detailed radiative transfer modeling of its spectral energy distribution (SED; plot of flux versus wavelength). Determining mass-loss rates from such SED-fitting makes use of more data per star than determining mass-loss rates from the stars' colors or excess fluxes, as other studies have done. By combining the IRAC and MIPS photometry from Spitzer with existing 2MASS and optical photometry, we can construct the SED of each evolved star in the SAGE surveys. Preliminary work modeling the SEDs of 3 AGB stars suggests the oxygen-rich (O-rich) AGB star contribution to the LMC mass budget could be much higher, and the carbon-rich (C-rich) AGB contribution much lower, than expected from determining mass-loss rates (MLRs) from colors or excess fluxes.

Our initial grid of ~50,000 SED models for RSGs, O-rich AGB stars and C-rich AGB stars show promising coverage of the SAGE-LMC evolved star sample's color and magnitude range. In this 3 year investigation, we will apply this grid to the SAGE-LMC and SAGE-SMC samples and, as part of the process, continually test and improve our model grid with the feedback. In the first year, we will adapt an existing SED-fitting program used for young stellar objects to quantitatively compare the model SEDs of candidate RSGs, O-rich, C-rich and extreme AGBs to the SAGE-LMC photometry. This comparison will produce the mass-loss rate and luminosity for each evolved star. As part of the SED-fitting process, we will develop a means of distinguishing O-rich dust chemistry from C-rich dust chemistry for the extreme AGB candidates. In the second year, we will derive the mass-loss rates for the SAGE-SMC sample, and in the process improve the model grid to include the lower metallicity of the SMC. In the third year, we
propose to conduct studies of the dust composition of RSG and AGB stars by investigating the Spitzer IRS spectral samples. The luminosity and mass-loss rates for several tens of thousands of evolved stars will be used to study the physics of how dust is formed and expelled from these stars. Additionally, over all three years, we would make available on a public website all the model grids used to fit the SEDs of evolved stars in the Magellanic Clouds. Our proposed research to determine the mass-loss from evolved stars in the Magellanic Clouds will lay groundwork for future studies of mass loss in more distant galaxies, using data from future missions like the James Webb Space Telescope (JWST). We will synthesize broadband photometry in all of the bands of past, current, and future NASA missions for each of our models, and this synthetic photometry will also be available on our public website.

Stanimir Metchev/State University of New York, Stony Brook
Database Cross-Correlation at Scale: A Complete Census of Cool and Peculiar Brown Dwarfs in the 2MASS/SDSS Overlap

Cross-correlation of surveys at different wavelengths is an effective way to leverage existing data for the generation of new science. We propose to perform a cross-match of the complete 2MASS and SDSS surveys as a demonstration of database cross-correlation at scale.

The specific science case focuses on identifying cool brown dwarfs. Hundreds of L and T dwarfs have been discovered in the solar neighborhood, ~90% of which from 2MASS or SDSS. These have offered an unprecedented empirical context for the creation of sophisticated substellar phenomenology. A few dozen peculiar L and T dwarfs have also emerged from the larger sample. Their unusual spectral energy distributions have been particularly informative about the ranges of temperature, surface gravity, and dust content in ultra-cool atmospheres.

Nevertheless, fundamental aspects of our knowledge of substellar astrophysics remain fragmented. The local space density of T dwarfs is hardly known to better than a factor of several. In fact, some of the nearest cool brown dwarfs may have escaped detection. Dust and cloud dynamics in ultra-cool atmospheres, and their dependence on temperature, gravity, and metallicity remain poorly understood. And in all likelihood, the few known examples of peculiar L and T dwarfs represent merely the extremes of a broad range of existing atmospheric conditions that have yet to be revealed.

A combined search on 2MASS and SDSS is an effective way to generate a large, complete sample of L and T dwarfs to address these shortcomings. Cross-correlation of the two surveys can probe deeper, to cooler effective temperatures, and to a higher completeness level than searches on either survey alone. We validated this approach through a test cross-match of the 2099 sq.deg overlap area between 2MASS and SDSS Data Release 1. The demonstration project resulted not only in the first unbiased estimate of the space density and luminosity function of T0-T8 dwarfs, but also in doubling of the then known number of peculiar L dwarfs just from this relatively small surface area. We
will now expand the cross-correlation approach to the final SDSS footprint, which covers a 5.6 times larger area.

We expect the impact of this work to extend well beyond substellar astrophysics. The resulting eight-band (u, g, r, i, z, J, H, K) coverage over more than a quarter of the sky will create an unprecedentedly large multi-wavelength data set with broad applications to both galactic and extra-galactic astronomy. Implementation into the GATOR database query engine, maintained at the Caltech/JPL Infrared Processing and Analysis Center, and into the array of cross-matching products offered by the Virtual Astronomical Observatory, will ensure that the results will benefit the entire astronomical community. Finally, the design and validation tools developed in the course of the program will inform on the needs of future cross-comparisons among existing and next-generation survey databases.

Jon Miller/The University of Michigan
The Nature of Quiescent Emission in the Neutron Star Cen X-4

This proposal requests funding to support analysis of an approved XMM-Newton Cycle 9 observation of the nearby neutron star X-ray binary Cen X-4. The source will be observed on four occasions, for a total of 60,000 seconds. Thermal emission and cooling curves observed from quiescent neutron stars like Cen X-4 has enabled unique constraints on the nature of ultra-dense matter, which cannot be replicated in any laboratory. Such investigations are consistent with NASA science objectives such as "Discovering the nature of the universe". This program seeks to understand the nature of variability in quiescent neutron stars through the unique multi-wavelength capabilities of XMM-Newton. This variability may represent continued accretion on the star, which would serve to limit the ability of observations to reveal fundamental stellar parameters. It is therefore vital that the nature of this variability be understood.

Jon Miller/The University of Michigan
Does the Fe K line Evolve Around the Color-Color Diagram of the Neutron Star GX 17+2?

