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ABSTRACTS OF CONTRIBUTED PAPERS

ASYMMETRIC SUPERNOVAE: YES, ROTATION AND MAGNETIC FIELDS ARE IMPORTANT

Craig Wheeler[1]

We have known for decades that compact remnants of supernovae in the guise of pulsars involve rotation and magnetic fields at a fundamental level. What has not been clear is whether or not rotation and magnetic fields play a critical role in the formation of the supernova explosion itself. New observations, especially systematic spectropolarimetry, have brought new perspective to this issue. To date, all core collapse supernovae with adequate data are observed to be significantly polarized and hence substantially asymmetric. Many show a single dominant axis of orientation: they are substantially bi-polar. The observed increase in asymmetry with depth in the ejecta implies that it is the fundamental mechanism of the explosion itself that is asymmetric. Simulations have shown that this asymmetry could plausibly be generated by sufficiently energetic jets originating in core collapse. While it may be possible to generate strongly asymmetric flows by asymmetric neutrino deposition engendered by rotation alone, physical considerations suggest that the strong differential rotation that is intrinsic to core collapse must also generate associated magnetic fields. In particular, the magnetorotational instability coupled with modern dynamo theory suggests that toroidal fields of order 10^{15} Gauss will be generated in tens of milliseconds after core bounce. The open issues are whether or not these fields will produce dynamically-significant, jet- like flows and how to make connections to pulsars, magnetars and, perhaps, gamma-ray bursts.

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THE SPITZER SPACE TELESCOPE AND STAR FORMATION

Neal J. Evans II[1]

The Spitzer Space Telescope (SST) provides unprecedented sensitivity in the mid-infrared and far-infrared (3.6 to 160 micrometers). Observations with Spitzer will impact nearly all areas of astronomy. I will focus in this talk on studies of star and planet formation. After introducing the current picture and remaining questions in this area, I will describe some early results from the SST, focusing on those from the Cores to Disks (c2d) Legacy project. The c2d program focuses on the formation of low-mass stars in nearby (within about 300 pc) clouds. It covers the range of star formation from the earliest, starless cores up to stars about 10 million years old. Regions of star formation contain many previously unknown protostars and young stars with disks. Some dense molecular cores, previously thought to be starless, appear to contain objects of low luminosity, possibly sub-stellar in nature. Infrared excesses around somewhat older stars can be seen; systematic studies of these will constrain the timescales for planet formation. Spectroscopy of low-mass protostellar objects reveals a rich array of ices, confirming evidence from millimeter studies that many species are frozen-out from the gas phase.

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THE DOUBLE TELESCOPE PROJECT FOR SAN PEDRO MÁRTIR

J. Jesús González[1]

The Mexican astronomical community is up to consolidate a consortium to build and operate a telescope facility at the San Pedro Mártir Observatory, matched to exploit the excellent site characteristics with a cost- effective and short-timescale, but yet extremely competitive concept. The project considers a couple of complementary 6.5 m Magellan-like telescopes, one optimized for Wide-field (1.5 to 2 degrees in diameter) Integral-field spectroscopy; and the other optimized for Adaptive Optics and Infrared astronomy. The general concepts and status of the project are presented.

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PROPER MOTIONS OF THE HH 47 PROTOSTELLAR JET

Patrick Hartigan,[1] Steve Heathcote,[2] Jon A. Morse,[3] Bo Reipurth,[4] and John Bally[5]

We report the results of a proper motion survey of the HH 47 protostellar jet based on HST observations separated by five years. Because the uncertainties in the measurements are only a few km/s, it is possible to measure differential motions within the jet, and in the working surface of HH 47A between the bow shock and the Mach disk. The jet clearly precesses, and currently passes through an oblique shock at the northern edge of a cavity. Although the jet curves, knots within the jet move radially away from the exciting source. The working surface of HH 47A is very clumpy, and we observe small knots that penetrate the Mach disk and may emerge from the bow shock to give an overall bumpy appearance to the bow. The observed velocity variations within the jet of about 30 km/s agree with previous results inferred from shock models of the emission lines.

