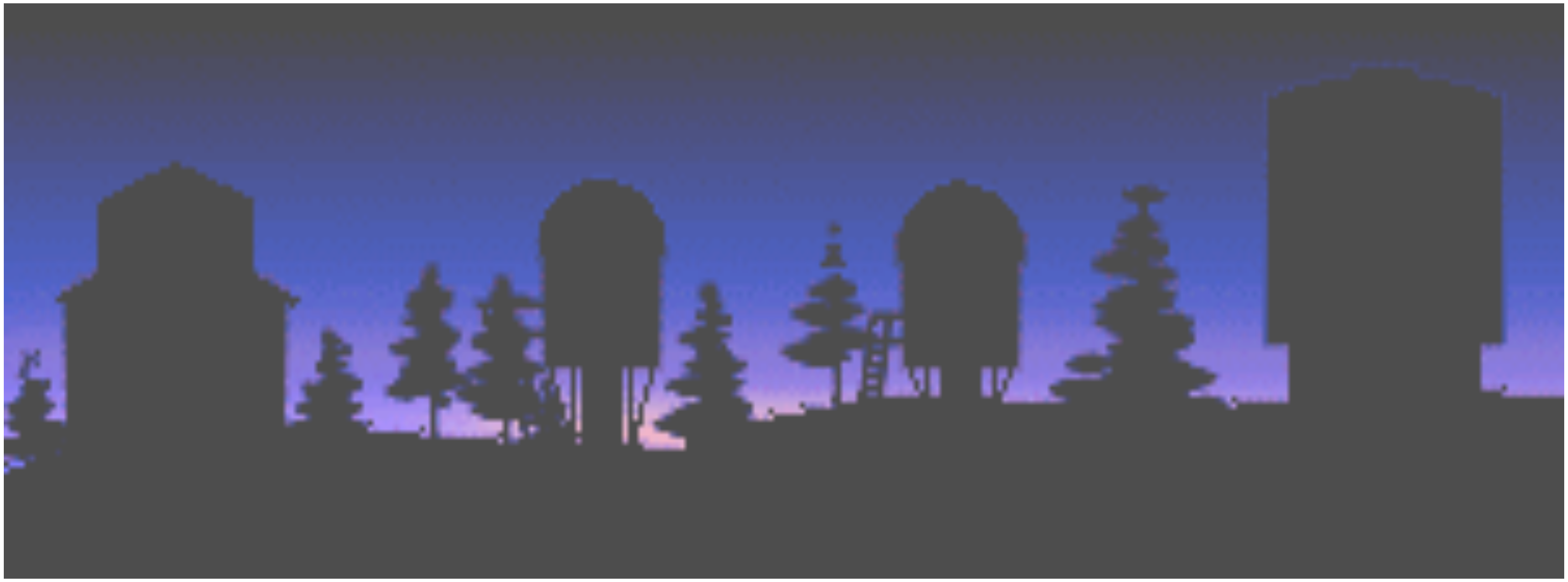


ARC 3.5-meter Telescope
Apache Point Observatory
Selected Science Highlights 2007-2011

3.5 m Ariel Occultation Observation Results

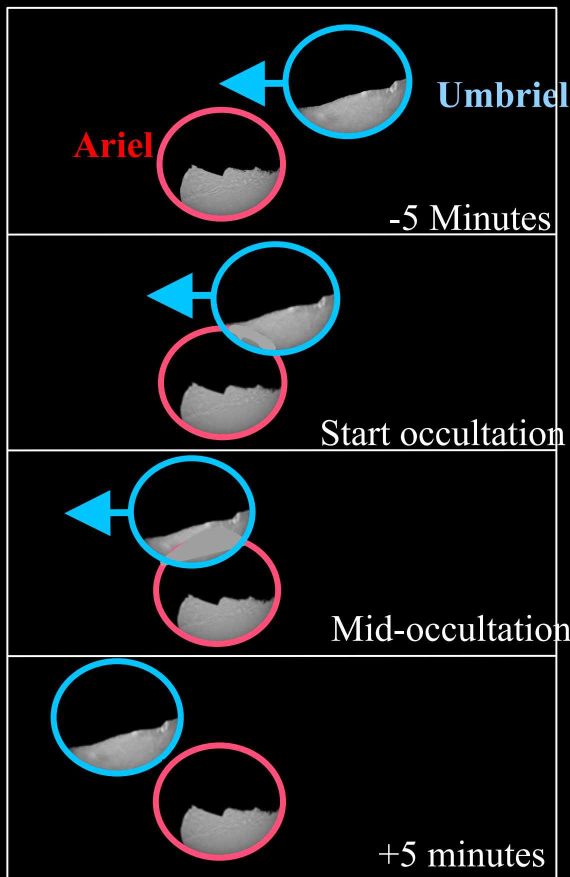
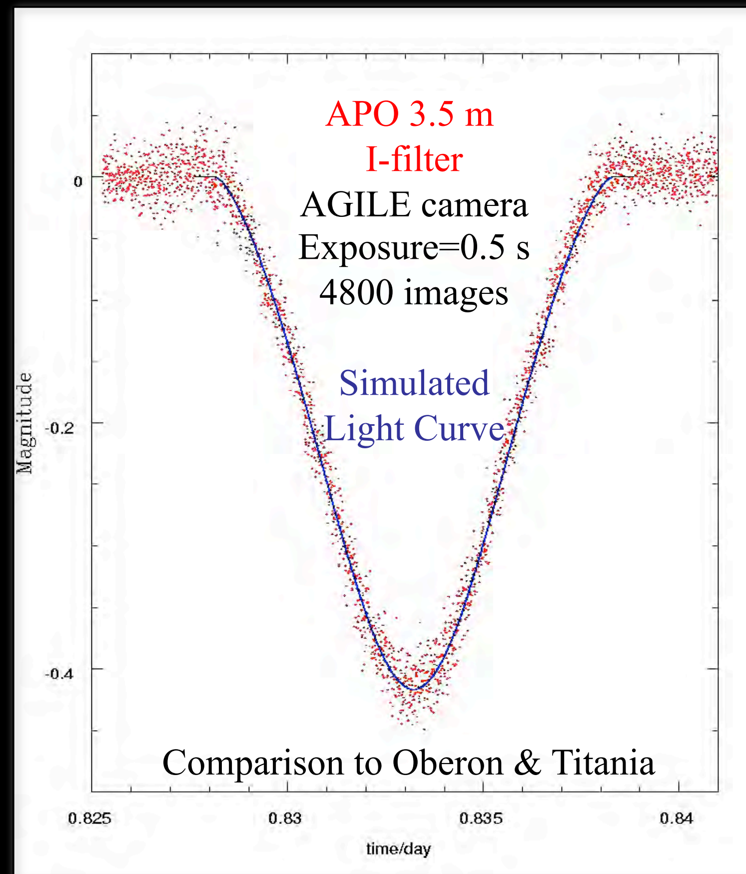


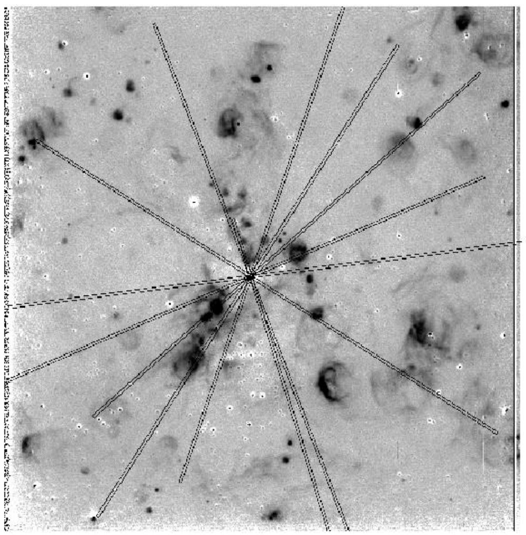
Illustration of Ariel partial occultation by Umbriel. Dark regions represent area not mapped by Voyager 2. Images from the JPL Solar System Simulator.