This proposal requests funding to support the reduction and analysis of an accepted XMM-Newton Cycle 9 observing program to study the neutron star X-ray binary GX 17+2. Iron lines emitted from the inner accretion disk around neutron star can provide constraints on the stellar radius, and thus the equation of state of ultradense matter. The same lines are also excellent tracers of the innermost accretion flow. Understanding ultradense matter and accretion power is central to NASA science themes such as "Discovering the nature of the universe", as well as the nature of space and time close in strong gravitational environments. This approved program will observe GX 17+2 for a total of 80 ksec on four separate occasions, to study the accretion flow at four different points. This is an unprecedented study for a source of this kind and will thus tap an emerging discovery space.
With this proposal, we request support for an approved XMM-Newton AO9 program, aimed to reveal Compton-Thick (CT) Luminous AGNs in 2 powerful [OIII] emitters: Mkn 477 and IRAS~15480-0344. The approved cycle 9 XMM-Newton (hereinafter XMM) science proposal (PI EP, Collaborator of this proposal) is designed to complete an observing program accepted during the previous XMM cycle and its main goal is to discover uncontroversial examples of the, still elusive, population of Compton-Thick (CT) quasars, by selecting them among the most [OIII]-luminous AGNs in the local Universe.

These selection and observational strategies are designed to minimize the risks of ambiguous results that have affected most of the blind searches for CT luminous AGNs performed so far, and their efficacy is demonstrated by the observation of our approved cycle-8 target IRAS 20210+1121, that has successfully revealed a CT-quasar (Piconcelli et al., in preparation).

The accepted cycle 9 XMM program will observe the powerful [OIII]-emitter AGN Mkn 477 (z=0.038), for 26 ks, while the other cycle-9 approved target, IRAS 15480-0344 (z=0.0303) has just recently been observed for 52 ks, as a C-priority target of our predecessor cycle-8 program: here we request support for the analysis of both the observations. While previous low-quality (Mkn 477), low S/N (IRAS 15480-0344) X-ray data of our two targets provided strong, although inconclusive, evidence for a reflection-dominated spectrum (Awaki et al., 2000: Mkn 477; Guainazzi et al., 2005: IRAS 15480-0344), the large [OIII] luminosity of these targets, L([OIII]) > 1e43 erg/s, is suggestive of strong nuclear activity, and indicates intrinsic X-ray luminosities L(2-10 keV) >~ 1e44 erg/s, typical of quasars. Our XMM observations will unambiguously discern between a X-ray reflection-dominated spectrum and a highly absorbed (but not reflection-dominated) intrinsic quasar continuum, and will therefore allow us to classify these two targets as belonging to the still-elusive population of CT-quasars, or to the much more common Seyfert 2 galaxy population in the local Universe.

George Pavlov/Pennsylvania State University
A Transient Anomalous X-ray Pulsar and Serendipitous Sources in a Deep XMM-Newton Observation

Observations of 1993 with the ASCA X-ray observatory revealed a point source, AX J1845.0-0258, whose 7 s period and spectrum strongly suggest that it is an anomalous X-ray pulsar (AXP). However, the brightest object seen in further observations with various X-ray missions in the ASCA error circle was a factor of 15 fainter, too faint to detect pulsations and confirm that this source is a transient AXP (TAXP) in a quiescent state. To detect the TAXP in quiescence via timing and spectral analysis, we proposed a deep XMM-Newton observation of this field. The proposal was accepted, and two observations were carried out in April 2010. Our inspection of the data has shown that they are of a sufficiently high quality to perform the originally proposed analysis of the TAXP candidate. In particular, the timing analysis should either detect pulsations from
the TAXP candidate, thus measuring the period derivative, age and magnetic field, or prove that this object is not related to the originally observed X-ray pulsar. In the latter case, we will either detect an even fainter actual TAXP or establish a very deep upper limit on its quiescent flux.

In the obtained XMM-Newton data, we serendipitously detected a puzzling extended source, possibly a pulsar wind nebula, which has apparent radio, infrared, and gamma-ray (TeV) counterparts. To establish the nature of this source, a thorough analysis of the multiwavelength data is needed.

To analyze and interpret the data on the TAXP candidate and the serendipitous sources, we request NASA funding. The results of our work will provide a significant contribution to the study of the extreme physics at the end of normal stellar lives, which is one of the NASA's Astrophysics Science Objectives.

Paul Plucinsky/Smithsonian Astrophysical Observatory
An XMM Archival Study of the LMC SNR N132D

We propose to study the X-ray brightest supernova remnant (SNR) in the Large Magellanic Cloud (LMC) N132D to determine the abundances of the high Z products of nucleosynthesis (Si, S, Ca, Ar, etc.) relative to Fe and compare those values to current models of nucleosynthetic yields. We will also characterize the evolutionary parameters of the SNR (age, initial explosion energy, average initial ambient density) to place this remnant in context with studies of other remnants at different evolutionary stages. We intend to take advantage of the unique opportunity presented by the existing ~900 ks of observations acquired by XMM-Newton over the past 10 years. N132D has been routinely observed as a calibration target but the full scientific potential of these data have yet to be realized. These archival data represent the equivalent of a "Large Program" which would be difficult or impossible to acquire under a Guest Observer program.

N132D has been extensively studied at other wavelengths and has been classified as an 'O-rich' remnant based on the optical spectra. The abundances derived from the optical suggest the progenitor was a massive star, perhaps as massive as 35 or more solar masses. The detection of only C, O, Ne, Mg, and Si in the ejecta suggest the progenitor may have been a WO Wolf Rayet star with an O rich mantle which did not mix with the deeper layers. The spectra of the bright optical knots do not show any emission from elements with higher Z than Si, yet the nucleosynthesis models predict significant quantities of these higher Z elements. Our preliminary analysis of the deep XMM-Newton data clearly show emission lines from S, Ar, Ca, and Fe, with indications of other possible lines between Ca and Fe. It is clear that the X-ray emitting and optically-emitting gas are probing different regions of the ejecta. Only with a complete characterization of all of the ejecta can a meaningful comparison to nucleosynthesis models be made and conclusions drawn about the progenitor.