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RECOLLECTIONS OF A FEW CREATIVE NEBULAR ASTROPHYSICISTS

Donald E. Osterbrock[1]

This will be an informal history-of-astronomy talk on some of the astronomers of the generation before mine who made important contributions to nebular astrophysics. Some of them you know well by name: Bengt Stromgren, Rudolph Minkowski, Walter Baade, Otto Struve; others of them perhaps less well: Karl-Otto Kiepenheuer, Thornton Page. I will try to give you some personal insights into what they did in nebular research and how they did it. I will also show transparencies of photographs of most of them.

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COSMIC MICROWAVE BACKGROUND, LARGE-SCALE STRUCTURE, AND INFLATIONARY UNIVERSE

Eiichiro Komatsu[1]

Did inflation happen? If it did, how did it happen? These are important questions we need to answer in the next decades. I will review the current observational constraints on inflationary cosmology, and discuss future prospects for finding a true model of inflation. The major breakthrough on this subject was recently made by precise measurements of the cosmic microwave background radiation by the Wilkinson Microwave Anisotropy Probe; however, constraints are still too weak to identify a true model. I show that future galaxy surveys at high redshifts combined with more precise measurements of CMB temperature and polarization anisotropy should bring us very close to identifying a true inflationary model, or disproving inflation with a single scalar field.

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THE FIRST STARS

Volker Bromm[1]

How and when did the cosmic dark ages end? I present simulations of the formation of the first stars and quasars, discuss their feedback on the IGM, and describe ways to probe their signature with WMAP and JWST. The first supernovae are responsible for the initial metal enrichment of the IGM, and I address the impact of this initial enrichment event on the subsequent history of structure formation.

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A COMPARISON OF THE PROPERTIES OF ACTIVE GALACTIC NUCLEI NEAR Z = 0.1 WITH THOSE NEAR Z = 2.1

Eugene Clark[1]

The two samples of AGN compared in this project are all Sloan Digital Sky Survey, DR2 sources with Target Flag = QSO or are sources with position matches to sources in the VLA FIRST radio catalog.

Two AGN samples were analyzed, one with Z near 0.1 and the second with Z near 2.1. There were about 500 AGN in each of these two samples. About 95% of the sources in these two samples were type 1 (broad line) AGN. The remainder were type 2 (narrow-line) sources. The apparent bolometric luminosities and masses of the type 1 AGN were calculated using empirical equations from Vestergaard, Ap. J. 601: 676-691, 2004. The corresponding absolute luminosities were calculated using $H_o = 75km/s^-1/Mpc^-1, q_o = 0.5$.

The distributions and inter-relationships of the masses, absolute luminosities, Eddington ratios, and continuum spectral indices of the type 1 AGN were very similar at Z near 0.1 and at Z near 2.1. The most significant difference was that the median absolute luminosity of the type 1 AGN at Z near 2.1 was about a factor of 30 larger than the median of the sample at small Z. It is not clear that the larger Z sample is intrinsically brighter. Selection effects could explain part of this luminosity difference. In addition, gravitational lensing by foreground masses is more likely to enhance the apparent luminosity of AGN in the sample at larger Z.

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INHOMOGENEITIES OF THE GAS AND DUST IN PLANETARY NEBULAE: NEW INSIGHTS FROM UV SPECTROSCOPY

Harriet L. Dinerstein,[1] and N. C. Sterling[1]

The presence of density inhomogeneities in the ionized regions of planetary nebulae has been established from high-spatial resolution images showing clumps down to sub-arcsecond scales. Furthermore, different diagnostic emission line ratios often yield different values of ne and Te even when they trace the same ionization zone, an indication of unresolved inhomogeneities. Based on UV spectra obtained with FUSE and HST, we show that inhomogeneity is also a characteristic of other nebular properties, in particular the molecular fraction and the dust-to-gas ratio. We searched for UV absorption lines of H2 in several nebulae that exhibit near-IR H2 line emission. In most cases no UV lines were seen, despite the fact that these resonance lines are sensitive to very small column densities. Our upper limits on N(H2) are several orders of magnitude lower than beam-averaged values indicated by the IR emission lines, demonstrating that the gas is devoid of molecules outside the localized emitting regions. For SwSt 1, we find an intriguing indication of internal variations in dust content. The Fe/S abundance inferred from the UV absorption lines is substantially higher than that derived from optical emission lines of the same ions. We intepret this in terms of different degrees of gas-phase depletion: the refractory element Fe is more heavily depleted into dust in the dense, emitting gas than in the low-density material sampled by the UV lines. It is unclear whether this is due to more effective dust destruction in lower-density gas, or to more efficient grain formation and growth in higher-density clumps in the original red giant wind.