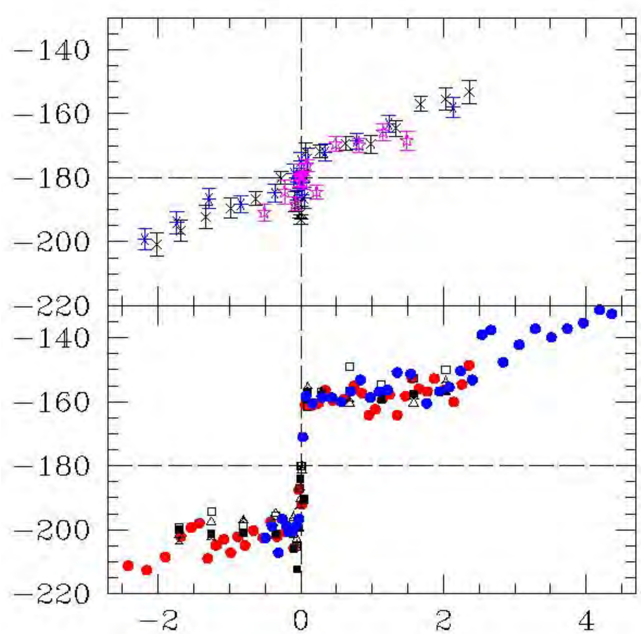


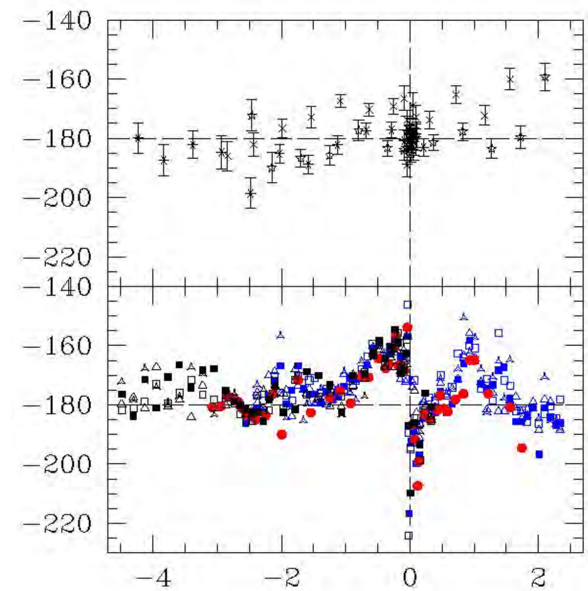
Data from observations with the APO 3.5m telescope of the Ariel partial occultation by Umbriel on Aug-19. Plot shows normalized differential magnitude of Ariel/Umbriel to reference moons Oberon and Titania at 0.5 second intervals. The blue line is the result of a simulated light curve of the event. [text by Chas Miller]

Kinematic evidence for a stellar bar in M33 from 3.5m spectroscopy

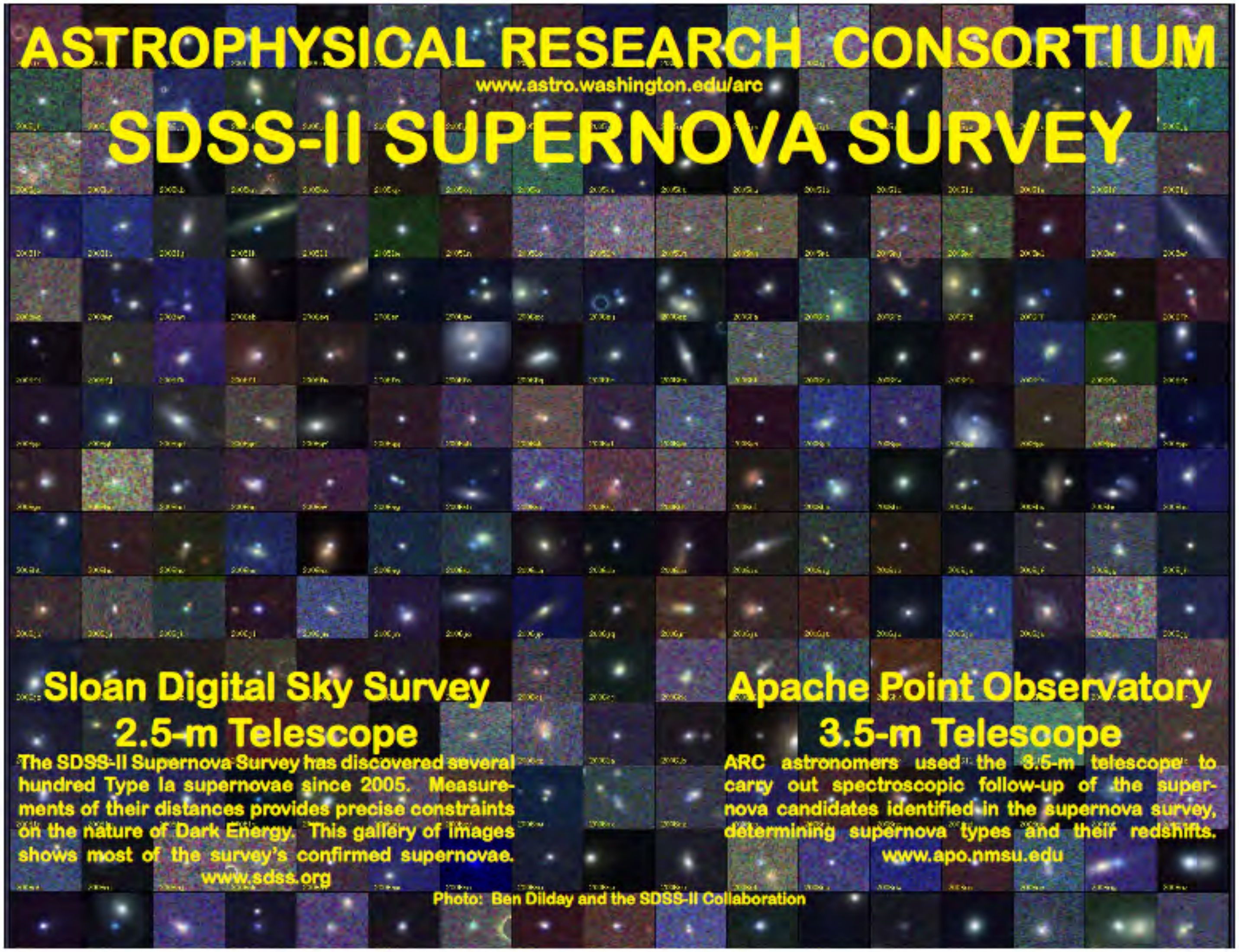
R. Walterbos (NMSU), E. Corbelli (Arcetri Observatory)



