Star Formation Histories Across M51, the Whirlpool galaxy

Eufrasio, Rafael; Lehmer, Bret; Markwardt, Larissa
University of Arkansas

We present a pixel-by-pixel UV-to-IR spectral energy distribution (SED) modeling in order to determine the star formation histories (SFHs) across the Whirlpool system, M51. The system is composed of two interacting galaxies, the spiral M51a and the lenticular M51b, and contains a large variety of physical conditions. We use SFHs composed of five discrete steps of time (0-10 Myrs, 10-100 Myrs, 0.1-1 Gyr, 1-5 Gyr, 5-13.6 Gyr) and employ a flexible extinction curve controlled by three parameters that accounts for possible higher attenuation in the youngest regions. Our code is very computationally efficient, fully parallelized and vectorized, and uses inversion techniques to minimize running time. It currently runs hundreds to thousands of times faster than other state of the art similar codes. The resulting maps contain derived quantities (i.e., star formations, stellar masses, luminosities, ionizing photon rates, attenuations) associated to all five epochs. We find the SFH of the spiral galaxy to peak between 1 and 5 Gyr ago and its companion's to peak at the oldest SFH step (5-13.6 Gyr) and progressively decline. We also find an enhancement of the SFR between 0.1 and 1 Gyr due to the interaction that affected mainly the outskirts of the spiral galaxy. We present how the FUV + IR hybrid SFR law changes across the system and the contribution of different ages to the IR luminosity.

Missing Mass: Gravity Wells Independent of Mass

Gruber, Jason; Seyedmadani, Kimia; Gruber, Jace; Laviano, Ricki; Reed, Bryan
IMSG Laboratories-Astronomy Division, University of Colorado Boulder-Aerospace Sciences, Chiles Elementary Advanced Gifted

Dark matter is the longest standing problem in astrophysics. The search for a weakly interactive massive particle (WIMP) has had zero detection in the last 30 years. Attempts of Modified Newtonian Dynamics (MOND) hasn’t work on small scales, and don’t account for dark matter halos observed separate from baryon matter. A new direction may be required. According to General Relativity gravity is a consequence of spacetime curvature when mass is present, but it is important to point out the gravity is a direct result of the warped geodesics, not the mass. The actual question of what is dark matter is should be, what is causing the unaccounted for spacetime curvature. Our novel approach to the dark matter theory is our hypothesis that dark matter is just distortions in spactime by which the curvature alone is the cause of the gravity. Spactime has been observed to react like a fabric by warping, twisting, and propagating waves. These properties have been proven with observations of gravitational lensing, frame dragging, and recently gravitational waves. Fabrics can be stretched, pressured, and/or heated to the point of deformation losing elasticity. Such extreme conditions were all present during inflation, so it is plausible that spacetime’s elastic nature hit its yield point and deformed. Therefore, if gravity is the direct result of warped spactime, and fabrics can be deformed, then a deformation of spacetime could create a gravitational effect independent of mass. Dark matter may simply be a particle of the spacetime’s structure, instead an exotic particle sitting in spacetime causing the warped geodesics. Using the cosmic microwave background we predict that N-body simulations will show an agreement in how imprints of the quantum fluctuations caused by inflation correspond and produce the amounts and locations of the dark matter gravity observed today.

Rotation Curves and the Mass Distribu tion of Growing Disk Galaxy Models

Berrier, Joel; Sellwood, J.A.
University of Nebraska Kearney, Rutgers University

We present evidence that spiral activity is responsible for the creation of featureless rotation curves. We examine a variety of simulations of disk galaxies beginning in equilibrium and allow them to evolve while adding particles in annuli to the hot disk using a variety of rules. Two unstable spiral modes develop when this new material forms a ridge-like feature in the surface density profile of the disk. The extra material is redistributed radially by the spiral

activity, and the associated angular momentum changes remove more particles from the ridge than are added to it. This process eventually removes the density feature from the galaxy and creates a locally flat rotation curve. We argue that the lack of a feature when transitioning from disk to halo dominance in the rotation curves of disk galaxies, the so called "disk-halo conspiracy", could also be accounted for by this mechanism. These results are verified in idealized simulations that mimic the growth of galaxy disks embedded in responsive halos and bulges. In these "live" simulations the disks manifested an almost overwhelming tendency to form strong bars that we found very difficult to prevent. Since our simulations included only collisionless star and halo particles, our findings may apply to gas-poor galaxies only; however, the conundrum persists for the substantial unbarred fraction of those galaxies.

