2014 SAO Summer Intern Project Abstracts

Discovery of Compact Quiescent Galaxies at Intermediate Redshifts in DEEP2

Kirsten Blancato[1] Igor Chilingarian[2,3], Ivana Damjanov[4], Sean Moran[3] , Ivan Katkov[4,3]
([1]*Wellesley College,* [2] *Smithsonian Astrophysical Observatory,* [3]*Sternberg Astronomical Institute, Moscow State University,* [4]*Harvard-Smithsonian Center for Astrophysics***)**

Compact quiescent galaxies in the redshift range $0.65 < z < 1.1$ are the missing link needed to complete the evolutionary histories of these objects from the high redshift $z \geq 2$ Universe to the local $z \sim 0$ Universe. We identify the first intermediate redshift compact quiescent galaxies by searching a sample of $1,125$ objects in the DEEP2 Redshift Survey that have multi-band photometry, spectral fitting, and readily available structural parameters. We find 32 compact quiescent candidates between $z = 0.65$ and $z = 1.1$ where each candidate galaxy has archival Hubble Space Telescope (HST) imaging and is visually confirmed to be early-type. The candidates have half-light radii ranging from $0.83 < Re,c < 7.14$ kpc (median $Re,c = 1.76$ kpc) and virial masses between 2.2×10^{10} and 6.0×10^{10} $M_\odot$ (median $M_{\rm dyn} = 7.3 \times 10^{10}$ $M_\odot$). Of our 32 compact quiescent candidates, 13 are truly compact with sizes at most half of the size of their $z \sim 0$ counterparts of the same mass. In addition to their structural properties bridging the gap between their high and low redshift counterparts, our sample of intermediate redshift quiescent galaxies span a large range of ages but is drawn from two distinct epochs of galaxy formation: formation at $z > 2$ which suggests these objects may be the relics of the observed high redshift compact galaxies and formation at $z \leq 2$ which suggests there is an additional population of more recently formed massive compact galaxies. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Can Thermal Instability Explain Cold Gas in Galaxy Cluster Cores?

Christopher Cappiello[1,2] Paul Nulsen[2]
([1]*Yale University* [2]*Harvard-Smithsonian Center for Astrophysics***)**

Massive galaxies in the cores of some galaxy clusters take part in a feedback cycle in which cooling gas powers their active galactic nuclei (AGN), while jets from the AGN heat the gas and reduce the rates of cooling and star formation. Thermal instabilities are believed to play a crucial role in feeding these AGN. The Field length is the distance scale above which thermal conduction is unable to smooth out inhomogeneities; if the radius of a cloud of gas is greater than the Field length, the cloud may become thermally unstable. Additionally, angular momentum can promote thermal instability by preventing a dense cloud from falling to its equilibrium position, where heating balances cooling. This requires a low viscosity, which can be tested by a similar criterion to the Field condition for thermal instability. For this reason, the Field parameter, given by the Field length squared over the radius squared, is calculated in order to determine whether a gas cloud at a given radius can become thermally unstable. In this study, we calculate the Field parameter as a function of the radius for a sample of five galaxy clusters known to produce Hα emission, a marker of cold gas and star formation, and one cluster known not to contain cool gas. We find that all of the clusters with Hα emission appear to be thermally unstable by the Field criterion, while the cluster without cool gas is not. This work was supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution. This research has made use of data obtained from the Chandra Data Archive and the Chandra Source

Catalog, and software provided by the Chandra X-ray Center (CXC) in the application packages CIAO and ChIPS.