We also find that radiative pumping by stellar photons affects the populations of the excited fine-structure levels of O I, which give rise to the far-infrared 63 and 145 m lines. In SwSt 1 the effect is extreme enough to have produced a population inversion; in sources where it is less dominant (and unrecognized), it may lead to overestimated values of T based on far- infrared [O I] line strengths.

This research was supported by NASA through FUSE data analysis support grants NAG 5-9239, 11597, 12731, and 13724.

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MEASUREMENT OF THE EVOLUTION OF THE STELLAR MASS FUNCTION

Niv Drory[1]

We present a measurement of the evolution of the stellar mass function (MF) of galaxies and the evolution of the total stellar mass density at $0 < z < 5$, extending previous measurements to higher redshift and fainter magnitudes (and lower masses). We use deep multicolor data in the Fors Deep Field (FDF; I-selected reaching $I_{AB} \sim 26.8$) and the GOODS-S/CDFS region (K- selected reaching $K_{AB} \sim 25.4$) to estimate stellar masses based on fits to composite

stellar population models for 5557 and 3367 sources, respectively. The MF of objects from the K-selected GOODS-S sample is very similar to that of the I-selected FDF down to the completeness limit of the GOODS-S sample. Near-IR selected surveys hence detect the more massive objects of the same principal population as do I-selected surveys. We find that the most massive galaxies harbor the oldest stellar populations at all redshifts. At low z, our MF follows the local MF very well, extending the local MF down by a decade to $10^8 M_{sun}$. Furthermore, the faint end slope is consistent with the local value of $\alpha \sim 1.1$ at least up to $z \sim 1.5$. Our MF also agrees very well with the MUNICS and K20 results at $z = 2$. The MF seems to evolve in a regular way at least up to $z \sim 2$ with the normalization decreasing by 50% to $z = 1$ and by 70% to $z = 2$. Objects with $M > 10^{10} M_{sun}$ which are the likely progenitors of todays $L > L*$ galaxies are found in much smaller numbers above $z \sim 2$. However, we note that massive galaxies with $M > 10^{11} M_{sun}$ are present even to the largest redshift we probe. Beyond $z \sim 2$ the evolution of the mass function becomes more rapid. We find that the total stellar mass density at $z = 1$ is 50% of the local value. At $z = 2$, 25% of the local mass density is assembled, and at $z = 3$ and $z = 5$ we find that at least 15% and 5% of the mass in stars is in place, respectively. The number density of galaxies with $M > 10^{11} M_{sun}$ evolves very similarly to the evolution at lower masses. It decreases by 0.4 dex to $z \sim 1$, by 0.6 dex to $z \sim 2$, and by 1 dex to $z \sim 4$.

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THE RICE UNIVERSITY CCD IMAGER FOR THE AEOS TELESCOPE

R. J. Dufour,[1] I. A. Smith,[1] E. P. Lang,[1] L. C. Hardin,[2] and R. Forgey[2]

We describe the details of our new versatile CCD imager (RUCCD) that has recently been constructed for use on the AEOS telescope. It is a flexible instrument capable of performing imaging photometry, spectroscopy, and polarimetry of both bright and faint sources. It will be in a permanent state of readiness for making observations. Its primary objective will be performing comprehensive studies of the early emission from gamma-ray burst counterparts. However, it will be made available to the Air Force and other visiting scientists. The RUCCD was successfully installed and aligned in Coude' room 6 of the AEOS 3.63m telescope at Haleakala, Maui, Hawaii on 2004 February 3-4 and several test images of astronomical objects made. Examples of two of the objects observed (Saturn and the planetary nebula NGC 2392) are presented here.