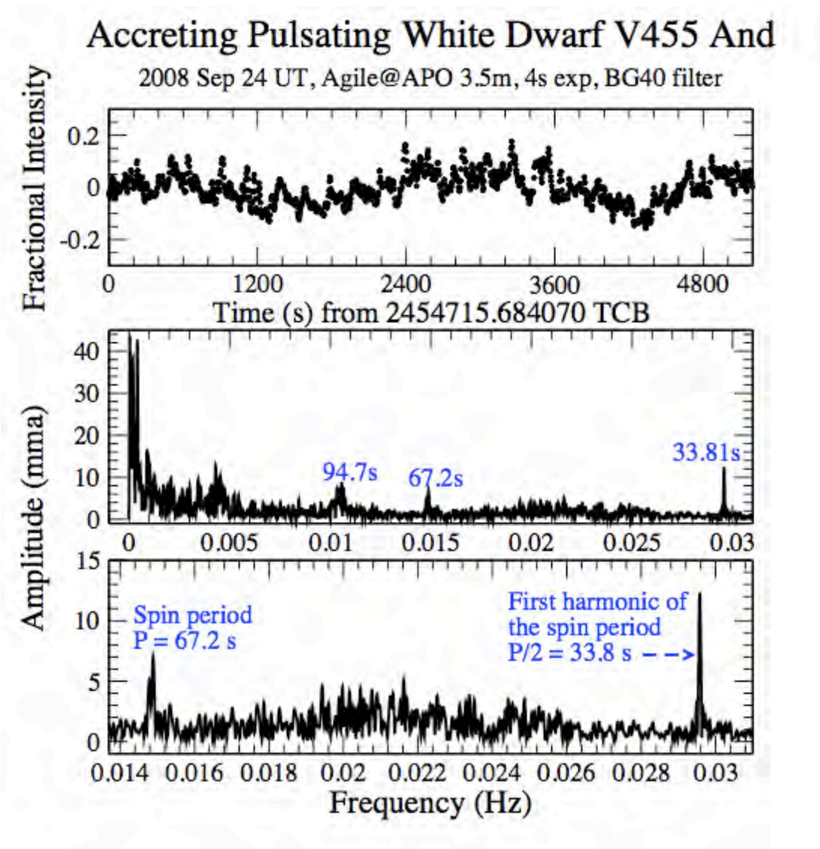




- SPIcam H-alpha image (left) of inner region in Local Group spiral M33, with spectroscopic slit positions that were observed with DIS shown.
- Major axis (middle) and minor axis(right) stellar (top) and ionized gas velocities (bottom) observed with DIS. Velocity patterns consistent with weak bar in M33, not with purely circular rotation. The bar's position angle is close to that of the minor axis.
- With M33 included as well, all major Local Group galaxies have a bar.

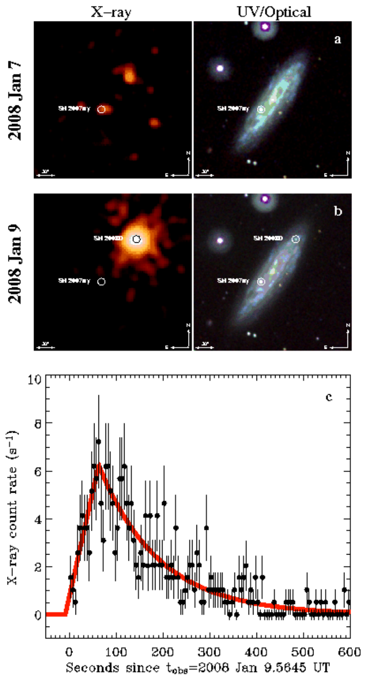


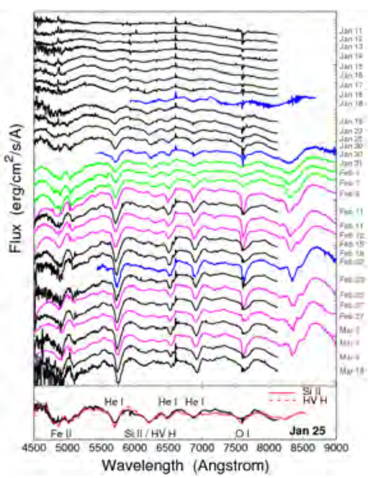
The ARC 3.5-m with the DIS spectrograph has been used to obtain spectroscopic confirmation and redshift determination for over 150 supernovae (and/or their host galaxies)discovered by the SDSS in the Fall months of 2005, 2006, and 2007. [text by Josh Frieman]



The figure shows a cataclysmic variable V455 And a year after it underwent an outburst. The white dwarf was a non-radial pulsator prior to the outburst. The outburst heated the white dwarf, thus causing the pulsations to cease. Several groups are monitoring this star to watch for when the white dwarf cools sufficiently for pulsations to return to the white dwarf. The time-series photometry acquired using the high-speed photometer Agile at the 3.5-m telescope shows several periodicities present in the light curve of this star. We clearly identify the spin period of the star at 67s along with the first harmonic. The peak evident close to 95s may perhaps be suggestive of pulsations, but this requires further investigation. [from Anjum Mukadam]

Target of Opportunity observations of SN 2008D





In the four years since it's launch, the Swift satellite has discovered hundreds of long-duration gamma-ray bursts (GRBs): a rare class of massive star explosion intimately related to supernovae but 1000 times less common and orders of magnitude more powerful. The rapid follow-up of GRBs enabled by Swift's prompt triggering and localization capability has revolutionized our understanding of these extraordinary explosions. Lacking the prompt gamma-ray pulse of GRBs, ordinary supernovae are invariably discovered by their optical emission which only reaches peak brightness several weeks after the explosion. In fact, by the time most supernovae are discovered, most of the fireworks are already over. Therefore, with the exception of a few neutrinos from SN 1987A, we lack an understanding of the first minutes, hours, and days in the evolution of supernovae.

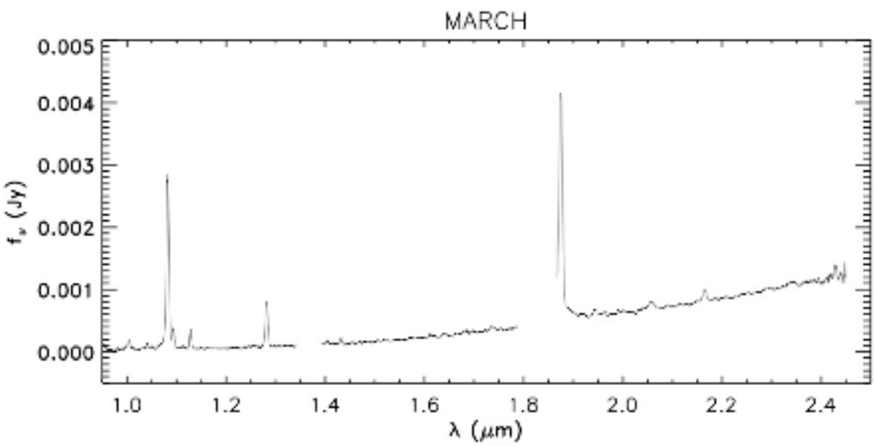
All of this changed on January 9 of this year. During my brief observation with Swift's on-board X-ray Telescope (XRT) of a supernova in nearby galaxy, NGC 2770 (d=27 Mpc), another star in the same galaxy exploded. The explosion was marked by an extremely luminous but fleeting burst of X-rays, L_X=10^44 erg/s, lasting just a few minutes.

