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This report covers the period September 2001 through August 2002 and comprises an account of astronomical research carried out in the Department of Physics and Astronomy.

1. INTRODUCTION

Seventeen years before Oklahoma became a state, the University of Oklahoma was founded by the first legislature of the Territory of Oklahoma. The first classes were held in 1892 with 119 students and four faculty members. More than 100 years later, OU enrolls more than 27,000 students and has approximately 1,830 full time faculty. The Department of Physics and Astronomy was founded in 1909, and currently employees 29 full time faculty in four cohesive research groups: astrophysics; atomic, molecular and chemical physics; high energy physics; and solid state physics.

2. PERSONNEL

Astrophysics faculty in the department include Ed Baron, David Branch, John Cowan, Dick Henry, Emeritus Professor Tibor Herczeg, Karen Leighly, Bill Romanishin, and Yun Wang. Faculty members Ron Kantowski, Chung Kao and Kim Milton from the particle physics group also participate in astrophysical research.

Pia Mukherjee joined the Department in August 2002 as a postdoctoral research associate working with Yun Wang. She was most recently a postdoc at Kansas State University. Chiho Matsumoto continued her position as a postdoctoral research associate with the AGN group led by Karen Leighly.

During the past year, Baron supervised research by graduate student Sebastien Bongard and Robert Mitchell. Robert Mitchell graduated with a Ph. D. degree, and has taken a faculty position at St Ambrose University in Cedar Rapids, Iowa. Branch supervised research by graduate students Rollin Thomas and Dean Richardson. Cowan has supervised research by graduate student Larry Maddox. Leighly supervised research by graduate students Darrin Casebeer and Aida Nava. Wang supervised research by Hamed Bagherpour.

Several faculty conducted research with undergraduates. Cowan supervised research by REU students Jason Collier and Faith Jordan. Leighly supervised research by John Moore. Wang supervised research by Geoffrey Lovelace, and REU students Bobby Fleshman and Jason Tenbarge.

The Department also hosted several long-term visitors. Toshihiro Kawaguchi joined the AGN group from July 2001 – November 2001, while he was a graduate student at the University of Tokyo. Andrea Pastorello, a graduate student at the University of Padua, visited the Department and worked with the supernova group from November 2001 to July 2002.

The astrophysics group has access to a number of resources for their research. They have been successful in obtaining observing time on both groundbased observatories including KECK, the VLA, and NOAO Kitt Peak, and on satellite observatories, recently including *HST*, *Chandra*, *XMM-Newton*, and *FUSE*, among others. The Department maintains modern computing facilities as well, including a network of nearly 70 UNIX workstations. On-line access is available to the NSF supercomputer network as well as other supercomputers in those groups with approved projects. Researchers also have access to supercomputer time at Livermore, San Diego, Los Alamos, Pittsburgh and NCSA.

The astrophysics group continued to be well funded through the 2001 – 2002 academic year, primarily through NSF and NASA. Once starting research, all graduate students were supported by research assistantship stipends, and funding has been available for travel to international meetings.

3. RESEARCH

3.1 Solar System and Extrasolar Planets

Romanishin continued to study minor bodies in the outer solar system, in collaboration with S. C. Tegler of Northern Arizona University. Analysis of colors of over 50 Kuiper Belt Objects (KBOs), obtained over the past 5 years by Tegler and Romanishin, as well as a similar sized sample from the literature supports the claim that these objects have a bimodal color distribution. The effect is subtle, and most of the colors in the literature do not have the precision to show the effect. The Tegler-Romanishin colors have smaller errors than the colors measured by other groups, due mostly to longer integration time per object, and do show the bimodal color effect.

Romanishin was a member of a team of astronomers, lead by Keith Noll of the Space Telescope Science Institute, that used the Hubble Space Telescope (*HST*) to study KBOs. The team discovered two new binary KBO objects. This brings the number of known KBO binaries to seven. Romanishin and Tegler also used the Keck 10 meter telescope to study one of the new KBO binaries. Romanishin is developing an image modelling program to extract separation and magnitude information for the individual components of KBO binaries from groundbased and *HST* data.