N132D offers distinct advantages over the Galactic O-rich remnants, Cas A, G292.2+1.8, and Puppis A for abundance determinations based on spectral analysis. The extinction to N132D is relatively low permitting detailed studies in the optical and UV and the reverse
shock has had more time to interact with the ejecta, resulting in smaller variations in the
temperature and ionization timescale compared to other remnants. Cas A, G292.2+1.8,
and Puppis A all have higher absorption than N132D. Cas A is only ~350 yr old such
that the variations in temperature and ionization timescale complicate any determination
of the elemental abundances. The Small Magellanic Cloud remnant 1E0102.2-7219 is an
appealing target except that the X-ray spectrum shows only weak lines of Si and perhaps
S with nothing in between these and Fe. Of all the O-rich remnants, N132D presents the
best opportunity to accurately determine the relative abundances of the high Z elements
and these 900ks of XMM-Newton data offer the most sensitive measure of the relevant
determination of the elemental abundances.

Andrew Ptak/NASA Goddard Space Flight Center
A Comparative X-ray and Infrared Analysis of Multiple Samples of Seyfert 2
Galaxies

Obscured (Type 2) AGN represent the majority of the population and thus play a vital
role in the growth and evolution of supermassive black holes. Two of the most powerful
ways to recognize such AGN are through their hard X-ray and mid-IR emission. To
better understand the relationship between AGN selected in these two ways, we propose
to analyze Spitzer, XMM-Newton, and Chandra observations that will provide mid-IR
and X-ray spectral analysis of the all of the Type 2 AGN in the complete IRAS 12
micron-selected sample with available X-ray and Spitzer IRS observations (29 out of 32,
all 32 have high-resolution Spitzer spectra in the archive) along with optically-selected
Seyfert 2s and very hard X-ray selected AGN. This combined data set will allow us to
determine the fraction of Compton-thick AGN and to determine whether Compton-thick
AGN differ systematically in terms of the other properties of the AGN and its host
galaxy.

Robert Rubin/NASA Ames Research Center
Spitzer Finds Cosmic Neon and Sulfur's Sweet Spot

Elemental abundances are the fossil remnants of the life history of a galaxy. Abundance
ratios indicate the effects of star formation and the release of nuclear processed heavy
elements via planetary nebulae and supernovae, plus other mechanisms. By deriving the
elemental abundances and judicious modeling, astronomers are able to determine the
relative importance of these processes in the chemical evolution of a galaxy. Modeling
requires the input of nucleosynthetic yields from stellar evolution and supernova
calculations.

Since most fusion reaction rates cannot be measured in any earthly laboratory, the
observed elemental ratios provide good tests of fusion reaction rate calculations. This
proposal addresses the means by which we determine elemental abundances. H II
regions are the prime laboratory for the measurement of the most abundant elements- He,
C, N, O, Ne, S, and Ar, (usually with respect to hydrogen)- because these elements have
strong lines in the ionization states produced by the Lyman continuum photons from
massive O-stars. With Spitzer's Infrared Spectrograph (IRS) Short-High (SH) module
(wavelength range 9.9-19.6 microns), we have the unique opportunity to measure lines from the two ions of neon (Ne+ & Ne++) and the two most abundant ions of sulfur (S++ & S+3) that are seen in H II regions: [Ne II] 12.8, [Ne III] 15.6, [S III] 18.7, and [S IV] 10.5 microns. These co-spatial/coeval spectra enable unprecedented accuracy for the measurement of these four lines and the estimate of the Ne/S abundance ratio. In Spitzer Cycles 1, 2, and 4 we measured respectively the Ne/S ratios for the galaxies M83 (a barred spiral), M33 (a local group spiral), and NGC 6822 (a local group dwarf irregular). With other GO programs, in Cycle 1 we measured the abundances in two Milky Way H II regions & the Arched Filaments in the Galactic Center, and in Cycle 5, the Orion Nebula. We propose to estimate the Ne and S abundances in many more H II regions, both extragalactic and Galactic, using archival Spitzer IRS-SH spectra. We wish to determine how much the true Ne/S ratio varies. There is a hint from our prior data that there is some metallicity dependence. We will also measure the abundances of other ions, including Si+, Fe+, and Fe++, for those sources that were also measured with the Spitzer IRS Long-High (LH) module (wavelength range 19-37 microns). The abundant elements Si and Fe are refractory and depleted onto dust grains; we will estimate the depletion from these gas-phase measurements. The LH also covers the [S III] 33.5 micron line that together with the 18.7 line provides a diagnostic of electron density.

In addition to the nebular abundances, geometry, and density structure, photoionization models of H II region require input of an ionizing spectral energy distribution (SED) as predicted by stellar atmosphere models. Our four 'major' Spitzer program lines probe ions with ionization potentials 21.6 (Ne+), 41.0 (Ne++), 23.3 (S++), and 34.8 eV (S+3); thus, the ionic ratios derived from the observations are sensitive to this part of the ionizing SED, which often differs considerably between the stellar atmosphere models. In support of this project, Co-I Pauldrach will compute an extensive new set of O-star atmosphere models that use different metallicities than the Solar values used previously. This is a needed advance in order to do more refined comparisons between predictions and observation. The Spitzer-derived ionic ratios we have studied appear to provide a strong discriminant between the various state-of-the-art atmosphere models. Our work will help test/validate which set appears to be most realistic, and provide feedback to that community.

Using the best SEDs provides the most reliable photoionization models for H II regions.

Raghvendra Sahai/Jet Propulsion Laboratory
The Beginning of the End: Mass Loss from Dying Stars in the Galactic Bulge

Almost all stars in the 0.8-8 solar mass range evolve through the Red Giant Branch (RGB), Asymptotic Giant Branch (AGB), and planetary nebula (PN) evolutionary phases. Most stars that leave the main sequence in less than a Hubble time will end their lives in this way. The dusty mass-loss process that begins as stars reach the tip of the RGB, continuing onto the very heavy mass loss that occurs during the AGB phase, is important across astrophysics. There are no good theoretical or observational
prescriptions on how to include mass-loss into theoretical models, and astronomers have relied on an outdated single empirical law based on observations of Pop I giants. A reliable mass-loss law directly calibrated using Pop II giants does not exist as yet: the two major causes being (i) the lack of a sensitive probe of dusty mass-loss down to the lowest mass-loss rates, and (ii) the lack of a sample of giants for which the distances are well known.