Information Content of the Angular Multipoles of Redshift-Space Galaxy Bispectrum

Praful Gagrani
Kansas State University

The redshift-space bispectrum (three point statistics) of galaxies depends on the expansion rate, the growth rate, and geometry of the Universe, and hence can be used to measure key cosmological parameters. In a homogeneous Universe the bispectrum is a function of five variables and unlike its two point statistics counterpart -- the power spectrum, which is a function of only two variables -- is difficult to analyse unless the information is somehow reduced. The most commonly considered reduction schemes rely on computing angular integrals over possible orientations of the bispectrum triangle, thus reducing it to sets of function of only three variables describing the triangle shape. We use Fisher information formalism to study the information loss associated with this angular integration. Without any reduction, the bispectrum alone can deliver constraints on the growth rate parameter f that are better by a factor of 2.5 compared to the power spectrum, for a sample of luminous red galaxies expected from near future galaxy surveys at a redshift of $z \approx 0.65$ if we consider all the wavenumbers up to $k \leq 0.2\ h\ Mpc^{-1}$. At lower redshifts the improvement could be up to a factor of 3. We find that most of the information is in the azimuthal averages of the first three even multipoles. This suggests that the bispectrum of every configuration can be reduced to just three numbers (instead of a 2D function) without significant loss of cosmologically relevant information.

Optimal weights for measuring redshift space distortions in multitracer galaxy catalogues

Pearson, David; Samushia, Lado; Gagrani, Praful
Kansas State University

Since the volume accessible to galaxy surveys is fundamentally limited, it is extremely important to analyse available data in the most optimal fashion. One way of enhancing the cosmological information extracted from the clustering of galaxies is by weighting the galaxy field. The most widely used weighting schemes assign weights to galaxies based on the average local density in the region (FKP weights) and their bias with respect to the dark matter field (PVP weights). They are designed to minimize the fractional variance of the galaxy power-spectrum. We demonstrate that the currently used bias dependent weighting scheme can be further optimized for specific cosmological parameters. We develop a procedure for computing the optimal weights and test them against mock catalogues for which the values of all fitting parameters, as well as the input power-spectrum are known. We show that by applying these weights to the joint power-spectrum of emission line galaxies and luminous red galaxies from the Dark Energy Spectroscopic Instrument survey, the variance in the measured growth rate parameter can be reduced by as much as 36 per cent.

A Physical Parameterization of the Evolution of X-Ray Binary Emission

Gilbertson, Woodrow; Lehmer,Bret; Eufrasio, Rafael
University of Arkansas

The 7 Ms Chandra Deep Field-South (CDF-S) survey contains measurements spanning a large redshift range of z = 0

to 7. This data-rich field provides a unique window into the cosmic history of X-ray emission from normal galaxies (i.e., not dominated by AGN). Scaling relations between normal-galaxy X-ray luminosity and quantities, such as star formation rate (SFR) and stellar mass (M*), have been used to constrain the redshift evolution of the formation rates of low-mass and high-mass X-ray binaries (LMXB and HMXB, respectively). However, these measurements do not directly reveal the driving forces behind the redshift evolution of X-ray binaries (XRBs). We hypothesize that changes in the mean stellar age and metallicity of the Universe drives the evolution of LMXB and HMXB emission, respectively. By studying the properties of the galaxies in the CDF-S, this study examines the correlations between the physical quantities of stellar age and metallicity with LMXB and HMXB emission, respectively. This study uses an X-ray stacking technique to group galaxy populations with similar metallicities and stellar ages and quantify the relationships between LMXB/M* versus stellar age and HMXB/SFR versus metallicity We show that this physical model provides a more useful parameterization of the evolution of X-ray binary emission, as it can be extrapolated out to high redshifts with more sensible predictions. This meaningful relation can be used to better estimate the emission of XRBs in the early Universe, where XRBs are predicted to play an important role in heating the intergalactic medium.