The recent announcement that sodium absorption has been observed in the atmosphere of HD 209458b, the only extrasolar giant planet (EGP) observed to transit its parent star, is the first direct detection of an EGP atmosphere. Barman *et al.* (with Baron) explored the possibility that neutral sodium is not in local thermodynamic equilibrium (LTE) in the outer atmosphere of irradiated EGPs and that the sodium concentration may be underestimated by models that make the LTE assumption. The results indicate that it may not be necessary to invoke excessive photoionization, low metallicity, or even high-altitude clouds to explain the observations.

3.2 Stars

With his collaborators, Jason Aufdenberg, Peter Hauschildt and others, Baron helped develop a stellar wind module for the PHOENIX stellar atmosphere code for the purpose of computing non-LTE, line-blanketed, expanding atmospheric structures and detailed synthetic spectra of hot luminous stars with winds. The code was applied to observations of Deneb. A range of mass-loss rates that is consistent with that derived from high-dispersion UV spectra when non-LTE metal-line blanketing is considered was found.

Leggett *et al.* (with Baron) presented spectroscopy for the M dwarfs Gl 229A and LHS 102A, and for the L dwarf LHS 102B. They also reported IZJHKL′ photometry for both components of the LHS 102 system, and L′ photometry for Gl 229A. The data were combined with previously published spectroscopy and photometry to produce flux distributions for each component of the kinematically old disc M/L dwarf binary system LHS 102 and the kinematically young disc M/T dwarf binary system Gliese 229. The data were analyzed using synthetic spectra generated by the latest 'AMES-dusty' and 'AMES-cond' models by Allard & Hauschildt. Leggett *et al.* found that the Gl 229 system is metal-poor despite having kinematics of the young disc, and that the LHS 102 system has solar metallicity. The observed luminosities and derived temperatures and gravities are consistent with evolutionary model predictions if the Gl 229 system is very young (age 30 Myr) and the LHS 102 system is older, aged 1–10 Gyr.

Hun-Bon-Hoa, LeBlanc, Hauschildt, and Baron presented calculations of radiative accelerations obtained with the general purpose model atmosphere code PHOENIX. The accelerations are computed simultaneously for all the elements He-Ga; Kr-Nb; Ba; La, using the opacity sampling method. The calculations are mainly performed with the LTE approximation. Tests are made to evaluate the influence of non-LTE effects and the validity of the radiative flux obtained through the diffusion approximation. It is shown that the abundances supported in the atmospheres of HgMn and He-weak stars are generally consistent with those observed.

3.3 Abundances and Nucleosynthesis

Cowan and collaborators have been making a large number of observational and theoretical studies of the heavy element abundances in Galactic halo stars. The observations have been made from the ground (Keck, McDonald, Kitt Peak) and from space (*HST*). Using the *HST* they have identified gold for the first time and uranium for only the second time in any halo star (BD+17 3248). Their abundance observations indicate the presence of rapid-neutron capture (i.e., r-process) elements in old Galactic halo and globular cluster stars. These observations demonstrate that the earliest generations of stars in the Galaxy, responsible for neutron-capture synthesis and the progenitors of the halo stars, were rapidly evolving. Abundance comparisons among large numbers of stars provide clues about the nature of neutron-capture element synthesis both during the earliest times and throughout the history of the Galaxy. In particular, these comparisons suggest differences in the way the heavier (including Ba and above) and lighter neutron capture elements are synthesized in nature. Understanding these differences will help to identify the astrophysical site (or sites) of and conditions in the r-process. The abundance comparisons also demonstrate a large star-to-star scatter in the neutron-capture/iron ratios at low metallicities (which disappears with increasing [Fe/H]) and suggests an early, chemically unmixed and inhomogeneous Galaxy. Their very recent neutron-capture element observations indicate that the early phases of Galactic nucleosynthesis, and the associated chemical evolution, are quite complex, with the yields from different (progenitor) mass-range stars contributing to different chemical mixes. Stellar abundance comparisons indicate a change from the r-process to the slow neutron capture (i.e., s-) process at higher metallicities (and later times) in the Galaxy. They are also using the observed abundances of the radioactive elements thorium and uranium in halo and globular cluster stars to determine the radioactive ages of the oldest stars in the Galaxy. These age estimates, clustering around 14 $\pm$ 4 Gyr, provide lower limits on the age of the Galaxy and provide constraints on cosmological age determinations. OU undergraduates Jason Collier and Faith Jordan worked with Cowan on this research.

