2013 SAO Summer Intern Project Abstracts

The Brightest AGN: Characterizing their Hot Gas Environments and the Accretion of Cooling Gas onto their SMBHs

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Over their lifetime, AGN switch form a radiatively bright QSO phase to a radiatively dim phase, where most of their energy output is in the form of mechanical feedback. For SMBHs in the cores of galaxy clusters, it is clear cooling cluster gas is sufficient to fuel the observed AGN outbursts. However, the question of fueling an AGN outburst in a poor group environment is not so obvious. We present Chandra observations for a small sample of powerful radio sources selected from the 3CRR catalog and not in rich clusters, and compare their X-ray characteristics to their radio morphologies. We find that hot gaseous atmospheres surrounding these AGN are common, and that cooling flows are present in four of our five sources. Our results indicate that cooling intracluster gas and stellar mass loss are sufficient to fuel these AGN, and that galaxy mergers are not required. In addition, our measured Eddington ratios for the SMBHs suggest that one source is in transition from radiatively bright to radiatively dim, which can provide additional insight into how AGN evolve. This work was supported in part by the NSF REU and DoD ASSURE programs under NSF Grant no. 1262851 and by the Smithsonian Institution.

Magnetic Dynamos and X-ray Activity in Ultracool Dwarfs (UCD): Constraining the Role of Rotation

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Although many fully-convective stars are magnetically active, the mechanisms by which they generate, sustain, and dissipate their magnetic fields are not well-understood. Observations suggest that empirical relations between X-ray activity, rotation, and radio activity evolve dramatically between the solar and ultracool dwarf (UCD; spectral types later than M6) regimes. The limited number of X-ray detections has prevented the drawing of firm conclusions, however. We combine new Chandra observations of seven late-M dwarfs with three previously-unpublished measurements from the Chandra archive and data from the literature to construct a database of 38 ultracool dwarfs with both X-ray and rotation measurements, the largest such catalog yet presented. We identify a substantial number of rapidly-rotating UCDs with X-ray activity as far as two orders of magnitude below the standard "saturation" level and find a significant anticorrelation between rotation and X-ray activity. We discuss several proposed "supersaturation" mechanisms that suggest a direct connection between faster rotation and suppression of X-ray activity and find many of them to be inconsistent with the data. We instead suggest the observed effect may be indirectly driven by a separate parameter correlated with both X-ray activity and rotation. The strength and topology of large-scale stellar magnetic fields have been found to vary widely within UCDs of similar stellar parameters. We speculate varying field topologies could explain the observed trends. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851, NSF grant no AST-1008361, Chandra award G02-13007A, issued by the CXC under NASA contract NAS8-03060, and by the Smithsonian Institution.

Coronal Heating of M Dwarfs: The Flare-Energy Distribution of Fully Convective Stars

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Stochastic flaring is an important mechanism for the coronal heating of the Sun and solar-like stars. The driver for these flares is a magnetic dynamo anchored at the boundary layer between the convective zone and the radiative core. Fully convective M dwarfs have been observed to produce powerful flares as well, but they lack a radiative core and must possess a different dynamo mechanism. How their flaring behavior differs from the solar case is not fully understood yet. We have analyzed X-ray flares of 22 M dwarfs, including both fully and partially convective ones, using archival XMM-Newton data. We extracted flares from the individual X-ray light curves and determined the amount of energy released by each flare in the observed X-ray band. We constructed flare-energy distributions of the targets to investigate the degree to which flares heat stellar coronae. We fitted the slopes of the flare-energy distributions for individual targets and for groups of targets bundled by spectral type. Depending on the value of the slope, the total energy released by flares, as extrapolated from the flare-energy distributions, could be sufficient to heat the entire corona. We find that the slopes of the flare-energy distributions are very similar to that of the Sun, for both partially and fully convective M dwarfs. The dynamo process at work in the fully convective stars of our sample needs to have a flare production efficiency which is very close to the solar case. Further observations will cover ultracool targets near the brown dwarfs boundary to test for which masses this solar analogy is valid. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

A Joint Optical & X-ray Analysis of the Triple Merging Cluster MACS J1226.8+2153

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We present a multi-wavelength characterization of the massive merging triple galaxy cluster MACS J1226.8+2153 at $z = 0.436$, combining Chandra X-ray observations, deep Subaru optical imaging, and spectroscopic redshifts of hundreds of individual galaxies. We find good agreement between the spatial distribution of X-ray emission and optical light from red sequence cluster member galaxies. Redshifts of galaxies within the three cluster components are confirmed to be at a common redshift, and we detect no significant bulk line-of-sight peculiar velocity offsets between the three components. The velocity distributions of two of the individual cluster components exhibit strong bimodality, indicating that they are not completely relaxed and may have recently undergone mergers themselves. From the X-ray surface brightness and temperature profiles there is a clear shock propagating from the most massive cluster component with a Mach number $M = 1.48 \pm 0.20$. This shock feature could either be a remnant of a recent interaction internal to this component, or a bi-product of the early stages of merger interactions between the three cluster-scale components. We also present evidence for three large-scale filaments extending from this complex system, indicating that MACS J1226.8+2153 lies at the center of a node of the cosmic web. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Merger Hydrodynamics of the Luminous Cluster RXJ1347.5-1145