An Investigation of Quasar Variability as a Damped Random Walk in the PanSTARRS-1 Medium Deep Fields

Virginia Cunningham[1] **Paul Green**[2],**Eric Morganson**[2], **Yue Shen**[3]
([1]*West Virginia University,* [2]*Harvard-Smithsonian Center for Astrophysics,* [3]*Carnegie Observatories*)

We model the lightcurves of 755 optically varying quasars from the Pan-STARRS Medium Deep Field 7 r band using a Damped Random Walk (DRW) model. The DRW describes quasar variability by its characteristic timescale, τ, and its variability at infinite time, V_∞. We use Monte Carlo techniques to fit our data as a DRW. The model parameters are compared to physical properties of the quasars such as black hole mass, Eddington ratio, and bolometric luminosity. We find that bolometric luminosity, Eddington ratio, and black hole mass are positively correlated with V_∞ and negatively correlated with τ. Quasars of greater luminosity, black hole mass, or Eddington ratio generally display smaller variations, and on longer timescales as estimated in the DRW model framework. This work was supported in part by the NSF REU and DoD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Searching for Proper-Motion Brown Dwarfs in the Mid-IR

Zequn Li[1] **Matthew Ashby**[2], **Joe Hora**[2]
([1]*Swarthmore College,* [2]*Harvard-Smithsonian Center for Astrophysics*)

We have carried out a sensitive search for infrared proper-motion sources in the 10 square degree Spitzer/IRAC Bootes field with imaging that covers a ten-year timespan. With the latest epoch, from the Decadal IRAC Survey of Bootes (DIBS), a Cycle 10 Spitzer program, we have identified more than 2000 4.5 micron sources with proper motions in excess of 3-sigma significance, between 0.05 and 0.7 arcsec/yr. Based on the extensive multiband photometry available for our sources, we estimate rough types and distances. A fraction of these dim, nearby sources are brown dwarfs–objects which are typically very difficult to detect at visible wavelengths because they are optically dim. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Testing Stellar Evolution Models: Absolute Dimensions of the Low Mass Eclipsing Binary Star V651 Cassiopeiae

Allison Matthews[1] **Guillermo Torres**[2]
([1]*Lafayette College,* [2]*Harvard-Smithsonian Center for Astrophysics*)

We report accurate values of several key quantities for the low-mass, 0.9968096 day period, double-lined eclipsing binary V651 Cas. We determine accurate values for the masses, radii and temperatures of the primary and secondary as follows: M = 0.8553(81) solar masses, R = 0.957(17) solar radii, and effective temperature = 5733(100) K for the primary component, and M = 0.7564(48) solar masses, R = 0.771(15) solar radii, and effective temperature = 5113(105) K for the secondary

component, with formal uncertainties shown in parentheses. A comparison with the stellar evolution models from the Dartmouth Stellar Evolution Program suggests an age of 11(1) Gyr for a best-fit metallicity of $[Fe/H] = -0.2$. While the isochrone mentioned correctly reproduces the measured radii and temperatures of the stars within the current uncertainties, we note that the secondary radius appears marginally larger and the temperature marginally cooler than models would predict. This is consistent with similar discrepancies found for other low-mass stars, generally accredited to surface activity. With further improvement in the measurement errors, and a spectroscopic measure of the metallicity, V651 Cas should be a valuable system for understanding the effects of magnetic activity on the global structure of low-mass stars and for providing guidance to improve stellar evolution models.

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Optimizing Focusing X-Ray Optics for Planetary Science Applications

Nicole Melso[1] Suzanne Romaine[2], Jaesop Hong[2],Vincenzo Cotroneo[2]
([1]*Penn State University,* [2]*Harvard-Smithsonian Center for Astrophysics***)**

X-Ray observations are a valuable tool for studying the composition, formation and evolution of the numerous X-Ray emitting objects in our Solar System. Although there are plenty of useful applications for in situ X-ray focusing instrumentation, X-Ray focusing optics have never been feasible for use onboard planetary missions due to their mass and cost. Recent advancements in small scale X-Ray instrumentation have made focusing X-Ray technology more practical and affordable for use onboard in situ spacecraft. Specifically, the technology of a metal-ceramic hybrid material combined with Electroformed Nickel Replication (ENR) holds great promise for realizing lightweight X-ray optics. We are working to optimize these lightweight focusing X-Ray optics for use in planetary science applications. We have explored multiple configurations and geometries that maximize the telescope's effective area and field of view while meeting practical mass and volume requirements. Each configuration was modeled via analytic calculations and Monte Carlo ray tracing simulations and compared to alternative Micro-pore Optics designs. The improved performance of our approach using hybrid materials has many exciting implications for the future of planetary science, X-Ray instrumentation, and the exploration of X-Ray sources in our Solar System.