Henry continued his work on planetary nebula abundances with Karen Kwitter (Williams College) and Jackie Milingo (Gettysburg College). Specifically, they have acquired spectrophotometry of over 80 planetaries and are using the data to study the abundance distributions of S, Cl, and Ar in the disk of the Galaxy. So far they have confirmed earlier evidence that these three elements track O, which is expected if these elements are made under similar conditions and in the same stars. All of data and abundance results have been published. Henry is now working on the final paper of the project, which is a comprehensive look at the abundances of these elements along with others such as O, Ne, and N. He is using chemical evolution models to test the hypothesis that Type Ia supernovae, predicted by theory to produce significant amounts of S, Cl, and Ar per event (in addition to the Fe they expel), play a noticeable role in the cosmic buildup of specific elements.

Henry spent much of his research effort over the past year working with Jason Prochaska (U.C. Santa Cruz) on an assessment of nitrogen abundances in damped Lyman alpha systems (DLAs). Using measured abundances of N, Si, and S (the latter two serve as metallicity indicators as well as proxies for O) for over 20 DLAs, they compared the positions of these objects with the distribution of H II regions, dwarf irregular galaxies, and stars in the $N/\alpha - \alpha/H$ plane, and uncovered a potential bimodality in the DLA distribution with respect to nitrogen abundance. Their evidence indicates that there are two abundance groups for DLAs in terms of N abundance. First, most of these objects appear to resemble low metallicity H II regions and dwarf irregular galaxies in so much as their N/α ratios agree with theoretical predictions of primary-like nitrogen nucleosynthesis, i.e. production in the absence of significant metals. However, a small subset of DLAs fall about 0.7 dex below the major group in terms of their observed N/α ratio. There is no apparent selection effect or physical process that could explain this right now. To speculate on the cause of this bimodality, Henry calculated numerous chemical evolution models in which he experimented with stellar yields, star formation rates, and forms of the initial mass function (IMF). In the end, he proposed that the low N group of DLAs must be due to star formation associated with a top-heavy or truncated IMF to suppress the relative number of intermediate mass stars ($1<M<8M_{\odot}$ and alleged to produce most of the N in the universe). This scenario is also consistent with the idea that nucleosynthesis from Population III stars, a group that many propose to comprise all massive stars, is responsible for the observed trend.

3.4 Observations of Supernovae and External Galaxies

OU graduate student Dean Richardson, Branch, Baron, and others used the Asiago Supernova Catalog to carry out a comparative study of supernova absolute–magnitude distributions. They presented an overview of the absolute magnitudes of supernovae in the current observational sample and examined the evidence for underluminous and overluminous events. Mean absolute magnitudes and dispersions were reported for each of the main supernova types.

Using the VLA, Cowan and collaborators, including OU alumnus Chris Stockdale and OU graduate student Larry Maddox, have been following the long-term radio behavior of intermediate-age extragalactic supernovae. They have found that these supernovae, such as SN 1970G in M101 and SN 1923A in M83, are still emitting in the radio decades after the supernova explosion. These observations are designed to understand how supernovae evolve into supernova remnants (SNRs), which typically take at least 100 years to become radio emitters. The observations also provide an indication of the circumstellar mass-loss rate, which affects the level and duration of the radio emission, from the supernova progenitor star.

In addition, Cowan and collaborators have been making coordinated multi-wavelength (Kitt Peak, VLA and *Chandra*) observations of point sources in nearby face-on galaxies. They are trying to identify previously undetected supernovae or SNRs. Their VLA observations are also being used to distinguish High & Low Mass X-ray Binaries (HMXBs & LMXBs) from supernovae remnants. They are also trying to identify the population of SNRs, HMXBs, and LMXBs in spiral galaxies and determine whether there are massive black holes (MBHs) in these spiral galaxies.