[1] Rice University
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C III] IMAGERY OF PLANETARY NEBULAE AND H II REGIONS

R. J. Dufour,[1] R. B. C. Henry,[2] K. B. Kwitter,[3] J. Bohigas,[4] and C. Esteban[5]

We report some early results of a Cycle 12 Hubble Space Telescope SNAP program imaging the C III] 1909 Ang lines in planetary nebulae (PNe) and extragalactic H II regions using WFPC2 with the F185W filter. To date(2005 April), four PNe (NGC 6210, NGC 6720, NGC 6826 & NGC 7662) and four H II regions (LMC N160A, SMC N81, NGC 2363 & IZw18) have been observed.

Using continuum imagery of the nebulae made with HST WFPC2 and the knowledge of the UV spectra of regions in the nebulae from archival HST FOS/STIS or IUE data, the UV continuum contribution onto the F185W images is calculated and subtracted to give images of the nebulae in the emission of C III] 1909 Ang. These are compared to similarly processed HST WFPC2 images of the nebulae in other emission lines, such as O III 5007 Ang and Halpha/Hbeta, to study the ionization structure of C+2 compared to O+2 and H+, for example. The objectives of the research include: (a) studying the effects that nebular variations in density, temperature and dust content have on the observed F(1909)/F(5007) line ratio across the nebulae, (b) studying the co-spatiality of the C+2 and O+2 ionization structure, and (c) evaluation of the accuracy of using observations of the integrated F(1909)/F(5007) line ratio in nebulae for determining the C+2/O+2 ratio and the tot total C/O abundance ratio in PNe and H II regions.

This research is supported in part by AURA/STScI grants HST-GO-09740 to Rice University, University of Oklahoma, and Williams College.

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SEARCHING FOR LOW-MASS COMPANIONS AROUND T TAURI STARS

Marcos Huerta,[1] Lisa Prato,[2] Patrick Hartigan,[1] Chris Johns-Krull,[1] and Dan Jaffe[3]

High precision radial velocity surveys of main sequence stars have discovered numerous extra solar planets and a few brown dwarfs over the last decade. However, no such objects have yet been found around pre-main-sequences stars, limiting our information about when low-mass companions may form. We present preliminary results of a new radial velocity survey of T Tauri stars using the coudéchelle spectrograph on the 2.7m telescope at McDonald Observatory. Wavelength calibration was performed using thorium-argon lamps taken just before and after each stellar observation. Radial velocity standards we observed on each night show a scatter of about 100 m/s. Three T-Tauri stars monitored on each night of our ten-day observing run show significantly stronger radial velocity variations (a standard deviation of 500 m/s) than any of the radial velocity standards. With only our present observations, it is unknown whether these signals are attributable to stellar activity or to the reflex motion caused by possible low-mass-companions. In addition, we observed a few known high-amplitude extrasolar planetary systems. Our data are consistent with their published orbital parameters.

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A NEW PARALLAX MEASUREMENT TO THE PLEIADES STAR CLUSTER

C. M. Johns-Krull[1] and J. A. Anderson[1]

We report on a new program to determine the distance to the Pleiades Open cluster by means of measuring its trigonometric parallax. Digital Sky Survey images from 1951 November are used with widefield I band imaging obtained at McDonald Observatory in 2002 February to determine the proper motion of the cluster and to identify low mass cluster stars. Using this membership list, 3 fields were identified in which multiple cluster stars fit onto a single Hubble Space Telescope ACS/WFC image. HST-ACS observations of these fields were obtained in 2003 July and 2004 January through the F475W and F814W filters. Combined with our previous proper motion measurement for the cluster, the HST-ACS data are used to measure the parallax of 10 low mass cluster stars. We will present our data and parallax determination which we expect to be accurate to $\sim 5\%$.