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We present deep (186 ks) Chandra X-ray observations of baryonic gas hydrodynamics in the merging galaxy cluster RXJ1347.5-1145, a cool-core cluster at a redshift of 0.451. We find that, although the mean gas distribution in the primary cluster is well fit by a spherical beta model, the X-ray surface brightness distribution shows cold fronts to the west, south, and east of the cluster center that form a clockwise spiral, characteristic of gas 'sloshing' induced by a merger in the plane of the sky. Spectral analysis reveals temperatures ~ 20 keV southeast of the primary cluster, suggesting shock heating from a merging subcluster. We identify two edges in X-ray surface brightness forming a 'Mach-cone', coincident with the maximum Sunyaev-Zel'dovich decrement from previous work. We model the density across this shock feature, and use the Rankine-Hugoniot conditions to determine the Mach number and velocity of the shock. The Mach cone and excess X-ray emission associated with the subcluster gas are displaced to the south of the subcluster's central cD galaxy, suggesting that the subcluster gas has been stripped. We measure the X-ray luminosity of the subcluster gas, and use scaling relations to place a lower bound on the subcluster's total mass. Funding for this research has been provided in part by the Smithsonian Institution and NASA CXC grant GO2-13148X.

Electron-Ion Equilibrium and Shock Precursors in the Northeast Limb of The Cygnus Loop

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We present an observational study using high-resolution echelle spectroscopy of collisionless shocks in the Cygnus Loop supernova remnant. Measured Hα line profiles constrain pre- shock heating processes resulting in narrow component broadening, cosmic-ray acceleration, and electron-proton equilibration. The shocks produce faint Hα emission line profiles, which are characterized by narrow and broad components. The narrow component is representative of the pre-shock conditions, while the broad component is produced after charge transfer between neutrals entering the shock and protons in the post-shock gas, thus reflecting the properties of the post-shock gas. We observe a diffuse Hα region extending about 2.5 arcmin ahead of the shock with line width about 29 km s^{-1} , while the Hα profile of the shock itself consists of a broader than expected narrow (36 km s^{-1}) and a broad (250 km s^{-1}) component. The observed diffuse emission arises in a photoionization precursor heated to about $18,000$ K by He I and He II emission from the shock, with additional narrow component broadening originating from a thin cosmic-ray precursor. Broad to narrow component intensity ratios of about 1.0 imply full electron-proton temperature equilibration (equal ion and electron temperatures) in the post-shock region. Broad component line widths indicate shock velocities of about 400 km s^{-1} . Combining the shock velocities with proper motions suggests the distance to the Cygnus Loop is about 890 pc, significantly greater than the generally accepted upper limit of 637 pc. This work is supported in part by the National Science Foundation REU and Department of Defense ASSURE programs under NSF Grant no. 1262851 and by the Smithsonian Institution.

Identification and Investigation of Martian Dust Source Regions from Orbital Observation

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We have constructed a database of locations of active dust lifting on Mars from existing Mars Daily Global Maps (MDGMs). The daily global maps used in this study were generated from wide-angle images taken by the Mars Orbiter Camera (MOC) on Mars Global Surveyor (MGS) (Mars Years 24-27, July of 1999 to January of 2005). We have concentrated on the "equatorial map" (60° N-60° S) and the periods without global dust storms. Areas of active dust lifting in each MDGM were visually identified based on an analysis of albedo changes, color, and morphology. Using this database, we assess the spatial, temporal, and size distribution of lifting areas and classify lifting events by structure. Lifting is found to be concentrated in three seasonal windows: $Ls = 0° - 80°$, $Ls = 130° - 230°$, and $Ls = 260° - 360°$. Large-scale lifting mainly occurs in the $Ls = 130° - 230°$ seasonal window. Northern and southern lifting events also have preferred seasonal windows of occurrence, with northern ones concentrated during $Ls = 180° - 230°$ and $Ls = 280° - 360°$ and southern ones concentrated during $Ls = 20° - 60°$ and $Ls = 130° - 220°$. Both annually and for the identified seasonal windows, the number of small lifting events far exceeds the number of large ones. Observations indicate that active dust lifting is most frequently observed in the Arcadia, Acidalia, Argyre, and Hellas regions while inactive regions include Tharsis, Arabia Terra, and sections of Elysium. These locations correspond well with GCM predicted annual surface wind stress and dust deposition distributions. In our analysis, three morphological categories for active dust lifting are defined: puffy, pebbled, and plume. We demonstrate that these structures are apparent in all seasonal windows. Our data also suggests that pebbled and plume morphologies occur at similar latitudes and times of the year. Puffy structures are differentiated from pebbled and plume structures in that they occur more frequently at lower latitudes. This work is supported by the National Science Foundation REU and Department of Defense ASSURE programs under NSF Grant no. 1262851, the Smithsonian Institution, and the NASA MDAP program.