3.5 Type I Supernovae

Former OU graduate student Kazuhito Hatano (Un. Tokyo), with Branch, Baron, and others analyzed optical spectra of the peculiar Type Ia SN 1997br obtained by Yulei Qiu of the Beijing Astronomical Observatory. They emphasized that Ni III and Fe III features seen in early spectra of SN 1997br may have been produced by stable ^{58}Ni and ^{54}Fe rather than by radioactive ^{56}Ni and its granddaughter nucleus ^{56}Fe as is usually assumed. Mixing of freshly synthesized ^{56}Ni into the high–velocity outer layers of the ejected matter may not be required.

OU student Eric Lentz, Baron, Branch and collaborators have fitted the normal, well-observed, Type Ia Supernova (SN Ia) SN 1994D with non-LTE spectra of the deflagration model W7. They found that well before maximum luminosity, W7 fits the optical spectra of SN 1994D. After maximum brightness the quality of the fits weakens as the spectrum forms in a core rich in iron-peak elements. They show the basic structure of W7 is likely to be representative of the typical SN Ia. They present UVOIR (UBVRIJKH) synthetic photometry and colors and compare with observation. They have computed the distance to the host galaxy, NGC 4526, obtaining a distance modulus of $\mu=30.8\pm0.3$ using the SEAM method. They discuss further application of this direct measurement of SNe Ia distances.

Former OU visitor Stefano Benetti (Un. Padua), with Branch, Baron, and others presented observations and analysis of the exceptionally bright Type Ib SN 1991D. They presented evidence that the spectra contained lines of Ne I; these would need to be nonthermally excited, as are the He I lines. They suggested that SN 1991D may have been the explosion of a white dwarf inside the envelope of its giant companion.

Branch studied spectra of a sample of Type Ic supernovae. He found evidence that the spectra may contain He I lines and perhaps even hydrogen. He discussed how spectroscopic differences between Type Ib and Type Ic supernovae may depend as much on the radial distributions of the helium and hydrogen as on the total masses of these elements.

3.6 Type II Supernovae

Supernova 1987A remains the most well studied supernova to date. Observations produced excellent broadband photometric and spectroscopic coverage over a wide wavelength range at all epochs. The observed spectra were modelled from day 1 to day 81. Using the Spectral-fitting Expanding Atmosphere Method (SEAM) that Baron has developed, OU graduate student Robert Mitchel and collaborators obtained a distance to SN 1987A in good agreement with other methods. They were also are able to constrain the explosion time to be within 0.9 days of the neutrino burst.

3.7 Active Galaxies

Branch, Leighly, Thomas, and Baron explored a resonance–scattering interpretation of the FeLoBAL quasar FBQS 1214+2803. The spectrum of a FeLoBAL quasar contains numerous broad absorption lines from excited levels of Fe II. In this model, the line emission and absorption components are formed in the same region, in contrast to the usual model in which they are formed in separate regions. The resonance–scattering model appears to be consistent with recent arguments that some broad–absorption–line quasars are new or refueled quasars rather than ordinary quasars seen from a special angle (evolution, not orientation).

Leighly has devoted most of her research time during the past year to continuing research on Narrow-line Seyfert 1 galaxies (NLS1s). This optically identified subclass of Active Galaxies has been shown to exhibit peculiar properties, including narrower optical permitted lines (an identifying feature), steeper soft and hard X-ray spectra, and higher amplitude/more rapid X-ray variability than Seyfert galaxies with broader optical permitted lines. The now-accepted explanation for these properties is that NLS1 have accretion rates higher relative to the Eddington limit than Seyfert 1 galaxies with broad optical lines. Thus the study of these objects is motivated by the desire to understand the effect of the rate of accretion, one of the primary intrinsic parameters for accretion driven systems, on observed properties.