[1] Rice University

EXAMINING THE OFFSET BETWEEN NEBULAR AND STELLAR OXYGEN ABUNDANCES IN THE LOCAL GROUP DWARF IRREGULAR GALAXY WLM

H. Lee,[1] E. D. Skillman,[1] and K. A. Venn[2,1]

We obtained optical spectra of 13 H II regions in WLM with the EFOSC2 spectrograph on the ESO 3.6-m telescope at La Silla; oxygen abundances are derived for nine H II regions (Lee, Skillman, & Venn 2005). The temperature-sensitive O IIIλ4363 emission line was measured in two bright H II regions HM 7 and HM 9, and their resulting direct oxygen abundances were 12+log(O/H) $= 7.72 \pm 0.04$ and 7.91 ± 0.04, respectively. We adopt a mean oxygen abundance of 12+log(O/H) $= 7.83 \pm 0.06$, which corresponds to [O/H] $= -0.83$ dex, or 15% of the solar value. In H II regions without O IIIλ4363 measurements, oxygen abundances derived with bright-line methods agree with direct abundances to an accuracy of about 0.2 dex.

Our H II region oxygen abundances agree with previous values in the literature. The upper end of the range of direct nebular oxygen abundances is consistent with the mean stellar magnesium abundance ([Mg/H] $= -0.62$). However, there is still 0.62 dex difference in oxygen abundance between the nebular result and the A-type supergiant star WLM 15 ([O/H] $= -0.21$; Venn et al. 2003). Despite the low foreground reddening to WLM, non-zero reddening values derived from Balmer line ratios were found in H II regions near a second H I peak (Jackson et al. 2004). There may be a connection between the location of the second H I peak, regions of higher extinction, and the position of WLM 15 on the eastern side of the galaxy. However, radial differences in the stellar populations in WLM cannot yet be ruled out as an explanation for the higher extinctions.

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ON THE SPITZER IRAC 4.5 μm LUMINOSITY-METALLICITY RELATION FOR DWARF IRREGULAR GALAXIES IN THE LOCAL VOLUME

H. Lee,[1] D. C. Jackson,[1] E. D. Skillman,[1] J. M. Cannon,[2] R. D. Gehrz,[1] E. Polomski,[1] and C. E. Woodward[1]

Dwarf irregular galaxies display a correlation between metallicity and total luminosity, which may be a manifestation of mass loss due to galactic winds. However, the relationship at optical wavelengths shows significant dispersion, and part of the dispersion may be due to variations in luminosity caused by variations in the star formation rate. Infrared luminosities are less affected by changes in the star formation rate, so it is of interest to study the correlation at infrared wavelengths.

We present new 4.5 μm luminosities for eight dwarf irregular galaxies observed with the *Spitzer Space Telescope* under the GTO program #128 (P. I. R. Gehrz). All of these galaxies have distances under 3 Mpc. For the first time, we construct an infrared luminosity-metallicity relationship for dwarf irregular galaxies to complement the near-infrared versions being obtained by other workers with ground-based data. At 4.5 μm, the infrared luminosity of metal-poor dwarf galaxies is still dominated by the light of the underlying stellar population, and is not contaminated by PAH emission. Tentatively, the resulting least-squares fit to the existing data thus far yields the following relation: $12+\log(\mathrm{O/H}) = (5.45 \pm 0.38) + (-0.122 \pm 0.020)\, M_{[4.5]}$, where $M_{[4.5]}$ is the absolute magnitude of galaxies at 4.5 μm (IRAC band-2). It is interesting that the slope agrees within errors with the optical B-band luminosity-metallicity relation (see Lee et al. 2003). The current sample will be expanded by at least 50% with the completion of our GTO sample, and the inclusion of additional dwarf galaxies from the SINGS survey.

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DYNAMICS AT THE CENTER OF GLOBULAR CLUSTERS

E. Noyola[1]

Globular clusters are thought to be highly relaxed dynamical systems due to their relatively small size ($10^4 - 10^6$ solar masses) and old age. Their structure is generally assumed to be well described by a lowered isothermal otherwise known as King model. We present evidence both from photometric and spectroscopic measurements that challenge this assumption.