Understanding Supermassive Black Hole Growth Mechanisms in the SSA 22 Protocluster

Bonine, Brett
University of Arkanas

The SSA22 protocluster is a collection of galaxies at redshift z = 3.09, corresponding to a look back time of 11.6 billion years. Observations of the protocluster allow for the investigation of galaxy properties of such protocluster environments in the early universe, potentially giving insight into the formation and evolution of galaxy clusters visible in the local universe (e.g., the Coma Cluster). Compared to other field galaxies at a similar redshift, a larger fraction of galaxies in SSA22 have been found to possess active galactic nuclei (AGN). This enhanced AGN activity suggests a relationship between the environment within the cluster and the growth of supermassive black holes (SMBHs). I will clarify the role that the protocluster environment at z = 3.09 plays in enhancing the growth of SMBHs in the cluster. To accomplish this, we are analyzing recently obtained data from the Hubble Space Telescope (HST), using both visual and computational morphology classifications, to determine whether galaxy mergers and/or the presence of larger galaxies and SMBHs are responsible for the enhanced AGN activity. The results will then be compared with archival HST data of field galaxies at the same redshift to assess how more typical galaxies and SMBHs in the z = 3 universe grow.

A First Robust Measurement of the Aging of Field Low Mass X-ray Binary Populations from Hubble and Chandra

Ferrell, Andrew; Lehmer, B.D.; Eufrasio, R.
University of Arkansas

Due to the difficulty in identifying counterparts to X-ray sources in nearby galaxies, low mass X-ray binaries (LMXBs) found within the field of galaxies (field LMXBs) and globular clusters (GC LMXBs) are not usually studied separately. However, it is thought that field LMXBs form on the evolutionary timescales of the stars in the binary systems, while GC LMXBs are constantly forming due to tidal and multi-body interactions with other stars, so differentiation between field and GC LMXBs is important. A study conducted by Kim & Fabbiano (2010), found that young galaxies contain more LMXBs per unit stellar mass compared to galaxies with “old” stellar populations. Another study, conducted by Zhang et al. (2012), found that LMXBs were found in greater numbers within older galaxies; however, the number of GCs also increases with galaxy stellar age, suggesting that there are likely more GC LMXBs in older galaxies. Lehmer et al. (2014) studied field and GC LMXBs separately, as a pilot to this study, and found field LMXBs were more numerous within a single relatively young galaxy that was observed, NGC3384. However, the Lehmer study did not provide a statistically robust result. This study will focus on looking within the field LMXB environments of 16 elliptical galaxies of stellar age between ≈2–12 Gyr.

We will then be able to empirically constrain how the field LMXB formation rate, and X-ray luminosity function, varies as a function of host stellar population age.

MSSM neutralino as a dark matter candidate

Maleki Sanukesh, Mehdi
Creighton University

Historically one of the most promising dark matter candidates has been the Neutralino from the Minimal Supersymmetric Standard Model (MSSM). Although Supersymmetry has not been experimentally confirmed, it has been tightly constrained by both accelerator limits and astrophysical bounds. DarkSUSY is a computer code that is based on the MSSM, and which allows for the calculation of Neutralino densities, cross sections, and expected detection rates in both direct and indirect detection experiments. In this work we use DarkSUSY, together with the latest accelerator constraints and astrophysical bounds, to explore parameter space. Beginning with 700,000+ randomly generated models we explore if the MSSM has been experimentally ruled out. Surviving models and interesting regions of surviving parameter space will be presented and discussed.