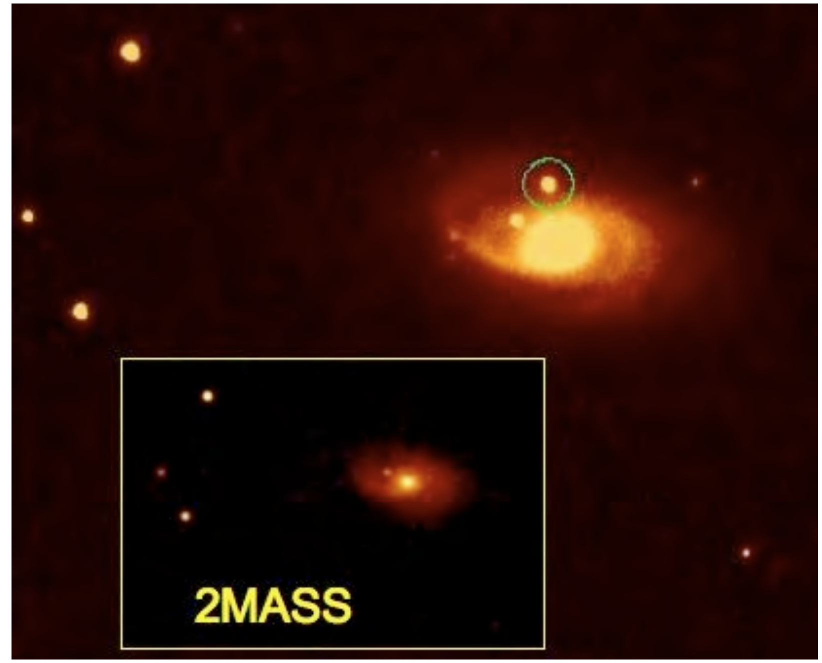
Thanks to our prompt notification, telescopes around the globe quickly slewed in the direction of NGC 2770, anxious to uncover the nature of the enormous X-ray outburst. Within just a day, we discovered an optical counterpart and through optical spectroscopy we found the tell-tale signature of a brand new supernova, dubbed SN 2008D. The response timescale and breadth of these observations exceed even those of SN 1987A, known for years as the best studied supernova in history.

With its flexible remote observing capability and well-structured Director's Discretionary Time allocation program, the ARC APO 3.5-m played a key role in the ensuing follow-up, enabling nearly daily spectroscopic monitoring of SN 2008D in the days, weeks, and months that followed. Through these observations, we were able to show that SN 2008D was a perfectly ordinary supernova, simply observed earlier than any other SN to date. In this context, the observed X-ray pulse can be fully understood as the fabled shock breakout emission, a long-predicted SN signal that has never been seen, until now.

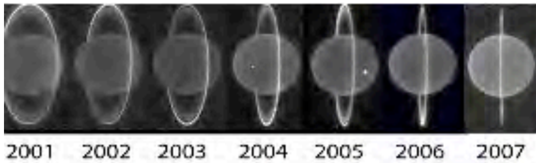
This leads to the exciting conclusion that we can expect all ordinary supernovae to produce a similarly spectacular X-ray outburst at the time of explosion. These outbursts serve as an early warning beacons to enable follow-up from ground based facilities such as the APO 3.5-m. Looking forward, the field of supernova discovery and study is on the brink of a paradigm shift -- with more powerful X-ray satellites being designed now, we predict that hundreds of supernovae will be discovered each year in the act of exploding, thanks to their powerful X-ray outbursts. These early beacons are essential to search for coincident neutrino and gravitational wave searches which have not been possible until now but which hold the key to unraveling the mysteries of the SN explosion mechanism.
[contributed by Alicia Soderberg]

TripleSpec observations of SN 2005ip





For the past three years, SN 2005ip has remained incredibly bright in the infrared. The evolution of this supernova is quite unique, considering most supernovae dim sufficiently within a few months. UVa grad student Ori Fox, who is part of the team that built TripleSpec, made the discovery with UVa's local, homegrown infrared imager, FanCam, at Fan Mountain Observatory, just outside Charlottesville, VA. Optical spectra identify the supernova as a Type IIn event, where the 'n' refers to the narrow H-alpha line that arises from a dense, preexisting circumstellar medium (CSM) that is excited by the peak supernova luminosity. Fox et al. (2008) believe that new dust may be condensing in the cold, dense shell that forms in between the forward and reverse shocks as the ejecta plow into the dense CSM. Recent APO/TripleSpec near-infrared spectra will reveal further information. The left figure shows a sample spectrum from March, 2008, where the dust continuum and several spectral lines are clearly visible. These data will provide tighter constraints concerning the nature of the dust, such as temperature and composition. Supernovae have long been considered as possible dust sources, but limited direct evidence of dust formation exist. Considering Type IIn events comprise no more than 5% of supernovae, this is an incredible opportunity to study the possibility of supernovae as sources of dust in our universe. [provided by Ori Fox]



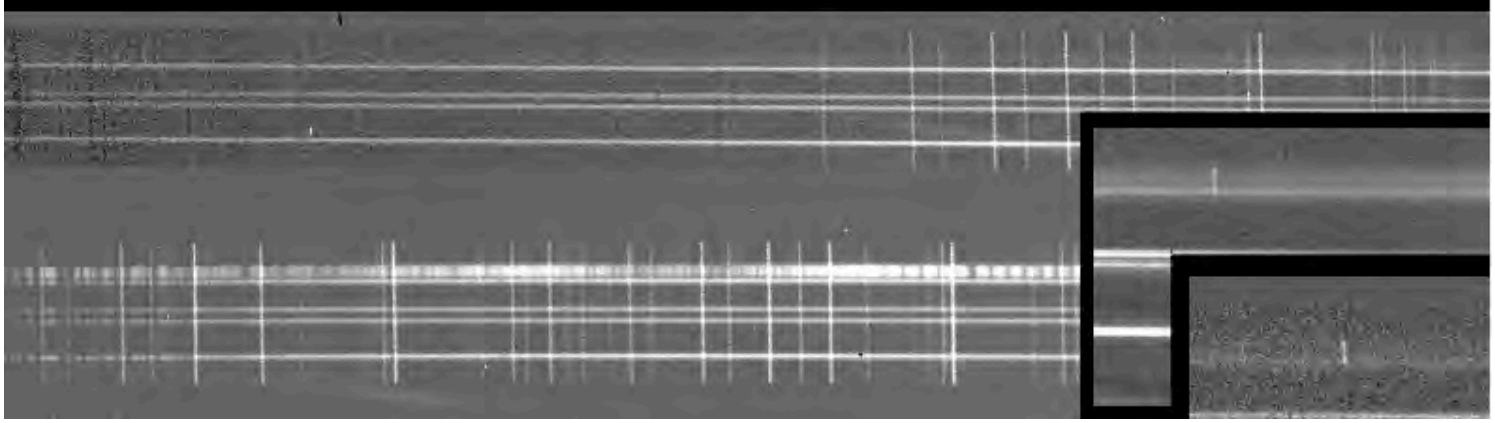
de Pater/Hammel (Keck)

TripleSpec in Application: Uranian System (Verbiscer and Skrutskie, UVa, Oct 17 UT)

Currently Uranus is located near ring plane crossing, concentrating the ring flux in the spectrograph slit.

