

2015 SAO Summer Intern AAS Abstracts

Measuring M Dwarf Rotation in the Pan-STARRS 1 Medium Deep Survey

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The rise of large-format CCDs and automated detection methods has greatly increased the tractability of large-scale studies of stellar rotation. Studies of the relationship between stellar rotation and magnetic activity show a strong correlation, supporting the concept of a rotationally-driven dynamo. However, the number of confirmed rotation periods for stars in the fully convective regime, whose magnetic dynamos are less well understood, remains low. Here we report on ongoing work to measure rotation periods for the M dwarf stellar population observed by the Pan-STARRS 1 Medium Deep Survey (PS1/MDS). We refine an initial sample of around 4.3 million sources using color cuts in each of the five Pan-STARRS 1 filters. Of these sources, we estimate there to be around 135,000 sources which are candidate M dwarfs with a spectral type of M1 or higher. We discuss the outcomes of various rotation period detection methods and present preliminary results. 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.

A Search for Gravitationally Bound Cloud Cores within the CMZ

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In general, current star formation theories successfully model the rate at which stars are forming throughout our Galaxy as well as others, with the star formation rate (SFR) in a given region being proportional to the amount of gas above a threshold density. The Central Molecular Zone (CMZ) of our Galaxy is an excellent place to test these models. It is home to the highest amount of dense, molecular gas within our Galaxy – and yet, the SFR within this region is an order of magnitude lower than would be expected using current star formation models. This project utilizes data taken from the SMA Legacy Survey of the CMZ, in a search for gravitationally bound structures within three small gas clouds near the Galactic Center, as well as the 1.6° cloud. Dense gas structures are detected using H₂CO, a dense gas tracer, and 1.3mm cold, dust continuum. These regions are catalogued using dendrograms to identify which structures have continuous and significant H₂CO emission. Gravitationally bound candidates were identified by deriving each structure's virial ratio. Within the three clouds near the Galactic center, 40 structures were catalogued, with one structure that was found to be gravitationally bound. Very large virial ratios are the result of large H₂CO line widths, possibly due to a high degree of tidal compression. This analysis is also performed on the 1.6° cloud, in a region with two suspected bound cores. One of these two cores is close to virial equilibrium and likely gravitationally bound, thus providing support for the use of this method on other clouds within the CMZ. This work supported in part by the NSF REU and DoD ASSURE programs under grant no. 1262851 and by the Smithsonian Institution.

Magnetic Turbulence and Line Broadening in Lyman- α Absorption

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We use the Illustris cosmological AREPO simulations to study the effects of gas turbulence and magnetic fields on measurements from the Lyman-Alpha forest. We generate simulated Lyman-Alpha spectra and plot the distributions of Column Density (CDD) and Doppler Width (b) both by adhering to the canonical method of fitting Voigt profiles to absorption lines and by directly measuring the column density and equivalent widths from snapshot data. We investigate the effects of additional unresolved gas turbulence in Illustris by adding an additional broadening term to the line profiles to mimic turbulent broadening. When we do this, we find a measurable effect in the CDD and an offset in the mean of the b distribution corresponding to the additional turbulence. We also compare different MHD runs in AREPO. We find that the CDD can measurably differentiate between magnetic seed field at redshifts as low as 0.1, but we do not find that the b distribution is affected at a detectable level. Our work suggests that the effects of turbulence and magnetic fields from $z = 2 - 0.1$ can potentially be measured with these diagnostics. This work was supported in part by the NSF REU and DoD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Narrowband Imaging of Massive Star-Forming Regions: Tracing Outflows and the Rate of Star Formation

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Narrowband images targeting ionized hydrogen (Brackett gamma, 2.17 microns) and molecular hydrogen (2.12 microns) were obtained for six massive star-forming regions within the Milky Way, NGC 6334, G305, G3333, G3264, G3266, and G351. These regions are within 1–4 kpc from our solar system. The narrowband flux in Brackett gamma was used as a star-formation tracer to calculate a star-formation rate for each region. This is compared with other star-formation rates found using other methods such as the count of young stars and YSOs, and rates calculated from using other tracers (e.g. 70 micron monochromatic luminosity). The molecular hydrogen narrowband images were manually searched to locate outflows from young stars. Once these outflows are identified, it may help to get a better survey of the young stellar population. A better understanding of the stellar population distribution can lead to more accurate star-formation rates to compare to those calculated from star-formation tracers. We found the regions NGC 6334 and G3266 to have the highest levels of ongoing star formation activity as indicated by the number of molecular hydrogen objects (MHOs) detected. There are a total of 279 cataloged MHOs in 181 categorized systems for the six regions. There are a total of 150 identified potential driving sources. This work was supported in part by the NSF REU and DoD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Radio and X-ray Observations fo the Ultra-long GRB 150518A