Testing Accretion Disk Winds Models of Broad Absorption Line Quasars with SDSS Spectra

Lindgren, Sean; Gabel, Jack
Creighton University

We present an investigation of a large sample of Broad absorption line (BAL) quasars (QSO) from the Sloan Digital Sky Survey (SDSS) Data Release 5 (DR5). Properties of the BALs, such as absorption equivalent width, outflow velocities, and depth of BAL, are obtained from Gibson et al. 2009. We perform correlation analysis on these data to test the predictions made by the radiation driven, accretion disk streamline model of Murray et al. (1995). We find the CIV BAL maximum velocity and the continuum luminosity are correlated, consistent with radiation driven models. The mean max velocity of CIV is higher in low ionization BALs (LoBALs), than highly ionized BALs (HiBALS), suggesting an orientation effect consistent with the Murray et al model. Finally, we find that HiBALs greatly outnumber LoBALs in the general BAL population, supporting prediction of Murray et al. that HiBALs have a greater global covering factor than LoBALs.

Measuring X-ray Binary Accretion State Distributions in Extragalactic Environments using XMM-Newton

West, Lacey; Lehmer, Bret; Yukita, Mihoko; Hornschemeier, Ann; Ptak, Andrew; Wik, Daniel; Zezas, Andreas
University of Arkansas, University of Arkansas, Johns Hopkins University, NASA/GSFC, NASA/GSFC, NASA/GSFC, Crete

X-ray binary systems (XRBs) in the MW can exist in several different accretion states, and many have been found to vary along specific tracks on intensity-color diagrams. Observationally measuring the distributions of these accretion states in a variety of environments can aid in population synthesis modeling and ultimately help us understand the formation and evolution of XRBs and their compact object components (i.e., black holes and neutron stars). Recent innovative studies with NuSTAR have demonstrated the utility of color-color and intensity-color diagrams in differentiating between XRB accretion states in extragalactic environments (NGC 253, M83, and M31). The key to NuSTAR's success is its sensitivity above ≈10 keV, where spectral differences between accretion states are most pronounced. However, due to the relatively low spatial resolution and large background of NuSTAR, the constraints from these diagrams are limited to only bright sources in nearby galaxies. In this poster, we present evidence that XMM-Newton observations of M83 in the 4.0-12.0 keV range can be used to create similar color-intensity and color-color diagrams and therefore differentiate between these accretion states. We will further discuss plans to leverage XMM-Newton's vast archive and 17-year baseline to dramatically expand studies of accretion state distributions and state transitions for XRB populations in extragalactic environments.

The Star-Formation History Dependence of X-ray Binary Formation: Clues from M51 (NGC 5194)

Lehmer, Bret; Eufrasio, Rafael; Markwardt, Larissa
University of Arkansas

Recently, we found, in the Chandra Deep Field-South, that the emission from X-ray binary (XRB) populations in galaxies evolves significantly with cosmic time, most likely due to changes in the physical properties of galaxies like star-formation rate, stellar mass, stellar age, and metallicity. However, it has been challenging to directly show that these same physical properties are connected to XRB populations using data from nearby galaxies. We present a new technique for empirically calibrating how X-ray binary (XRB) populations evolve over time following their formation. We first utilize detailed stellar population synthesis modeling of far-UV to far-IR broadband data of nearby (< 12 Mpc) face-on spiral galaxies to construct maps of the star-formation histories on subgalactic scales. Using Chandra data, we then identify the locations of the XRBs within these galaxies and correlate their formation frequencies with local galaxy properties. In this talk, I will show promising first results for the Whirlpool galaxy (M51 or NGC 5194), and will discuss how expanding our sample to an archival sample of roughly 20 face-on spirals will lead to a detailed empirical timeline for how XRBs form and evolve in a variety of environments.