We propose a study which will overcome both of these issues by utilising a new sample of giants observed at five wavelengths spanning the 3.6-24 micron range (using the Spitzer IRAC and MIPS instruments) towards the Galactic Bulge (GB). The GB is an important dynamical and morphological component of our Galaxy, and offers an environment distinct from the Galactic disk, for the study of stellar populations, stellar evolution and the mass-loss processes which accompany, and in the end, control late stellar evolution. We propose to analyse archival Spitzer IRAC and MIPS data towards the Galactic Bulge, in order to (1) detect stars with mass-loss rates 10-20 times lower than those detected previously, and thus determine whether mass-loss (dM/dt) is already prevalent on the RGB, (2) determine how dM/dt depends on luminosity and stellar effective temperature (3) determine how dM/dt changes as stars evolve up the RGB and then to the AGB, (4) determine the census of mass-losing stars at different rates, and (5) together with existing studies which probe higher mass-loss rate stars, infer the total rate of mass loss in the Bulge, as input to evolutionary models of the Bulge. Furthermore, we will examine whether the mass loss in the Bulge is distributed vertically (i.e., as a function of Galactic latitude), in a similar manner as the stars, or whether it is relatively more concentrated toward the Galactic plane (as expected from the vertical segregation of stellar ages due to the scattering of stars off molecular clouds in the Central Molecular Zone).

This work is proposed to be conducted as Fundamental Research.

Rita Sambruna/NASA Goddard Space Flight Center

Ultra-Fast Outflows in Radio-Loud AGN: New Constraints on Jet-Disk Connection

There is strong observational and theoretical evidence that outflows/jets are coupled to accretion disks in black hole accreting systems, from Galactic to extragalactic sizes. While in radio-quiet AGN there is ample evidence for the presence of Ultra-Fast Outflows (UFOs) from the presence of blue-shifted absorption features in their 4-10~keV spectra, sub-relativistic winds are expected on theoretical basis in radio-loud AGN but have not been observed until now. Our recent Suzaku observations of 5 bright Broad-Line Radio Galaxies (BLRGs, the radio-loud counterparts of Seyferts) has started to change this picture. We found strong evidence for UFOs in 3 out of 5 BLRGs, with ionization parameters, column densities, and velocities of the absorber similar to Seyferts. Moreover, the outflows in BLRGs are likely to be energetically very significant: from the Suzaku data of the three sources, outflow masses similar to the accretion masses and kinetic energies of the wind similar to the X-ray luminosity and radio power of the jet are
inferred. Clearly, UFOs in radio-loud AGN represent a new key ingredient to understand their central engines and in particular, the jet-disk linkage.

Our discovery of UFOs in a handful of BLRGs raises the questions of how common disk winds are in radio-loud AGN, what the absorber physical and dynamical characteristics are, and what is the outflow role in broader picture of galaxy-black hole connection for radio sources, i.e., for large-scale feedback models. To address these and other issues, we propose to use archival XMM-Newton and Suzaku spectra to search for Ultra-Fast Outflows in a large number of radio sources. Over a period of two years, we will conduct a systematic, uniform analysis of the archival X-ray data, building on our extensive experience with a similar previous project for Seyferts, and using robust analysis and statistical methodologies. As an important side product, we will also obtain accurate, self-consistent measurements of the broad-band X-ray spectra of radio-loud AGN for comparison to radio-quiet, addressing the origin of the division between the two classes. In addition, the upcoming Astro-H mission will greatly benefit from the outcomes of this project, which will provide templates for realistic simulations to define the scientific requirements of the calorimeter, and a list of targets to design a sample for the core AGN projects of the team.

David Sanders/University of Hawaii

We propose to use NASAs multi-mission archives to assemble and produce calibrated, multi-wavelength (X-Ray to radio) spectral energy distributions (SEDs) for ~500 luminous infrared-selected galaxies drawn from two complete, flux-limited, all-sky samples: the IRAS Revised Bright Galaxy Sample (RBGS) and the 1-Jy Sample of ULIRGs. As the brightest extragalactic infrared sources in the sky, these samples offer the best chance for detailed studies of the origin and evolution of luminous infrared galaxies, and for understanding the nature of their power source. Specifically, we plan to process ~10,000 images drawn primarily from 2MASS, Spitzer, GALEX, XMM, ASCA, Chandra and HST in order to obtain accurate total as well as aperture photometry for the individual components of this sample of largely interacting/merger systems. These data will be made public through NEDs graphic tools interface in the form of calibrated WCS image overlays and standard data tables along with accompanying SED plots.

Luminous Infrared Galaxies (LIRGs) are an extremely important class of extragalactic objects. Studies of the complete samples of (U)LIRGs in the RBGS and 1-Jy samples have shown that LIRGs appear to represent a critical stage in galaxy transformations, triggered by strong interactions/mergers of gas-rich spirals, with the most luminous systems representing major mergers powered by a mixture of powerful starburst and the fueling and buildup of a massive black hole (MBH). Evidence suggests that ULIRGs may represent a precursor stage to the formation of Quasars, where the merger will eventually expel its massive nuclear concentration of gas and dust through starburst superwinds and radiation pressure from AGN accretion, the end product being a massive elliptical galaxy. More recent studies of faint sources detected in Spitzer deep fields,
along with ground-based detections of faint submillimeter sources, suggests that (U)LIRGs were much more common at earlier epochs, with a comoving volume density increasing by a factor of ~500x over the redshift range z=0-2. (U)LIRGs may actually dominate the total luminosity output of all galaxies at high redshifts! Calibrated, multi-wavelength images and SEDs for (U)LIRGs in the RBGS and 1-Jy samples offer the best hope for a better understanding the properties of (U)LIRGs in the local as well as the distant universe, and it is therefore somewhat surprising that good SED templates and WCS images simply are not currently available for large samples of these objects. Our proposed ADP project will produce a NASA Atlas of Luminous Infrared Galaxies that will be of timely importance for more detailed studies of (U)LIRGs in the local universe as well as new sources that are being discovered in deep surveys with Spitzer and Herschel.