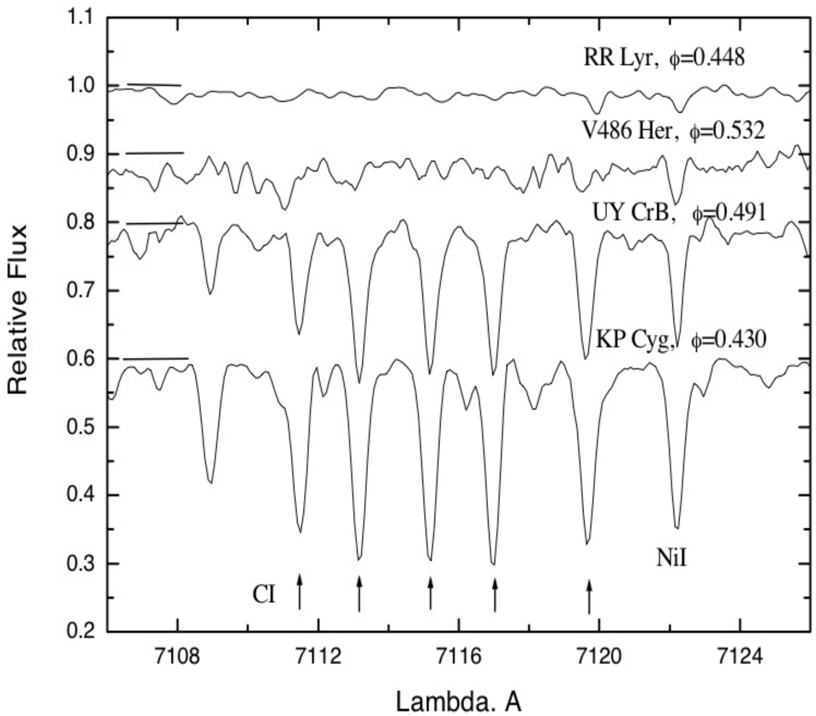
The satellite orbits are also on edge at this time permitting the observation of planet, rings, and satellites in one TripleSpec slit.

Below is the H and K band spectral orders obtained with the view at left in the slit. The planetary atmospheric spectrum is spatially resolved. High SNR spectra of Titania, Umbriel, Ariel, and Oberon are obtained simultaneously. Auroral emission from molecular hydrogen and H3+ is visible in the K-band (inset). The exposure time was 240s.



[provided by Mike Skrutskie]

Tracing Carbon Production in the Helium Flash

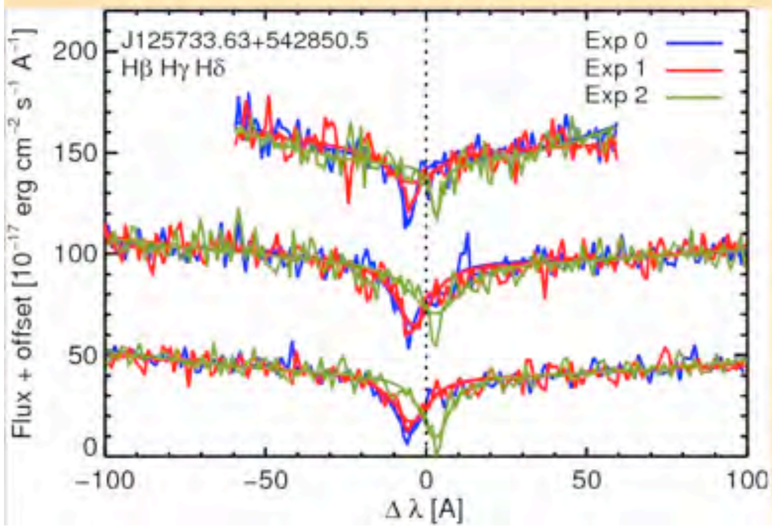


George Wallerstein, together with V.V. Kovtyukh and S.M. Andrievsky of Odessa University, Ukraine, have analyzed the chemical composition of 12 RR Lyrae stars from APO 3.5m Echelle spectra. They have found substantial excesses of carbon in the more metal-rich stars of their sample. This indicates that significant amounts of carbon were produced by the triple-alpha reaction which convected to the surface of these stars during the helium flash, an event that initiates the evolution from the red-giant tip to the horizontal branch.

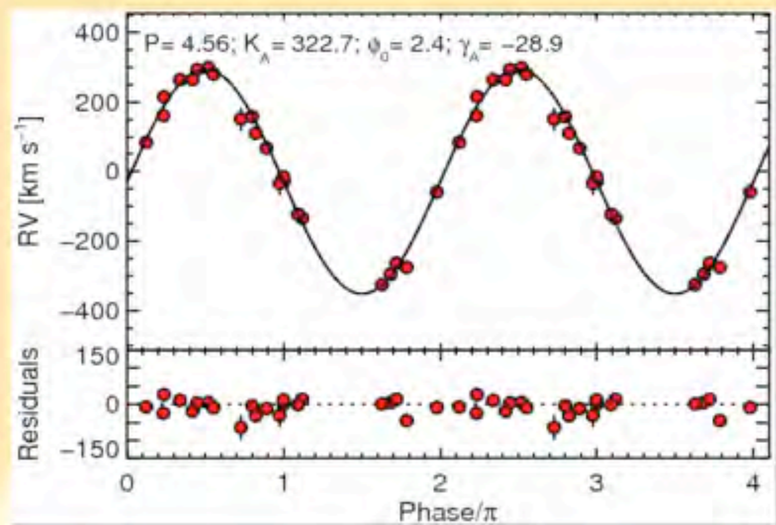
Searching for Type 1a Supernova progenitors in SDSS Short period Double Degnerate White Dwarf systems