A Quest for Stellar Streams

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The Milky Way's dwarf satellite galaxies provide tests of theoretical predictions concerning the number and internal structure of low-mass dark matter halos. Here, we present results from high precision velocities attained with Hectochelle spectroscopy of 166 and 799 stellar targets around the Milky Way satellites Draco and Segue 2, respectively. We find ~ 60 likely members of Draco and ~ 13 likely members of Segue 2 and use these samples to estimate velocity dispersions and dynamical masses. Finally, we search for evidence of tidal features in order to explore a potential solution to the core/cusp and missing satellite problems. This work is supported in part by the National Science Foundation REU and Department of Defense ASSURE programs under NSF Grant no. 1262851 and by the Smithsonian Institution.

Electron-Impact Uncertainty Analysis and its Impact on Certain Temperature Diagnostics

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In this study we calculate the electron-impact uncertainties in atomic data for direct ionization and recombination, and investigate the role of these uncertainties on spectral diagnostics. We outline a systematic approach to assigning meaningful uncertainties that vary with electron temperature. Once these uncertainty parameters have been evaluated, we can then calculate the uncertainties on key diagnoistics through a Monte Carlo routine, using the Astrophysical Emission Code()APEC)[Smith et al. 2001]. We incorporate these uncertainties into well known temperature diagnostics, such as the Lyman alpha versus resonance line ratio and the G ration. We compare these calculations to a study performed by [Testa et al. 2004], where significant discrepancies in the two diagnostic rations were observed. We conclude that while the atomic physics uncertainties play a noticeable role in the discrepancies observed by Testa, they do not explain all of them. This indicates that there is another physical process occurring in the system that is not being taken into account. This work is supported in part by the National Science Foundation REU and Department of Defence ASSURE programs under NF Grant no. 1262851 and by the Smithsonian Institution.

Stellar Autopsies: The Analysis of Two GRB-SNE in the Nebular Phase

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Spectroscopy and photometry of core-collapse supernovae (SNe) during the nebular phase (T$\gtrsim$ 40 days) can be used to constrain explosion characteristics, including asymmetry. Here we model the nebular phase light curves of two hydrogen-stripped SNe, SN 2003dh and SN 2006aj, associated with gamma-ray bursts 030329 and 060218, respectively. We estimate the kinetic energy, nickel mass and ejected mass of the explosions. Using Hubble Legacy data in the F814W [I-band], F625W [R-band], F606W [V-band] and F435W [B-band] filters taken between 50 and 450 days after the gamma ray bursts, we reconstruct the bolometric light curve and apply a spherically symmetric, radiative decay model. For SN 2003dh, we find a nickel mass of $\sim 0.35 M_{\odot}$, and for SN 2006aj we find a nickel mass of $\sim 0.18 M_{\odot}$. Both are in good agreement with estimates from early photometric data suggesting minimal asymmetry within the SN explosion. We compare our results with other supernovae associated with gamma ray bursts. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Bayesian Multiscale Analysis of X-Ray Jet Features in High Redshift Quasars

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The source of emission for X-rays in extragalactic jets is not well determined. One possibility is that high-energy X-ray radiation is formed when photons from the Cosmic Microwave Background (CMB) collide with the jet's relativistic electrons and gain energy via the inverse Compton (IC) effect. A step toward understanding the X-ray emission process is to study the Radio and X-ray morphologies of the jet. We implement a sophisticated Bayesian image analysis program, Low-count Image Reconstruction and Analysis (LIRA) (Conners & van Dyk 2007; Esch et al. 2004), to analyze jet features in 11 Chandra images of high redshift quasars ($z \sim 2-4.8$). Out of the thirty six regions where knots are visible in the radio jets, 9 showed detectable X-ray emission. We measured the ratios of the X-ray and radio luminosities of the detected features and found that they are consistent with the CMB radiation relationship. We derived a range of the bulk lorentz factor (Γ) for detected jet features under the CMB jet emission model. There were no observed trends of Γ within the sample's redshift range. We also study the efficiency of the X-ray emission between the detected jet feature and the corresponding quasar which shows no correlation with redshift.
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