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The AGN Contribution to Galaxy Merger Infrared Luminosities

Lee Rosenthal[1] Chris Hayward[3], Howard Smith[2], Matt Ashby[2], Chao-Ling Hung[2], Rafael Martinez-Galarza[2], Aaron Wiener[2], Andreas Zezas[2], and Lauranne Lanz[4],
([1]*Penn State University,* [2]*Harvard-Smithsonian Center for Astrophysics,* [3]*Heidelberg Institute for Theoretical Studies),* [4]*IPAC***)**

We investigate the contribution of AGN activity to the infrared luminosity of interacting galaxies by analyzing dust radiative transfer calculations of a hydrodynamically simulated merger, created with the code GADGET-2. We focus on emission in the mid-IR to far-IR wavelength ranges, and trace the luminosity density of a simulated gas-rich merger throughout the simulation timeline. We find that the AGN contribution to IR luminosity is greatest during and immediately after coalescence, a period of roughly 80 Myr during which time the increased inflow of gas to center of the merger increases the luminosity by a factor of a thousand or more due to both increased star formation rate (SFR) and black hole accretion. We compare different interstellar medium models used to describe sub-resolution gas and dust clouds in the radiative transfer calculations by studying the color evolution of our merger in the Herschel Space Observatory photometric filter bands, and compare the results to observations. We conclude that using infrared luminosity as a simple surrogate for SFR can overestimate the true rate, due to the contribution of AGN or other dust heating mechanisms. This conclusion has an especially significant impact in assessing the star formation activity in high-redshift galaxies for which the luminosity (the best measured property) may not accurately measure the SFR, and in cases where the molecular gas content can differ from that of local systems. Further work will extend this analysis to simulations of mergers between late-type galaxies and will include comparisons with observed mergers. This work was supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851, by the Smithsonian Institution and by NASA grant NNX14AJ6IG.

Searching for Distant Galaxies with HST and Spitzer

Peter Senchyna[1] **Matthew Ashby**[2], **Joe Hora**[2]
([1]*Washington University,* [2]*Harvard-Smithsonian Center for Astrophysics***)**

The recently completed Spitzer-Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey (S-CANDELS) provides an extremely deep NIR view of five extragalactic fields: COSMOS, EGS, UDS, HDF-N, and ECDFS. The addition of this deep near-infrared photometry to the existing CANDELS HST imaging is expected to improve redshift and stellar population parameter estimation, and enable selection of galaxies to higher redshift by capturing the 4000 Angstrom break out to 3.6 microns. Here we present an isolated galaxy sample based upon IRAC detection that is free from the effects of source confusion. The sample includes both objects for which CANDELS HST photometry is available, and a small number of objects detected by SCANDELS but not by WFC3/F160W. We derive photometric redshifts for the matched objects, and demonstrate the efficacy of an IRAC color cut in selecting high-redshift sources. In addition, we apply aperture photometry to the HST images of apparent F160W dropouts. We explore the properties of the high-significance dropouts at other wavelengths, and attempt to distinguish between heavily-shrouded AGN and sources at redshift greater than 7. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Finding X-ray Coronal Cycles in Low Mass Stars

Maurice Wilson[1] **Han Moritz Guenther**[2], **Katie Auchettl**[2]
([1]*Embry-Riddle Aeronautical University,* [2]*Harvard-Smithsonian Center for Astrophysics***)**