Leighly continues work on the UV emission lines from NLS1s. Using the photoionization spectral synthesis code *Cloudy*, she showed that the equivalent widths of the broad, blueshifted high-ionization lines from NLS1s IRAS 13224−3809 and 1H 0707−495 can be explained by a combination of enhanced metallicity and intrinsically weak X-ray emission, which have the effect of cooling the gas when the ionization parameter is high. The optimal ionization parameter and column density were determined, and a toy dynamical model was then constructed that was used to determine the distance from the continuum source and the volume filling factor under the assumption that the acceleration was provided by resonance-line scattering, and that the confinement mechanism is nonthermal. John Moore, an OU undergraduate, contributed to this project by reducing the *HST* FOS data from a sample of NLS1s from the archive. The properties of these will be compared with the properties of the target objects.

During December 2001, Leighly and collaborators made coordinated *HST* and *Chandra* observations of the luminous NLS1 PHL 1811. PHL 1811 was recently discovered during the VLA FIRST survey to be the second brightest quasar beyond z=0.1 after 3C 273. This quasar was not detected in the *ROSAT* All Sky Survey and was very faint in a followup *BeppoSAX* observation. The two *Chandra* observations revealed a faint object with a steep, unabsorbed spectrum, and variability by a factor of four between the observations separated by 12 days. The UV spectrum shows absorption by up to 7 intervening absorbers, but little evidence for intrinsic absorption by the quasar. These results are interpreted as evidence that PHL 1811 is intrinsically X-ray weak. The UV and optical spectra are very unusual. No forbidden or semiforbidden line emission was seen. Strong optical and UV Fe II emission, Ca H&K and NaD in emission indicate high optical depths. A very large Fe II to Mg II ratio probably indicates enhanced metallicity.

In collaboration with Andrzej Zdziarski (CAMK), Toshihiro Kawaguchi (Meudon) and OU postdoc Chiho Matsumoto, Leighly analyzed the *Chandra* HETG observation of the extreme Narrow-line Seyfert 1 galaxy 1H 0707−495. The spectrum revealed a strong soft excess, a weak power law, and absorption near 1 keV that may be the direct result of the strong soft excess. They discovered strong spectral variability in which the soft component varied much less than the hard component, a behavior that is both quite suggestive of soft-state X-ray binaries, and in contrast with the colorless variability of other NLS1s observed by *Chandra* and *XMM-Newton*. 1H 0707-495 was bright when observed by *Chandra*, and a comparison of historical observations reveals suggestively bimodal behavior. Leighly *et al.* interpret this bimodality as the signature of the radiation pressure instability, and suggest that this instability may be expected in this object, resulting from a high accretion rate, and lack of strong corona that could stabilize the accretion disk.

The investigation of the *Chandra* HETGS observation of the low-luminosity Narrow-line Seyfert 1 galaxy Ark 564 was completed this year by OU postdoc Chiho Matsumoto, in collaboration with Leighly, and Herman Marshall (MIT). This object was chosen for high resolution X-ray spectroscopy because the low-resolution spectrum exhibited a peculiar emission line-like feature at 1 keV. They found no prominent narrow emission lines around 1 keV in the *Chandra* spectrum, and could rule out a possible origin of blends of several narrow emission lines. They detected evidence for a highly ionized warm absorber, including narrow absorption lines O VII, O VIII, Ne IX and Mg XI at the systemic velocity. The inferred photoionization parameter and the column density of the warm absorber were $\log\xi\sim 2$ and a few $\times 10^{21}$ cm $^{-2}$, respectively. They also detected an edge-like feature at 0.71 keV in the source rest frame. This feature is quite similar to one observed in a Seyfert-1 galaxy MCG−6-30-15, the interpretation of which has caused a large controversy. The favored interpretation in Ark 564 is a second warm absorber producing absorption from blended L lines from slightly ionized iron that may be the same gas that produces strong UV absorption in this object.