Noyola & Gebhardt (2005) obtained surface brightness profiles for a sample of 38 galactic globular clusters from HST images. The distribution of central slopes shows an important number of objects with intermediate slopes between zero and those predicted for post core-collapse morphology. 50% of the sample is not well represented by King models. Currently, the only model that predicts intermediate central slopes is that where an intermediate mass black hole is present. We have obtained SB measurements for 26 globular clusters around the Large Magellanic Cloud, the Small Magellanic Cloud and Fornax galaxies. Preliminary results show that some clusters show intermediate central surface brightness slopes like those observed in galactic clusters.

Close analysis of a heavily smoothed U-band WFPC2 image for the galactic cluster M15 reveals flattening of the light distribution in the central 4 arcseconds. The three-dimensional velocity distribution of stars inside the same region shows a 6 km/sec rotation. The rotation axis PA coincides with the minor axis PA of the ellipse in the light distribution. The major axis PA for this central region is different from the major axis PA measured at large radii, which suggests the presence of a decoupled core at the center of M15.

The detection of shallow surface brightness cusps as well as what appears to be a decoupled core in globular clusters suggest that relaxation processes alone cannot explain their current dynamical structure. Interesting processes seem to be taking place at the center of some globular clusters.

[1] The University of Texas at Austin.

PARSEC-SCALE POLARIZATION STRUCTURE IN LOBE-DOMINATED QUASARS

Erin Perez,[1] Renan Moreira,[1,2] Christian Aars,[1,3] and David Hough[1]

Polarization-sensitive imaging is a powerful tool for exploring the magnetic field structures in parsec-scale radio jets and their environment. Many previous studies have focused on the brightest compact radio sources, which results in strong orientation bias due to beaming of their relativistic jets near our line of sight.

Relativistic jet models predict that many source properties will be strong functions of orientation angle. To minimize orientation bias, we have selected two samples of lobe-dominated quasars on the basis of their extended, unbeamed emission. The samples are drawn from the 3CR and Jodrell Bank surveys, and total about 50 objects (Aars & Hough 2005). To date, we have completed multi-frequency polarization VLBA imaging of 15 objects at 5, 8, and 15 GHz. Nine sources show clear polarization structure in their parsec-scale jets, with a strong tendency for transverse polarization, indicative of a longitudinal magnetic field component in the jets. The distribution of fractional polarization is consistent with Lorentz factors 5 or greater, and suggests that the ratio of uniform to random magnetic field components does not exceed unity. Faraday rotation is observed in seven sources, and shows a definite change of sign in several cases. Further studies are under way to determine the implications of this result for models of the magnetic field configuration in the ionized medium surrounding the jets.

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MID-IR STUDY OF UCHII REGION G29.96-0.02

Qing-Feng Zhu[1] and John Lacy[1]

Ultra-compact HII (UCHII) regions are small (0.1 pc), dense (Ne $\geq 10^4$ cm^{-3}) ionized regions. The classical Strömgren model of HII regions predicts that UCHII regions are short-lived (Dyson & Williams, 1980). However, observations contradict the prediction and call for models to explain both the one order of magnitude longer lifetime and the morphologies of UCHII regions (Wood & Churchwell 1989; Kurtz et al. 1994).

The bow shock model proposes that a cometary UCHII region forms when a massive star with a wind moves supersonically through a uniform density molecular cloud, and swept-up material is forced to flow along a shell in front of the star. (Mac Low et al. 1991). Wilkin (1996) developed an analytical solution for the shell.

We present our high resolution mid-infrared fine structure line observations of a cometary UCHII region - G29.96-0.02. We map the region at [Ne II] 12.8μm, [Ar III] 8.99μm, [S III] 18.7μm, [S IV] 10.51μm, Hua 12.3μm with the Texas Echelon Cross Echelle Spectrograph (TEXES) on the NASA IRTF 3-m infrared telescope at Mauna Kea, Hawaii. Our 4 km s$^-1$ resolution observations show that unique kinematics are present in the UCHII region.

Using an iteration approach, we examine the bow shock model and investigate the acceleration effect of the pressure gradient along the shell. Modeling results show that the morphology and kinematical features seen in G29.96-0.02 are the natural results of a stellar wind supported bow shock. The pressure gradient along the shock front accelerates gas to a speed higher than the value predicted by Wilkin's theory.

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