We seek to increase the number of stars known to have an X-ray coronal cycle. Four stars (including the Sun) are known to experience periodic long-term coronal flux variability but the statistics are not superb. In this analysis, we analyze four stellar sources that have been observed frequently by Chandra and XMM-Newton over the last ~ 11 years. These four sources were the brightest among numerous stellar point sources within the Chandra Deep Field South. Solar flares can dramatically increase the flux measured for our stars on short time intervals and, in observations with insufficient time coverage, can be confused for the maximum of the stars' magnetic cycles (if they have one). We have discarded times where solar proton flares are detected in the data. We utilize an APEC model, which represents the coronal plasma, to fit our stellar spectra. As our sources are very faint, we do not subtract the background, but instead we fit the background and source spectra simultaneously. We use the chi-squared statistic to evaluate the confidence of our fits. We present four light curves which suggest that a long-term X-ray flux variability similar to our Sun (the solar X-ray flux can vary by a factor of 10 over $\sim$ 11 years) is not present in these stellar sources. None of our stars experienced a flux variability exceeding a factor of 3 over an 11 year time scale but one of the four stars in our sample exhibits short term variability over a one year period. However, our stellar sources are too faint to conclusively state that the flux remains constant throughout all epochs. This work is supported by the National Science Foundation REU and Department of Defense ASSURE programs under NSF Grant no. 1262851 and by the Smithsonian Institution.

The Milky Way Skeleton

Catherine Zucker[1] **Cara Battersby**[2], **Alyssa Goodman**[2]
([1]*University of Virginia*, [2]*Harvard-Smithsonian Center for Astrophysics*)

Recently, Goodman et al. (2014) argued that a very long, very thin infrared dark cloud "Nessie" lies directly in the Galactic mid plane and runs along the Scutum-Centaurus arm in position-position-velocity space as traced by low density CO and high density NH3 gas. Nessie was presented as the first "bone" of the Milky Way, an extraordinarily long, thin, high contrast filament that can be used to map our galaxy's "skeleton." We present the first evidence of additional "bones" in the Milky Way galaxy, arguing that Nessie is not a curiosity but one of many filaments that could potentially trace galactic structure. Our list of ten bone candidates are all long, filamentary, mid-infrared extinction features which lie parallel to, and no more than twenty parsecs from, the physical Galactic mid plane. We use CO, N2H+, and NH3 radial velocity data to establish the location of the candidates in position-velocity space. Of the ten filaments, three candidates have a projected aspect ratio of $> 50:1$ and run along, or extremely close to, the Scutum-Centaurus arm in position-velocity space. Evidence suggests that these three candidates are Nessie-like features which mark the location of the spiral arms in both physical space and position-velocity space. Other candidates could be spurs, feathers, or interarm clouds associated with the Milky Way's galactic structure. As molecular spectral-line and extinction maps cover more of the sky at increasing resolution and sensitivity, we hope to find more bones in future studies, to ultimately create a global-fit to the galaxy's spiral arms by piecing together individual skeletal features. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851, and by the Smithsonian Institution.

The Chandra Observation of the Planck SZ Selected Cluster RXC J0528.9-3927

Zhoujian Zhang[1,2] **C. Jones**[2], **M. E. Machacek**[2], **R. P. Kraft**[1], **S. W. Randall**[1], **F. Andrade-Santos**[1]
([1]*Nanjing University*, [2]*Harvard-Smithsonian Center for Astrophysics*)

With the benefit of high resolution of Chandra observations, we now have access to more detailed information on the evolution of galaxy clusters than ever before. Here we perform a spectroscopy and imaging analysis for the Chandra observation of a merging cluster RXC J0528.9-3927

(RXJ0528 hereafter). We carefully examine the morphology of the cluster, and find a cold front and three boxy “sloshing edges” near the BCG center, which are signatures of the gas sloshing. We detect a hot region to the northeast of the main cluster, which may be a subcluster. The gaseous atmosphere of the subcluster is hotter than expected for its mass, which suggests the subcluster gas has been shock heated through an interaction with the main cluster. Similar structures have been found in another cluster RXCJ 1347.5-1145 (Johnson et al. 2012), where a subcluster to the southeast of the main cluster is interacting with the main cluster. However the subcluster gas in RXJ0528 is more diffuse than the gas in the RXCJ1347.5-1145 subcluster. Here we suggest that a subcluster, whose gas mass is at least $\sim 10^{12}$ solar mass, triggered the core gas sloshing in RXJ0528 a few Gyrs ago, and has been disrupted through the merging process. Excluding the subcluster region, we also measure the global temperature, luminosity, overall temperature profile and density profile for the main cluster, and estimate its gas mass and total mass. This work is supported in part by the School of Astronomy and Space Science in Nanjing University and by the Smithsonian Institution.