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Gamma Ray Burst (GRB) 150518A, discovered on 2015 May 18 by the MAXI and KONUS-Wind satellites, lasted for about 1000 s, making it an important addition to the recently established class of very long duration GRBs. We report on the JVLA radio observations of the afterglow of GRB 150518A. Additionally, we report the analysis of X-ray afterglow observations by Swift-XRT. Multi-band light curves of the radio afterglow display an unusual, conspicuous rise around 10 days after the burst, possibly due to enhanced mass-loss from the progenitor in the final stages of evolution before the GRB. The X-ray afterglow spectrum is significantly soft (photon index $\Gamma_x > 3$) and heavily absorbed ($NH_{x,i} > 8 \times 10^{21} \text{ cm}^{-2}$). These properties suggest peculiar behavior that is different from the predictions of the standard fireball model of GRBs. In the light of these properties, we compare different models of progenitors for very long duration GRBs. This work was supported in part by the NSF REU and DoD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Supersonic Inflation of the Radio Lobes of NGC 1052: Evidence for Non-Thermal Particle Acceleration

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We analyze archival Chandra data of the nearby AGN NGC 1052 to determine the nature of the interaction of the radio lobes with the ambient hot gas. NGC 1052 is typically classified as a Seyfert galaxy, but has a radio bright core and extended diffuse radio lobes on kpc scales. We report the detection of X-ray bright shells around the radio lobes, suggestive of compression of the ISM by the supersonic inflation of the lobes. We determine the temperature and density of the gas in these shells and of the ambient ISM. We find that the temperature of the ISM is 0.8 keV, and that of the shells around the E and W radio lobes are 0.72 and 0.69 keV, respectively, fitting a single temperature APEC model. The statistical quality of the fits is low, so systematic uncertainties dominate our ability to distinguish temperature variations between regions. NGC 1052's outburst is relatively young (9×10^{13} sec) and comparatively low power (1.9×10^{41} erg/s). Interestingly, the density jump between the shells and the ambient ISM is larger than the maximum compression allowed by the Rankine-Hugoniot conditions, suggesting that the emission from the shells is not thermal. We proposed that the bubbles are highly supersonic (Mach number > 5) and that the emission of the shell is due to synchrotron radiation from a population of ultrarelativistic electrons created by the powerful shock. If this interpretation is correct, NGC 1052 would be only the second AGN in which this process has been observed. This work was supported in part by the NSFREU and DoD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Fingerprinting Hydrogen in Core-Collapse Supernovae

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This is a preliminary report on the mass of remaining hydrogen envelopes for stars massive enough to explode under core collapse. Using the stellar evolution code, MESA, our initial findings suggest that a significant fraction of massive stars with $M_{\text{ZAMS}} = 20 - 60 M_{\text{sun}}$ lose all but $10^{-3} M_{\text{sun}} - 10^{-1} M_{\text{sun}}$ as they near eventual core collapse. This result is dependent on the mass-loss prescription, degree of rotation, metallicity, rates of nuclear burning in the core, and the final stellar configuration. Nevertheless, each of our test cases include a few stars that retain trace amounts of surface hydrogen, which would then be detected as faint H in type IIb/IIc supernova spectra. We also compare our findings to the progenitor candidate identified for iPTF13bvn using the most recent photometric corrections. We agree with the previous conclusion found by Groh et al. (2013) that the progenitor had an initial mass of $32 M_{\text{sun}}$, but now with an additional condition of $0.06 M_{\text{sun}}$ of hydrogen on its surface just prior to the explosion. We demonstrate through our study that not all Type Ib supernovae are fully devoid of hydrogen at the time of explosion, which has implications for the nature of the progenitor star and thus provides impetus for a revised classification scheme for 'stripped envelope' supernovae. This work was supported in part by the NSF REU and DoD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Systematic Uncertainties in Characterizing Cluster Outskirts: The Case of Abell 133