It has long been thought that the shape of the ionizing continuum of an Active Galactic Nucleus (AGN) should influence their broad emission lines. OU graduate student Darrin Casebeer, in collaboration with Leighly, has been investigating this problem using multiwavelength observations of RE 1034+39, an object with an unusual spectral energy distribution (SED) that is strongly peaked in soft X-rays. Coordinated *FUSE*, *EUVE*, *ASCA* and optical observations were attained, and the archival *HST* FOS spectrum was reanalyzed. The photoionization spectral synthesis code *Cloudy* was used to demonstrate that the observed SED indeed produces the lines that are observed, although a range of densities in the line-emitting region may be called for. They then made a systematic investigation of the effect of the SED on emission lines in AGN, with a focus on line ratios sensitive to the SED, and an investigation of the effect of the SED on the density and metallicity indicators.

OU postdoc Chiho Matsumoto, in collaboration with Leighly, OU undergraduate student John Moore, and Dirk Grupe (Ohio State University), is studying the influence of soft X-ray selection on hard X-ray and optical properties of active galaxies. The X-ray soft excess component is thought to be the high energy tail of the accretion disk spectrum. The emission from accretion disk provides the primary energy source for the formation of the optical and UV lines, as well as the seed photons that are Compton-upscattered to produce the hard X-ray power-law. Thus, correlations are expected among the optical, UV and X-ray properties. They chose a complete sample of the 20 brightest and softest objects with the lowest Galactic absorption from the *ROSAT* sample of soft X-ray selected AGN. They obtained *ASCA* observations of all of them, and coordinated *EUVE* observations of about half. *ASCA* and optical spectra have been reduced and currently statistical tests are being run to look for correlations among properties.

An atlas of light curves exceeding 5 days in duration from AGN observations using the Deep Survey instrument on *EUVE* was produced by Jules Halpern (Columbia University), in collaboration with Leighly and Herman Marshall (MIT). They performed time series analysis on the longer observations, and found evidence for a periodic signal in three galaxies. The periods were between 0.9 and 6 days and were correlated with the luminosity of the objects. Using simulated light curves, they determined the confidence of the period detections; these range from a low significance of $\sim$65% to 98% for the most convincing case.

OU graduate student Aida Nava, in collaboration with Leighly, OU postdoc Chiho Matsumoto and Dirk Grupe (Ohio State University), analyzed the *XMM-Newton* observation of the bright Seyfert 2 galaxy NGC 6300. They found that the nuclear emission is described by a power law with a Compton-thin absorber, a soft unabsorbed component, and an Fe Kα line at 6.4 keV. The object exhibited rapid and fairly high amplitude variability during the observation. Spectral variability was confirmed by examination of the variability in narrow energy bands. Notable was the reduced-amplitude variability in the energy band containing the iron line, a result that indicates that the iron line is produced in an extended emission region. The X-ray image is being analyzed by OU graduate student Larry Maddox in collaboration with Leighly. Two point sources are detected within 1 arcminute of the nucleus in this nearby ring galaxy. One of them is associated with a near-UV source on the ring detected in the Optical Monitor image. If associated with the galaxy, it has an X-ray luminosity of $\sim 1\times 10^{39}$ erg s^{-1}, and may be an ultraluminous X-ray source as has been found in other nearby galaxies.