Craig Sarazin/University of Virginia
The Physics of Cosmic Shocks: An XMM-Newton Large Project to Observe the NW Merger Shock and Radio Relic in Abell 3667

We have an approved XMM-Newton Large Program to observe the North-West (NW) radio relic region in the Abell 3667 cluster of galaxies for 311 ksec. Abell 3667 is the archetype of a merging cluster with radio relics. The NW relic is the brightest cluster relic or halo known. Previously, we imaged this region with XMM in AO-7. We detected a X-ray brightness and hardness jump at the edge of the NW relic. This could be due to a merger shock, or to inverse Compton (IC) emission from the relic; both are consistent with the observed spectra to within the errors, although a number of argument suggest that the merger shock may dominate the X-ray emission. Our long observations will determine the contributions of shock and IC emission. We will determine the extent to which nonequipartition of electrons and ions and non-equilibrium ionization affect the post-shock gas in this very low density region. Comparison of the shock properties and the radio relic will be a critical test of the shock acceleration model for relics. The relic IC emission will give the magnetic field and cosmic ray energy of the relic. We will determine the efficiency of particle acceleration, and provide the first data on the physics of cosmic shock fronts.

Here, we are requesting funding to allow the analysis of this data. The Large Program consists of five observation of the northwest radio relic and merger shock region. These 5 observations will be analyzed and combined with the existing shorter XMM observation of this region and the 7 other XMM observations of the Abell 3667 cluster. We also have 3 Suzaku observations of this cluster, including one long one on the NW radio relic region. The new XMM observations will be combined with the Suzaku Hard X-ray Detector data to give an independent measurement of the IC emission from the relic. The Suzaku XIS ccd spectra will augment the XMM data in determining the properties of the cluster at large radio. The XMM observations will also be compared in detail to the existing SUMSS and ATCA radio data on the relic.
In a recent study of nearby low metallicity dwarf galaxies using archival Spitzer data, we found strong excesses at 4.5 microns above that expected by starlight. This excess is correlated with metallicity, in that the systems with the largest excesses always have low metallicity. However, the reverse is not always true: some low metallicity systems do not show strong excesses. Comparison to data at other wavelength and to population synthesis models indicated that this excess is due to a combination of Br-alpha, reddening by dust, and the nebular continuum, as well as possible contributions from hot dust emission. The galaxies with the largest excesses tend to be classified as compact and/or interacting/merging. We propose to expand and extend this study to include additional low metallicity systems, to better quantify these results and to investigate selection effects. We will also conduct a quantitative analysis of the morphologies of these galaxies, determining compactness and asymmetry of the galaxies using Spitzer and available optical images, for comparison with the Spitzer colors. This project will provide valuable ground-work for future infrared spectroscopy using SOFIA, JWST, and AKARI.

We request modest, 1-year funding to support two programs for which XMM-Newton and RXTE time have been awarded for research on two "gamma Cas X-ray variables," HD 110432 and gamma Cas itself, respectively. For the first program some travel money is requested because the program relies upon a broad array of contemporaneous ground-based observations. The science justification for these programs is to determine the circumstances to the "long cycles" of these stars, which have been shown exist in both X-ray and optical wavebands for gamma Cas and probably for HD 110432. It is important to establish the presence of these cycles in order to explore the possible interaction of the central Be star and its surrounding decretion disk (including a disk dynamos) that may be responsible for the generation of the mysterious hard X-ray emission coming from local hot (100 MK) plasma from these hard X-ray objects.

Planetary debris disks allow us to study the evolution of planetary systems similar to our own, advancing our ultimate goal to understand the prevalence of habitable, terrestrial planets. We will model well-characterized debris disks (those resolved in HST imaging and with Spitzer spectra and imaging) to: 1.) test for periods of high dynamical activity in planetary system evolution; 2.) probe the evolution of planetesimals near the ice lines; 3.)
identify nearby stars that may have massive planets in large radial orbits; and 4.)
determine the extent of the outermost planetesimal zones analogous to the Kuiper Belt.

From the Spitzer data, we will assemble detailed spectroscopic 10-100 micron spectral
energy distributions (SEDs) of 82 debris disks with high-quality IRS and MIPS-SED
observations. Within this sample are 16 systems resolved by HST in scattered light.
These systems can be used to test and refine model inputs such as grain optical properties
and the particle size distribution. We will use this information to improve our existing
tools that use the combination of scattered light and thermally-reradiated data as common
constraints on debris disk models. We will then extend the models to 18 additional
systems resolved by Spitzer, and from there to the 48 systems that are unresolved but
have similarly detailed 10-100 micron spectroscopic SEDs from Spitzer.

These models will be used to test whether the extended halos around some disks are a
steady-state phenomenon or indicate recent dynamical activity. They will also probe
whether the narrow range of temperatures of warm disk components (independent of
stellar type) is related to the sublimation of planetesimals near the ice lines. We will
enhance current methods to predict the positions of massive planets from debris disk
SEDs. Finally, our theoretical work on the size distribution of particles in collisional
cascades will provide new insights to the extent of the cold planetesimal belts (similar to
the Kuiper Belt) seen by Spitzer and to be observed in detail with Herschel.

Jonathan Tan/Dept. of Astronomy
Shadows and Dust: Mid-Infrared Extinction Mapping of the Initial Conditions of
Massive Star and Star Cluster Formation

We describe a research plan to develop and extend the mid-infrared (MIR) extinction
mapping technique presented by Butler & Tan (2009), who studied Infrared Dark Clouds
(IRDCs) using Spitzer Space Telescope Infrared Array Camera (IRAC) 8 micron images.
This method has the ability to probe the detailed spatial structure of very high column
density regions, i.e. the gas clouds thought to represent the initial conditions for massive
star and star cluster formation.