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The outskirts of galaxy clusters have low surface brightness compared to the X-ray background, making accurate background subtraction particularly important for analyzing cluster spectra out to and beyond the virial radius. We analyze the thermodynamic properties of the intracluster medium (ICM) of Abell 133 and assess the extent to which uncertainties on background subtraction affect measured quantities. We implement two methods of analyzing the ICM spectra: one in which the blank-sky background is subtracted, and another in which the sky background is modeled. We find that the two methods are consistent within the 90% confidence ranges. We were able to measure the thermodynamic properties of the cluster up to $R500$. Even at $R500$, the systematic uncertainties associated with the sky background in the direction of A133 are small, despite the ICM signal constituting only $\sim 25\%$ of the total signal. This work was supported in part by the NSF REU and DoD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Investigating the Orbital Period Valley in Kepler Data

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Transit light curves contain a wealth of information about the basic properties of a planet, such as its radius, semi-major axis, and orbital period. For the latter property, there is a distinct lack of planets with periods between 10 to 100 days. This gap could be caused by something as simple as observational bias, or as prominent as planetary formation or migration. Here, we report an investigation into the atmosphere of planets within this orbital period valley, to search for differences that may indicate a different formation mechanism or migration path to those outside of it. We do this by searching for the secondary eclipse of planets in the valley in order to measure their albedos. We determined an optimal target for this: KOI-366 b ($P \sim 75$ days). However, we find that despite the exquisite precision of Kepler data, it cannot constrain the albedo for this long-orbit planet candidate. We measure a 1σ upper limit on the geometric albedo of $A_g, 1\sigma \leq 2.0$. We highlight that additional scatter in the light curve is likely caused by a ~ 2 day pulsation of the giant host star, and that further data is required to measure the secondary eclipse. KOI-366 is one of the best suited of all host stars for follow-up due to its relatively bright magnitude ($K_p = 11.7$ mag), but the full investigation of the reflective properties of long period planets may require space-based observations from future instruments, such as WFIRST, that will be more sensitive to objects further away from their host stars. 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 work was performed in part under contract with the Jet Propulsion Laboratory (JPL) funded by NASA through the Sagan Fellowship Program executed by the NASA Exoplanet Science Institute.

Mechanisms Driving Gas Excitation within ULIRGS

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We present a systematic survey of molecular and atomic line fluxes in all star-forming galaxies observed by the Herschel PACs instrument with detectable OH lines the also contain Herschel SPIRE FTS spectra, to determine how physical conditions vary as a function of star formation rate. Specifically, we measured selected CO, H₂O, [CI], and [NII] integrated line fluxes in a sample of 147 star-forming galaxies covering a range of far-infrared luminosities ranging from 10^9 to above 10^{12} L_{Sun}. Thus, our sample includes typical, quiescent galaxies as well as Luminous Infrared Galaxies (LIRGs) and Ultra Luminous Infrared Galaxies (ULIRGs), known to be creating stars extremely rapidly. We find evidence suggesting that ULIRGs with far-infrared luminosities of $L_{\text{FIR}} > 10^{12}$ L_{Sun} require an additional heating mechanism other than UV heating from star formation, while LIRGs and less luminous star-forming galaxies may be heated primarily by their star formation. We also find that the [NII] 3P1 - 3P0 fine structure line flux and those of the CO J=5-4, CO J=7-6, and CO J=8-7 transitions are generally weaker for ULIRGs compared to LIRGs and less luminous star-forming galaxies, while we find the CO J=11-10, CO J=12-11, and CO J=13-12 transitions are generally stronger. In all these respects, ULIRGs are shown to differ significantly from other galaxies undergoing less extreme star formation. This work was supported in part by the NSF REU and DoD ASSURE programs under NSF grant no. 1262851 and by the

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Spatial Distribution of Small Organics in Prestellar and Protostellar Cores

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In the interstellar medium, H₂CO has efficient formation pathways in both the gas-phase and on the surfaces of dust grains. CH₃OH, on the other hand, is believed to form exclusively on grains as there are no efficient gas-phase reactions leading to CH₃OH. We present observations taken with the IRAM 30m telescope of several H₂CO and CH₃OH lines in a prestellar and protostellar core. We investigated the formation pathways of H₂CO and CH₃OH by comparing their spatial distributions. We find that in the prestellar core, the two species are anti-correlated in the densest region, while their emission is correlated in the low-density region. In contrast, for the protostellar core we find a correlation in the distribution of both species. We conclude that in the protostellar source, H₂CO and CH₃OH form together on grains and have been thermally desorbed due to the central newly formed star. In the prestellar core, on the other hand, CH₃OH forms on the ices and remains depleted in the coldest regions, while H₂CO can form efficiently in the gas-phase. This work was supported in part by the NSF REU and DoD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.