Fergal Mullally, Carles Badenes, Susan E. Thompson, Robert Lupton

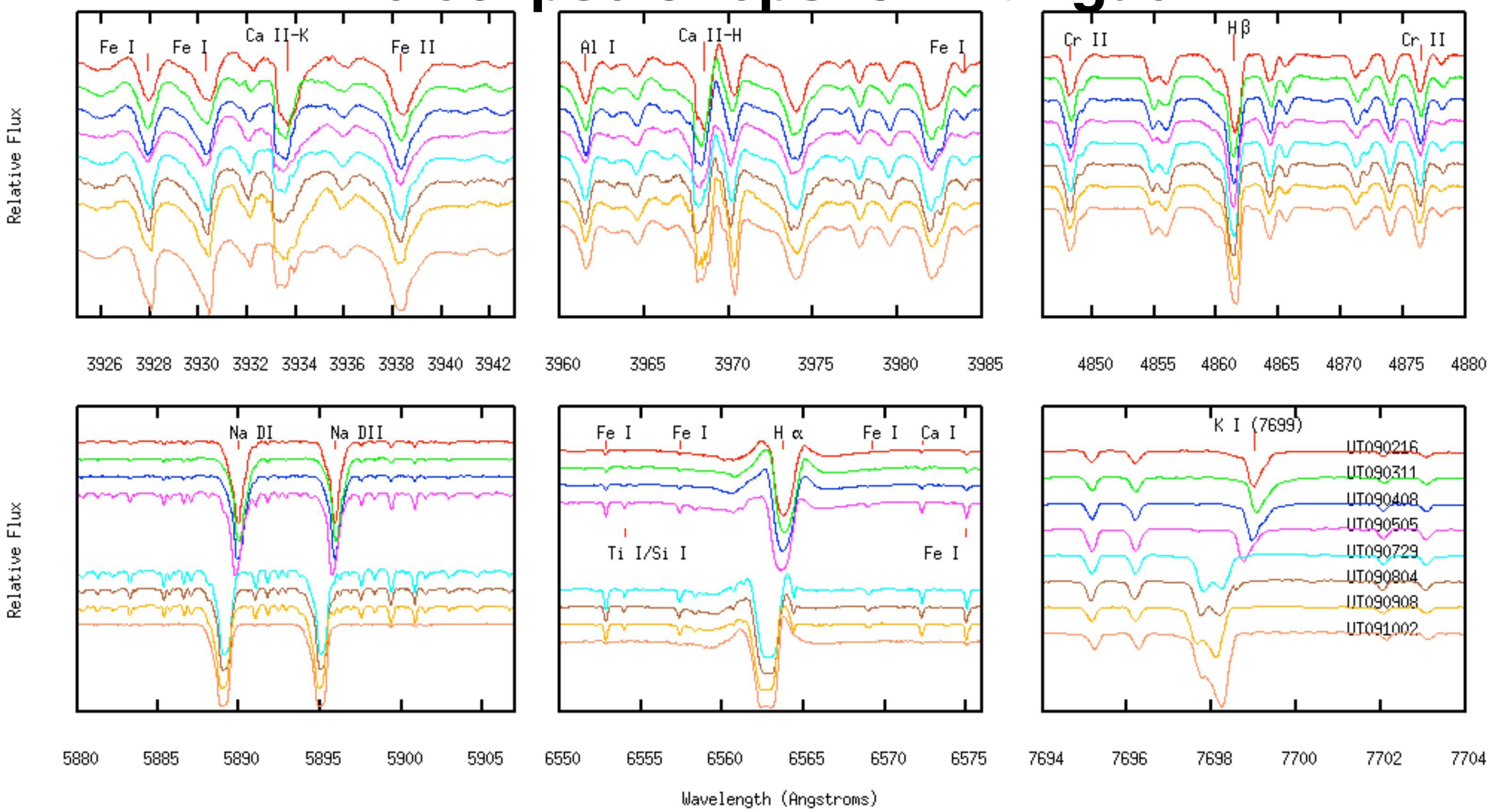
Individual exposues that make up an SDSS spectroscopic plate mined for WD binaries with periods $\lesssim$ 5hrs



Follow-up radial velocity observations with DIS at APO 3.5m confirm binary nature and measure orbital parameters



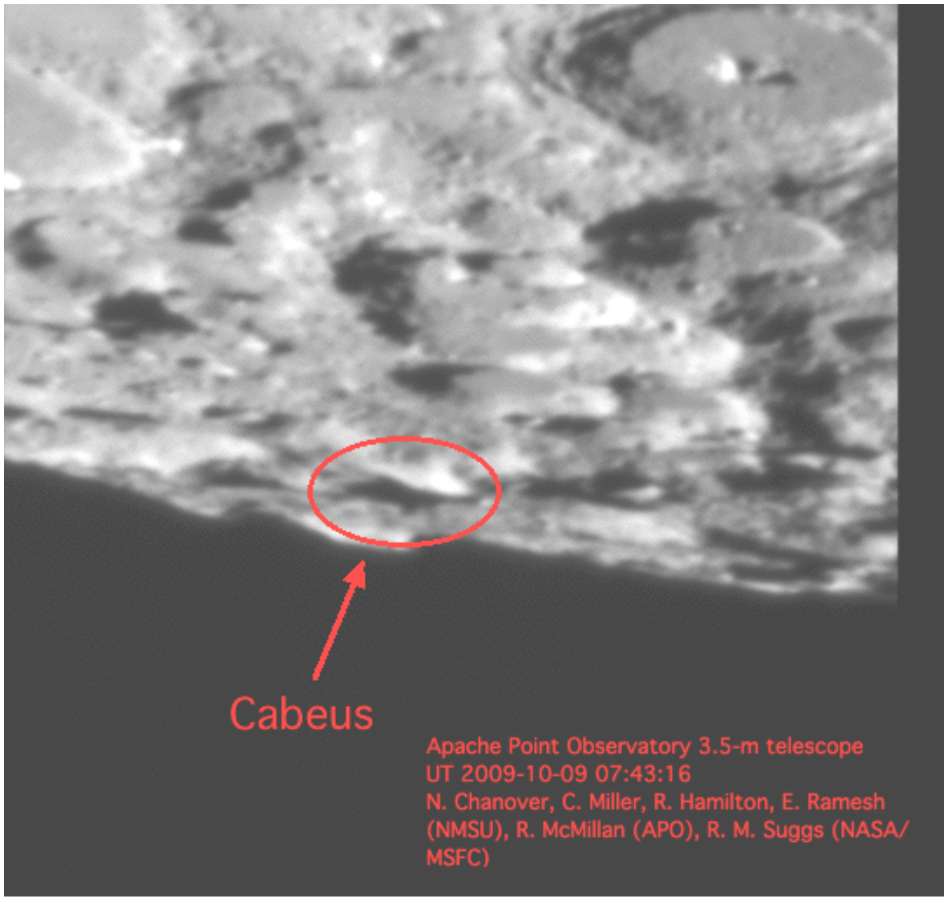
First results of a several year program to monitor the eclipse of epsilon Aurigae



Spectral Monitoring of the Long Period Eclipsing Binary Epsilon Aurigae (B. Ketzeback, J. Barentine, R. McMillan, J. Dembicky, G. Saurage, J. Huehnerhoff, J. Coughlin, S. Schmidt, S. Hawley, G. Wallerstein)

Earlier this year, we started a regular monitoring program of the 27.1 year period eclipsing binary system, Epsilon Aurigae, on the 3.5-m using both ARCES and Triplespec. Epsilon Aurigae, consists of a primary, pulsating F supergiant star and its secondary, an enormous, cool, spectrally grey disk. Although this system has been studied for more than a century little is known about the secondary component. We present a small sample of the lines we are monitoring through the eclipse spaced out at a cadence of one measurement per month. Many strong lines, such as those in the bottom 3 plots, show a blue shift (-40 km/s) after the start of first contact even though the photospheric lines continue to line up. The changing intensity seen in the photospheric lines are likely due to the pulsating nature of the primary and vary with Teff. The start of this 700 day long eclipse was observed early to mid-June, 2009, as seen in the double valued absorption of KI (7699A). Full eclipse is expected to start at the end of this calendar year. Egress is expected sometime in quarter two of 2011. [text by Bill Ketzeback]