We will analyze the data Spitzer obtained at other wavelengths, i.e. the IRAC bands at
3.6, 4.5 and 5.8 microns, and the Multiband Imaging Photometer (MIPS) bands,
especially at 24 microns. This will allow us to measure the dust extinction law across the
MIR and search for evidence of dust grain evolution, e.g. grain growth and ice mantle
formation, as a function of gas density and column density. We will also study the
detailed structure of the extinction features, including individual cores that may form
single stars or close binaries, especially focusing on those cores that may form massive
stars. By studying independent dark cores in a given IRDC, we will be able to test if they
have a common minimum observed intensity, which we will then attribute to the
foreground. This is a new method that should allow us to more accurately map distant,
high column density IRDCs, probing more extreme regimes of star formation. We will
combine MIR extinction mapping, which works best at high column densities, with near-
IR mapping based on 2MASS images of star fields, which is most useful at lower
columns that probe the extended giant molecular cloud structure. This information is crucial to help understand the formation process of IRDCs, which may be the rate limiting step for global galactic star formation rates. We will use our new extinction mapping methods to analyze large samples of IRDCs and thus search the Galaxy for the most extreme examples of high column density cores and assess the global star formation efficiency in dense gas. We will estimate the ability of future NASA missions, such as JWST, to carry out MIR extinction mapping science. We will develop the results of this research into an E/PO presentation to be included in the various public outreach events organized and courses taught by the PI.

John Tomsick/University of California, Berkeley
Jets and Accretion Disks in X-ray Binaries

The outflow of material in the form of jets is a common phenomenon in astronomical sources with accretion disks. Even though jets are seen coming from the cores of galaxies, Galactic compact objects in X-ray binaries, and stars as they are forming, we do not understand in detail what accretion disk conditions are necessary to support a relativistic jet. This proposal focuses on multi-wavelength studies of X-ray binaries in order to improve our understanding of the connection between the disk and the jet. Specifically, this proposal includes work on two approved cycle 14 Rossi X-ray Timing Explorer (RXTE) programs, an approved XMM-Newton program, as well as a synthesis study of transient black hole X-ray binaries using archival RXTE and radio data. We plan to use X-ray spectral and timing properties to determine the disk properties during the re-activation of the compact jet (as seen in the radio and infrared) during the decays of black hole transient outbursts, to determine how the inner disk properties change at low mass accretion rates, and to use RXTE along with multi-wavelength observations to constrain the jet properties required for the microquasar Cygnus~X-3 to produce high-energy emission. Due to the ubiquity of jets in astrophysical settings, these science topics are relevant to NASA programs dealing with the origin, structure, evolution, and destiny of the Universe, and especially to understanding phenomena near black holes.

Tracey Turner/University of Maryland Baltimore County
X-ray constraints on Accretion Disk Winds in Active Galactic Nuclei

Feature-rich X-ray spectra of AGN reveal signatures from circumnuclear reprocessing gas spanning at least four orders of magnitude in column density; this gas is likely dominant in shaping X-ray spectra and variability in AGN. Time lag signatures for X-ray continuum reverberation appear to demonstrate that the nuclear regions have a high covering fraction of absorbing, Compton-scattering gas existing on scales of light-hours and very likely outflowing material being blown off the accretion disk. We have developed a radiative transfer code which incorporates much of the physics need to determine the ionization structure of winds, and demonstrated qualitatively that we can reproduce many of the features seen in X-ray spectra of AGN. Here we propose to use our radiative transfer code to model archived XMM-Newton and Suzaku spectra in order to determine whether the qualitative picture that has been developed can be made
quantitative, and use it to constrain fundamental properties of the wind, such as the total mass outflow and overall shape of the wind and thus help us understand the accretion process along with the formation of disk winds.

Tracey Turner/University of Maryland Baltimore County

X-ray Reverberation: Mapping the Inner Regions of Active Galactic Nuclei

Time lags less than 1 ks between hard and soft bands have been known in AGN for several years. We have recently shown, with case studies of 1H0707-495 and NGC 4051, that lag energy-and frequency-dependences match extremely well the effects of reverberation from material surrounding the source at a few hundred gravitational radii. In 1H0707-495 we have demonstrated that the entire spectrum of lags, considering both the full energy range, 0.3-7.5 keV, and the full frequency range are inconsistent with previous claims of arising as reverberation associated with the innermost accretion disk. Data instead support a simple reverberation model, in which reflection is present in all X-ray bands, explaining the full set of lags without requiring any ad hoc explanation for the time lag sign changes. Consideration of the combined timing and spectral analysis shows strong evidence for high covering factors of absorbing and reflecting material around the central black hole. Having established this framework for interpretation, measuring the reverberation transfer function will allow us to derive strong constraints on the location and distribution of the circumnuclear gas. While reverberation between different wavebands has been performed on many AGN, our study of reverberation within the X-ray band is new, surpasses other models by describing both the timing and spectral data and tightly constrains the circumnuclear gas. It is obviously important to test the general applicability of this new X-ray reverberation model across a sample of uniformly analyzed AGN, and that is the aim of the proposed study.

Pieter van Dokkum/Yale University

A Complete Census of Passive Galaxies, Star Forming Galaxies, and Obscured AGN at 1<z<3

The processes that govern the formation and evolution of galaxies are not well understood. Through extensive efforts it has become clear that the epoch $z=1-3$, when the Universe was between 2 and 5 billion years old, was the "heyday" of galaxy formation when the basic characteristics of today's galaxies were put into place. However, it is not yet clear what happened during that period, despite extensive surveys with large telescopes on the ground and in space.

There are two reasons why it has been difficult to study this epoch in a systematic way. Firstly, it is difficult to measure spectroscopic redshifts of complete samples of galaxies at $z>1$, as familiar rest-frame optical spectral features are redshifted into the observer's near-IR. Second, it is not possible to disentangle the effects of dust, age, star formation, and AGN activity on the rest-frame UV and optical spectral energy distributions.