3.8 Cosmology

Wang and OU undergraduate student Lovelace studied optimal strategy for using Type Ia supernovae (SNe Ia) to derive an unbiased estimate of dark energy density. Type Ia supernovae (SNe Ia) are currently the best probes of the dark energy in the universe. To constrain the nature of dark energy, they assumed a flat universe and that the weak energy condition is satisfied, and allow the density of dark energy, $\rho_X(z)$, to be an *arbitrary* function of redshift. Using simulated data from a space-based supernova pencil beam survey, they found that by optimizing the number of parameters used to parametrize the dimensionless dark energy density, $f(z) = \rho_X(z)/\rho_X(z=0)$, they can obtain an unbiased estimate of both $f(z)$ and the fractional matter density of the universe Ω_m. A plausible supernova pencil beam survey (with a square degree field of view and for an observational duration of one year) can yield about 2000 SNe Ia with $0\leqslant z\leqslant 2$. Such a survey in space would yield SN peak luminosities with a combined intrinsic and observational dispersion of $\sigma(m_{int}) = 0.16$ mag. They found that for such an idealized survey, Ω_m can be measured to 10% accuracy, and the dark energy density can be estimated to $\sim$ 20% to $z\sim 1.5$, and $\sim$ 20-40% to $z\sim 2$, depending on the time dependence of the true dark energy density. Dark energy densities which vary more slowly can be more accurately measured. For the anticipated SNAP mission (based on the SNAP December 2000 DOE Science Proposal), they found that Ω_m can be measured to 14% accuracy, and the dark energy density can be estimated to $\sim$ 20% to $z\sim 1.2$. Their results suggest that SNAP may gain much sensitivity to the time-dependence of the dark energy density and Ω_m by devoting more observational time to the central pencil beam fields to obtain more SNe Ia at $z > 1.2$. They use both maximum likelihood analysis and Monte Carlo (when appropriate) to determine the errors of estimated parameters. They found that Monte Carlo analysis gives a more accurate estimate of the dark energy density than the maximum likelihood analysis. It is worth noting that this work has impacted the design of SNAP by showing that the originally proposed SNAP mission was far from optimal in probing the time-dependence of the dark energy density (the most important observable property of dark energy), and the critical importance of obtaining SNe Ia at the highest possible redshifts. The current SNAP mission design has been revised so that all SNe Ia up to $z=1.7$ can be obtained.

Wang and Munshi (Cambridge) studied the effect of dark energy on weak gravitational lensing. Future weak lensing surveys will directly probe the clustering of dark matter, in addition to providing a test for various cosmological models. Recent studies have provided them with the tools which can be used to construct the complete probability distribution function for convergence fields. It is also possible to construct the bias associated with the hot-spots in convergence maps. These techniques can be used in both the quasi-linear and the highly nonlinear regimes using various well-developed numerical methods. They used these results to study the weak lensing statistics of cosmological models with dark energy. They studied how well various classes of dark energy models can be distinguished from models with a cosmological constant. They found that the ratio of the square root of the variance of convergence is complementary to the convergence skewness S_3 in probing dark energy equation of state; it can be used to predict the expected difference in weak lensing statistics between various dark energy models, and for choosing optimized smoothing angles to constrain a given class of dark energy models. Their results should be useful for probing dark energy using future weak lensing data with high statistics from galaxy weak lensing surveys and supernova pencil beam surveys.

Wang, Holz (UC Santa Barbara), and Munshi (Cambridge) derived an approximate form for the weak lensing magnification distribution of standard candles, valid for all cosmological models, with arbitrary matter distributions, over all redshifts. Their results are based on a universal probability distribution function (UPDF), $P(\eta)$, for the reduced convergence, η. For a given cosmological model, the magnification probability distribution, $P(\mu)$, at redshift z is related to the UPDF by $P(\mu)=P(\eta)/2|\kappa_{min}|$, where $\eta=1+(\mu-1)/(2|\kappa_{min}|)$, and κ_{min} (the minimum convergence) can be directly computed from the cosmological parameters (Ω_m and Ω_Λ). They showed that the UPDF can be well approximated by a three-parameter stretched Gaussian distribution, where the values of the three parameters depend only on ξ_η, the variance of η. In short, all possible weak lensing probability distributions can be well approximated by a one-parameter family. They establish this family, normalizing to the numerical ray-shooting results for a ΛCDM model by Wambsganss *et al.* (1997). Each alternative cosmological model is then described by a single function $\xi_\eta(z)$. They found that this method gives $P(\mu)$ in excellent agreement with numerical ray-tracing and three-dimensional shear matrix calculations, and provide numerical fits for three representative models (SCDM, ΛCDM, and OCDM). Their results provide an easy, accurate, and efficient method to calculate the weak lensing magnification distribution of standard candles, and should be useful in the analysis of future high-redshift supernova data. The results of this work have been adopted by SNAP team members for estimating the weak lensing effect on observed type Ia supernovae.

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