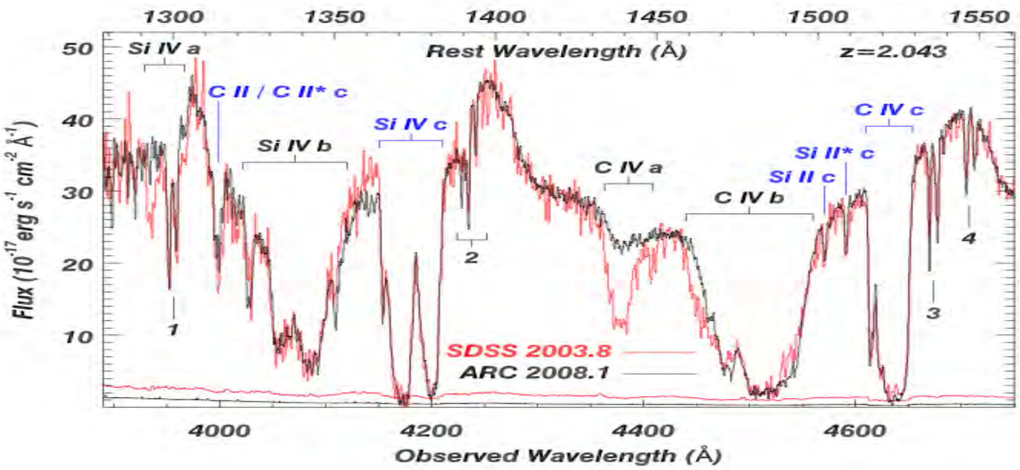
3.5m imaging to support LCROSS mission



Agile image of impact location

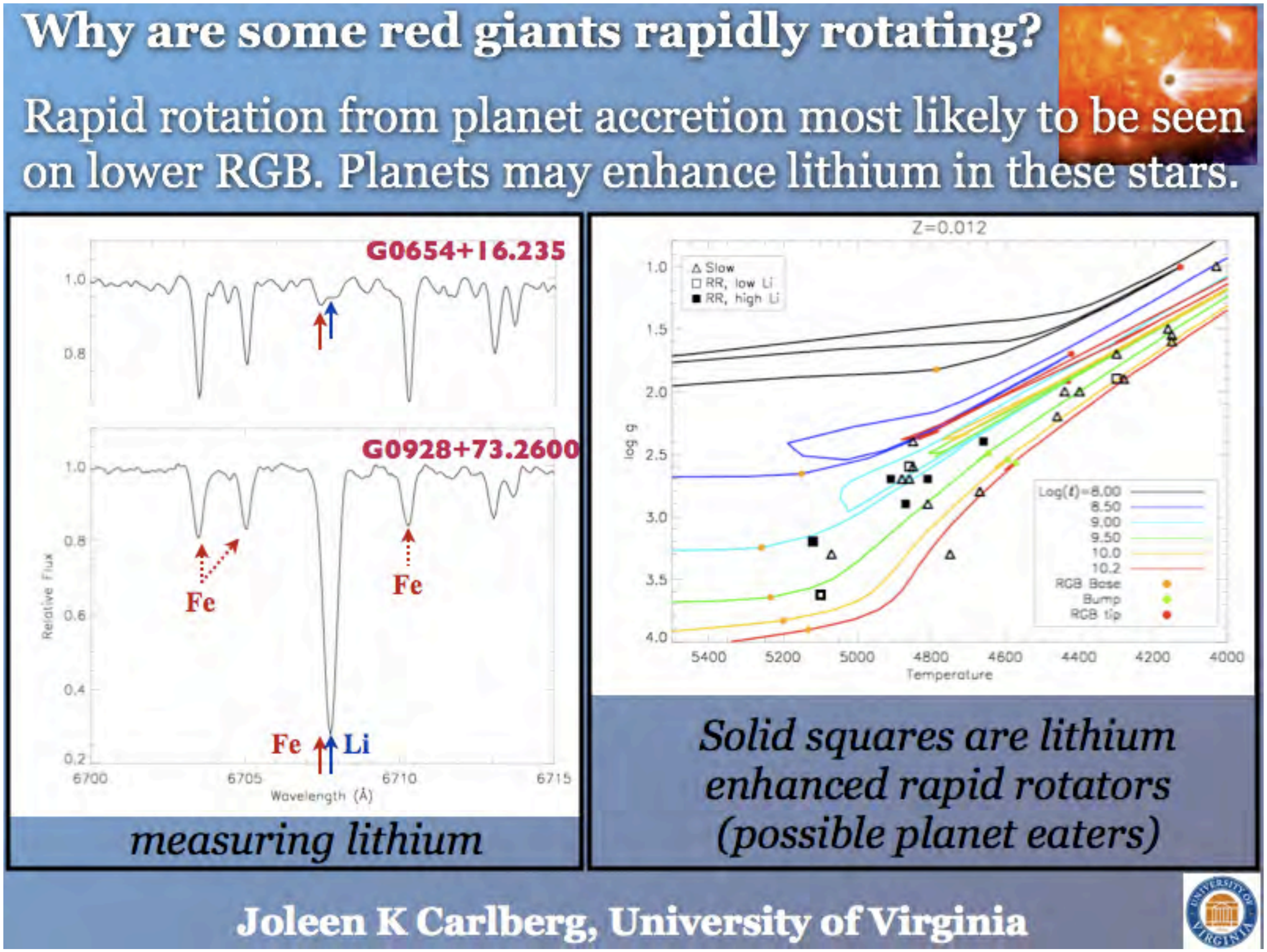
- Agile images acquired in support of LCROSS impacts on 09 October 2009.
- Telescope and instrument performed flawlessly.
- A quick-look at the data did not reveal the impact plume, but more detailed analysis is underway.
- The APO results were prominently featured in the post-impact press conference.

APO 3.5m DIS observations of QSO outflows



- Figure 1 compares the blue portion of the spectrum of QSO SDSS J0838+2955 from the SDSS data (red) taken in late 2003 to the ARC DIS data (black) taken in early 2008. The three separate outflow components at 22,000, 13,000, and 4,900 km/s are labeled "a" (note obvious variability in C~IV line), "b", and "c", while the narrow, most likely intervening systems are labeled 1-4. The presence of resonance Si II and metastable Si II* in component "c", along with the superior spectral resolution and S/N ratio of the ARC spectrum, allowed us to determine the electron number density to be ~5000 cm^-3 for that component. With the number density now known, photoionization analysis constrains the outflow to be located ~3.3 kpc from the cental AGN and moving with a kinetic luminosity of ~5x10^45 erg/s, which is ~2% the bolometric luminosity of the QSO itself. Such a large kinetic luminosity suggests that QSO outflows are a major contributor to AGN feedback mechanisms. For full details, see Moe et al. 2009 ApJ, in press.