Here we propose to address both these issues by combining state of the art public Spitzer IRAC and MIPS data with a unique set of 10,000 high-quality redshifts $z=1-3$ from the
NEWFIRM Medium Band Survey (NMBS). The Spitzer data provides the crucial longwavelength coverage necessary for constraining the stellar populations and AGN activity, and the NMBS provides the redshift accuracy which is needed for determining rest-frame colors, masses, and other parameters. The NMBS achieves this through the use of an innovative set of 5 medium-bandwidth near-IR filters, which sample the Balmer and 4000 Angstrom break as they shift through the J and H bands at z=1.3-3.5.

The proposed program has two components: 1) construction and public release of a combined NMBS + Spitzer catalog, which includes redshifts accurate to 1%-2% and derived stellar population parameters; and 2) science projects enabled by this catalog. The first component has priority, and we commit to publicly releasing the catalog and derived quantities within 18 months of acceptance of this proposal. Our science program has three components: the identification and study of quiescent and star-forming galaxies out to z=3; the identification of obscured AGN; and tests of stellar population synthesis models. Together these projects will provide a self-consistent description of the evolution of galaxies over the crucial redshift range z=1-3.

The returns from this program will be greatly amplified by the public release of the catalog, which will aid essentially all cosmological survey efforts with Spitzer in the AEGIS and COSMOS fields.

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Ted von Hippel/Siena College

New Leverage on Stellar Evolution: NASA Archives and Bayes

Motivation: Perhaps the most important achievement of stellar evolution is its ability to determine the ages for star clusters, and thus the ages and star formation histories of the Milky Way and other galaxies. Yet, stellar evolution still suffers limitations that make it extremely difficult to derive the ages to better than 1-2 Gyrs for globular clusters and to even lower precision for open clusters. Furthermore, these are the errors quoted in the literature, which usually include only data and fitting errors and not intrinsic uncertainties in the stellar evolution models themselves. Despite many successes, stellar evolution models are limited in two main ways: lack of understanding of certain physical processes (e.g., mass loss) and our inability to accurately model physical processes in 1-D (e.g., convective mixing).

Proposed Solution: We propose to take advantage of three new developments to significantly refine our understanding of stellar evolution, in particular the processes dominated by mass loss, parameterizations of convection, and issues that affect WD ages. The first of these three new developments is that we can now take advantage of large, homogenous photometry databases for open and globular clusters obtained by the Hubble Space Telescope (HST), the Spitzer Space Telescope (Spitzer), and the Two-Micron All-Sky Survey (2MASS). The second development is the creation of MESA, a fully verified and validated, open source stellar evolution code with updated physics and modern, sophisticated numerical methods. The third is a Bayesian code developed by our group that takes full advantage of all the available photometry and stellar evolution model information throughout the color-magnitude diagram, as well as ancillary data such as
membership probabilities through radial velocities or proper motions, spectroscopic masses, and spectroscopic effective temperatures.

Research Strategy: We will use HST, Spitzer, and 2MASS photometry of stars in ~300 open clusters and ~70 globular clusters to create spectral energy distributions for all stars in these cluster fields with sufficient photometric accuracy. The HST data will provide deep cluster sequences including white dwarfs and the lower main sequence for a few globular clusters and exquisite giant branch morphology down to and including the main sequence turn-off (MSTO) for ~70 Galactic globular clusters. The Spitzer data for a subset of these globular clusters will provide one of our three approaches to measuring mass loss on the giant branch. The 2MASS data will provide homogeneous near-infrared data, largely insensitive to intervening dust, for ~300 open clusters down to and including the MSTO.

Secondly, we will generate stellar evolution models sufficient to explore not only variations in age and chemical composition but also poorly constrained aspects of stellar evolution such as convective overshoot and the treatment of mass loss. In addition, we will also explore uncertainties in the evolution of white dwarfs, such as the core carbon-to-oxygen ratio and the processes of phase separation and crystallization.

Thirdly, we will test the family of relevant stellar evolution models against each open and globular cluster dataset with our Bayesian technique. This will allow us to objectively and precisely derive posterior distribution for every parameter of interest, marginalized over every other parameter.

Significance: With these three novel elements to our research program, we expect to refine the precision of stellar cluster ages to approximately 5% and then to systematically attack the major theoretical sources of uncertainty in stellar evolution, particularly convection parameterizations, mass loss, and outstanding issues in WD cooling. This in turn will refine the accuracy with which we can derive stellar evolutionary ages.

Bastiaan Wakker/University of Wisconsin
Metallicities of High-Velocity Clouds

We propose to use FUSE and HST spectra to measure the metallicities of high- and intermediate-velocity clouds (HVCs/IVCs). These objects serve as test particles for modeling Galactic phenomena, such as the Galactic Fountain, tidal stream and accreting low-metallicity gas. The properties of the latter type also appear similar those of intergalactic gas clouds seen in QSO absorption lines, and thus may hold clues to understanding the IGM. The proposed ADP project will complement our projects to determine distances to and understand the kinematics of the HVCs. HVC/IVC metallicities have been measured for a few clouds, but the FUSE and HST datasets contain unanalyzed spectra for many others. We will analyze 46 sightlines toward 16 different clouds (38 with FUSE data, 13 with both FUSE and HST data) to measure the column densities of ions such as OI, SII, SiII and FeII. The resulting metallicities and depletions will allow us to identify the origin of each cloud. Combined with the
HVC/IVC distances and an understanding of their motions, we can then determine flow rates for the Fountain and for infall.

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**Q. Daniel Wang/University of Massachusetts Amherst**  
**Peering Through the Dusty Veil: Multi-band Infrared Mapping of the Galactic Nuclear Region**

Our Galactic center is the only galactic nuclear region where the stellar population can be resolved. However, progress in understanding the population and spatial distribution of stars in the center as well as their formation mode and history has been hampered by strong and uncertain dust extinction. We propose a comprehensive data analysis program to map out the extinction toward the central region of our Galaxy, using available multi-band infrared imaging data from Spitzer/IRAC and HST/NICMOS observations, together with complementary ground-based surveys, including 2MASS. We will test various extinction laws and map out the extinction in two ways: one from multi-band photometry of individual detected stars; the other from pixel-based intensity colors. The constructed extinction maps will have a resolution better than about 10 arcseconds. In the mean time, we will detect essentially all evolved low-mass stars and a good sample of massive stars, particularly in regions outside the three known stellar clusters; and we will determine or tightly constrain the spectral shapes and line-of-sight extinctions of these stars. We will also statistically examine the global 3-D distribution and formation history of the overall stellar population. Ultimately, we will be able to address such questions as: Where and how do massive stars form in the extreme galactic nuclear environment? Is there evidence for a bottom-light initial mass function of stars? How do stellar clusters dissolve? And is there a lopsided and/or eccentric nuclear stellar disk or cluster (on scales of a few pc, similar to those observed in M31 and several other nearby galaxies)? Answering these questions will represent a critical step in understanding stellar properties in other galactic nuclei and how stars act collectively to regulate the activities of central supermassive black holes and affect the evolution of galaxies as whole.

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**Tony Wong/University of Illinois at Urbana-Champaign**  
**Testing Equilibrium Models of Molecular Gas in the Magellanic Clouds**

We propose to study the molecular gas fractions and physical conditions of diffuse molecular clouds in the Magellanic Clouds using ultraviolet (UV) and optical absorption spectra, principally from the Far Ultraviolet Spectroscopic Explorer (FUSE) and Hubble Space Telescope (HST) archives. We will use these data to constrain the abundance of molecular hydrogen (H$_2$) undetectable in CO emission surveys and to test equilibrium models that seek to predict the H$_2$ mass fraction and the H$_2$/HI ratio as functions of metallicity, column density, and thermal pressure. Our approach complements HI and CO surveys by providing direct estimates of HI and H$_2$ column densities. For sight lines where sufficiently high resolution spectra are available, we will use the excitation of CI to determine thermal pressures, allowing us to test models that assume thermodynamic equilibrium in order to determine the HI-H$_2$ balance. The recently completed Spitzer Legacy surveys of the MCs provide images of PAH emission on sub-parsec scales, which may provide a means to model the distribution and small-scale clumping of gas in the
vicinity of the absorption sight lines, and thus connect the absorption data with the much coarser resolution radio data. We will investigate this possibility and the implications that small-scale clumping have for comparisons with theoretical models.

A preliminary analysis of the FUSE and HST data is already underway, and we present a few early results. We seek support to continue this effort over the next two years and to disseminate our results. Our methodology is novel in several respects. It includes the use of high-resolution optical spectra to derive component models for the FUSE absorption spectra, in order to derive more accurate column densities, especially for the higher J transitions of H_2 which provide key diagnostics of density and radiation field strength. Such component models will also aid in the analysis of the CI spectra. We will work to increase the number of Magellanic sight lines with high-resolution ground-based spectroscopy, in order to aid in the interpretation of the UV data or supplement it with higher extinction sight lines. In addition, we are leading the largest sub-arcminute resolution survey of CO emission in the Large Magellanic Cloud (LMC) to date, providing us a wealth of comparison data on the properties of giant molecular clouds (GMCs), some of which are in close proximity to the FUSE sight lines.

This study aligns with the broad NASA goal of studying the origin and evolution of stars and galaxies, as evidence has been mounting that the processes which regulate the formation of dense clouds ultimately regulate star formation as well. It makes use of important data sets with high legacy value, and supplements them with ground-based astronomical data that add considerable value to their interpretation. The results of our analyses will be incorporated into an existing web database of Magellanic Clouds absorption spectra that we are enhancing to allow structured queries.

Tahir Yaqoob/Johns Hopkins University


We have been awarded a large-project monitoring campaign of the Seyfert galaxy NGC 2992 with XMM-Newton (eight 55 ks snapshots, totaling 440 ks). NGC 2992 is a nearby active galactic nucleus (AGN) that has revealed dramatic X-ray and optical variability over the last three decades. The aim of the monitoring campaign is to directly probe how, and on what timescale, the broad, relativistic Fe Kalpha line detected in NGC 2992 responds to the continuum. Previous X-ray observations of NGC 2992 revealed that its X-ray flux varies by a factor of over 10 on timescales of weeks, and by over a factor of 20 on longer timescales. More importantly, the broad Fe Kalpha line flux responds to the continuum variability. Such behavior is extremely rare and makes NGC 2992 a unique laboratory for investigating the central engine of AGN. In other well-known AGN the relativistic Fe Kalpha line does not respond to continuum variations. The discovery of the response of the Fe Kalpha line to the X-ray continuum in NGC 2992 was made only recently, using instrumentation from different satellite instruments. Our XMM-Newton campaign will be the first to measure and quantify, with CCD spectral resolution and a single X-ray mission, the broad relativistic Fe Kalpha line in an AGN that exhibits a response of that line to the continuum. Quantifying the relationship between the line and
continuum is important because it reveals fundamental physical constraints on the X-ray source and the illuminated matter, which is thought to be an accretion disk in this case. The new data are expected to better constrain the physical state, emissivity and inclination angle of the accretion disk and yield new information on size scales (inner and outer line-emitting radii). The latter can only be derived from time-resolved spectroscopy. The XMM-Newton program was designed to cover as much of the dynamic range of the continuum and Fe Kalpha line variability as possible and to obtain the best constraints to date on the Fe Kalpha line properties, and the associated physical implications, for each flux state. The study may yield new insights on accreting supermassive black-hole systems in general, and begin to help lay the foundations for reverberation studies of the accretion disk with future missions. Our team has lead several X-ray studies of NGC 2992 in recent years and was responsible for the discovery of the response of the Fe Kalpha line flux to the X-ray continuum. We request funds for a systematic analysis, spectral modeling, and interpretation of the new XMM-Newton data, as well as for writing-up and publication of the results.