APO 3.5m echelle observations of red giants

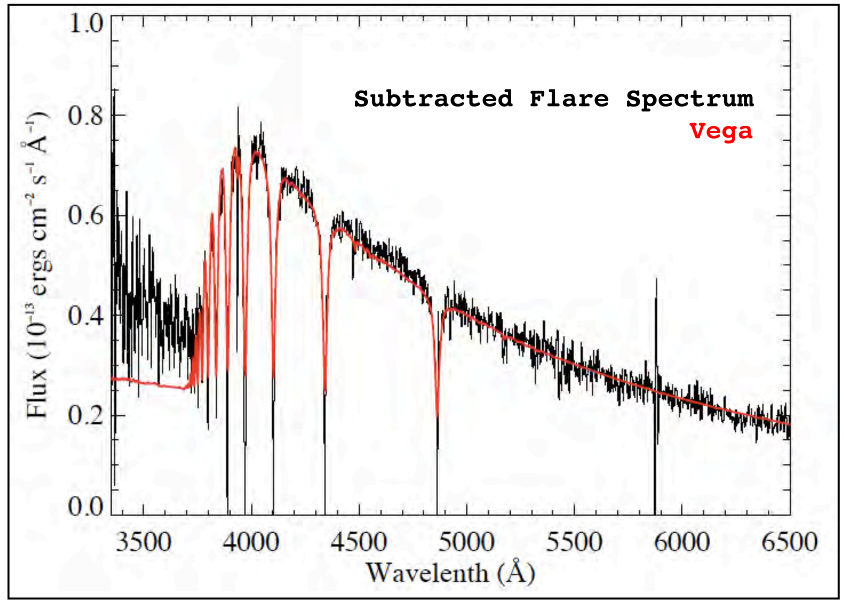


Observing Flare Stars at APO

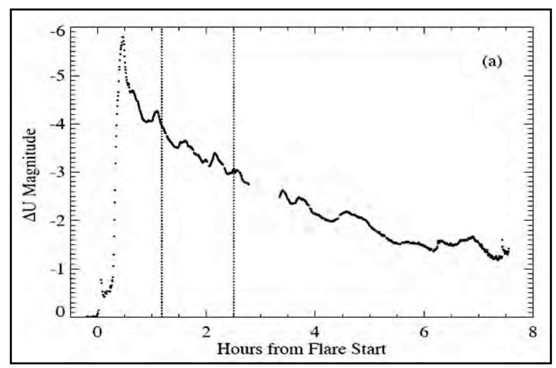
A. Kowalski, S. Hawley

- **A tiny A star appears on an M star during a flare within a flare**

- On UT 2009 Jan 16, we obtained time-resolved spectra with the ARC 3.5m/DIS (B400+R300) during the decay of an incredible flare on the dM4.5e YZ CMi (Kowalski et al 2010, ApJL). The flare produced a change of nearly 6 mags during the peak in the U band (above left). During the decay, several secondary flares occurred; we show the emission from the rise phase of one of these secondary flares in the above (right) figure. The spectral characteristics are similar to the A0 V star Vega, with the Hydrogen lines and Balmer continuum in absorption. This spectrum and initial modeling results were presented at the Canfield-fest Solar Physics conference, IAU Symposium 273, and at Cool Stars 16.



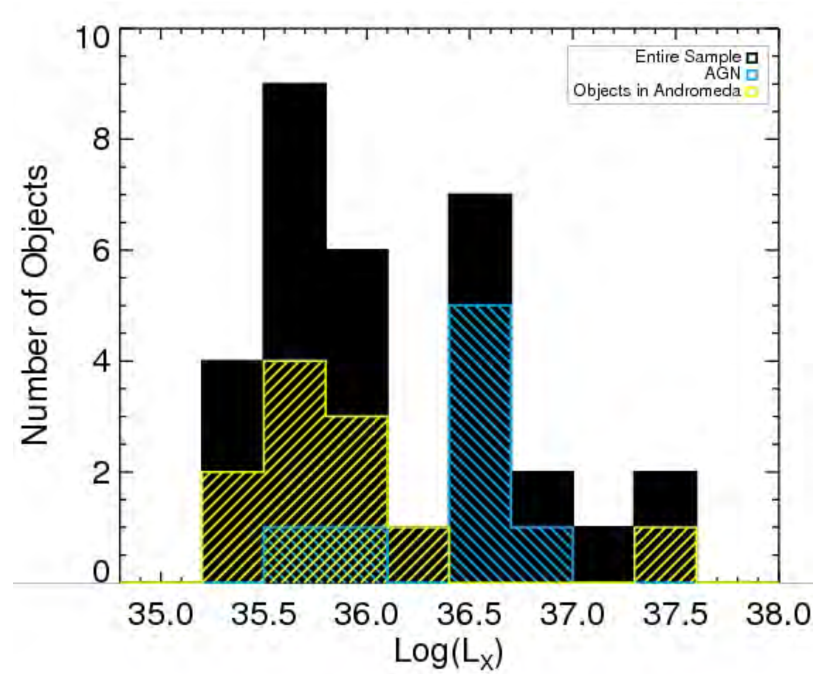
The YZ CMi "Megaflare" U band data; NMSU 1m



APO 3.5m DIS Spectra of Xray sources in M31

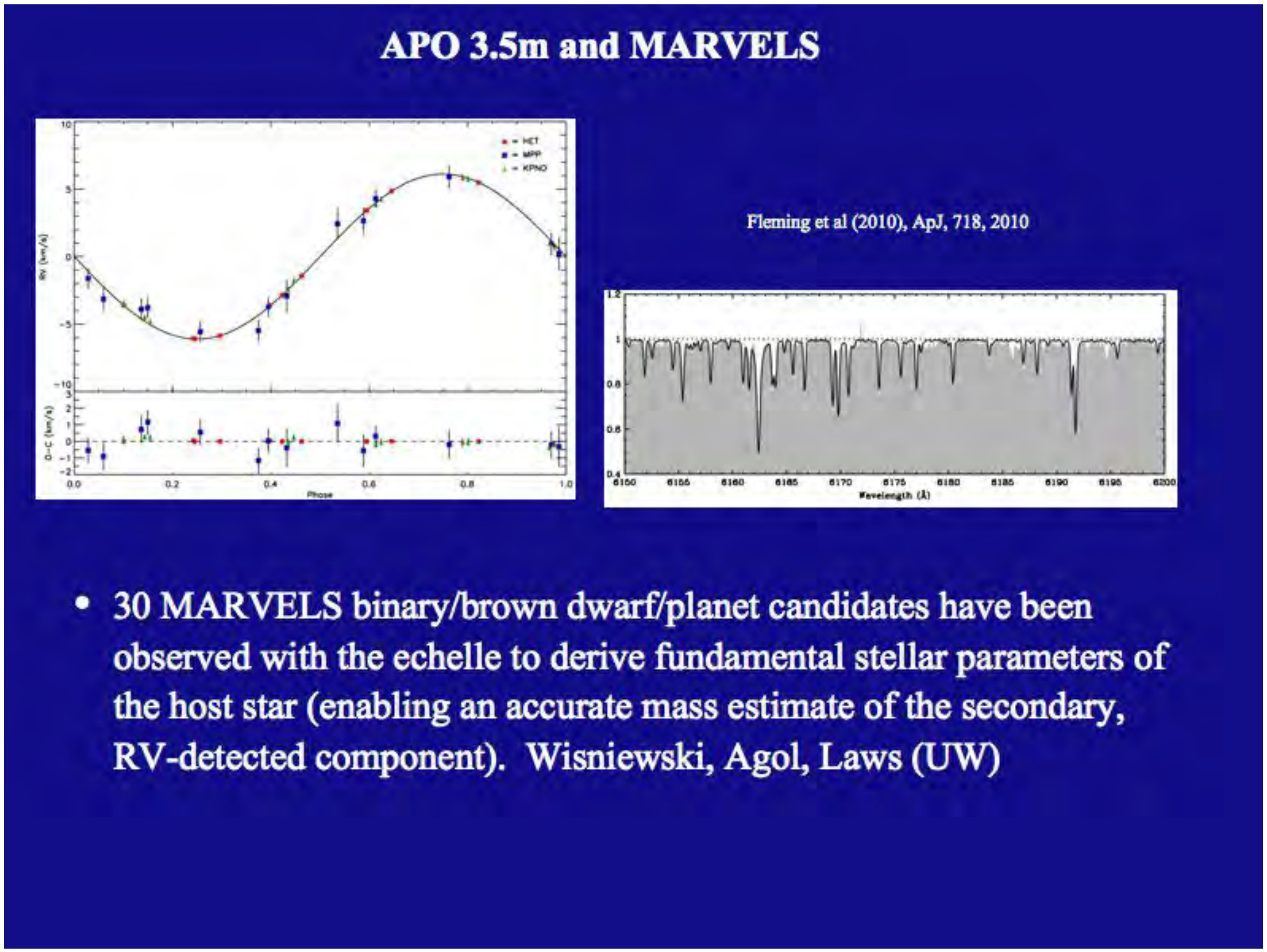
Jerica Green and Ben Williams

- Plot of X-ray sources in M31 we have observed with DIS on APO. It shows, somewhat unexpectedly, that many of the higher X-ray flux sources spatially coincident with the M31 disk are actually background AGN, while more of the fainter ones are turning out to be in M31.



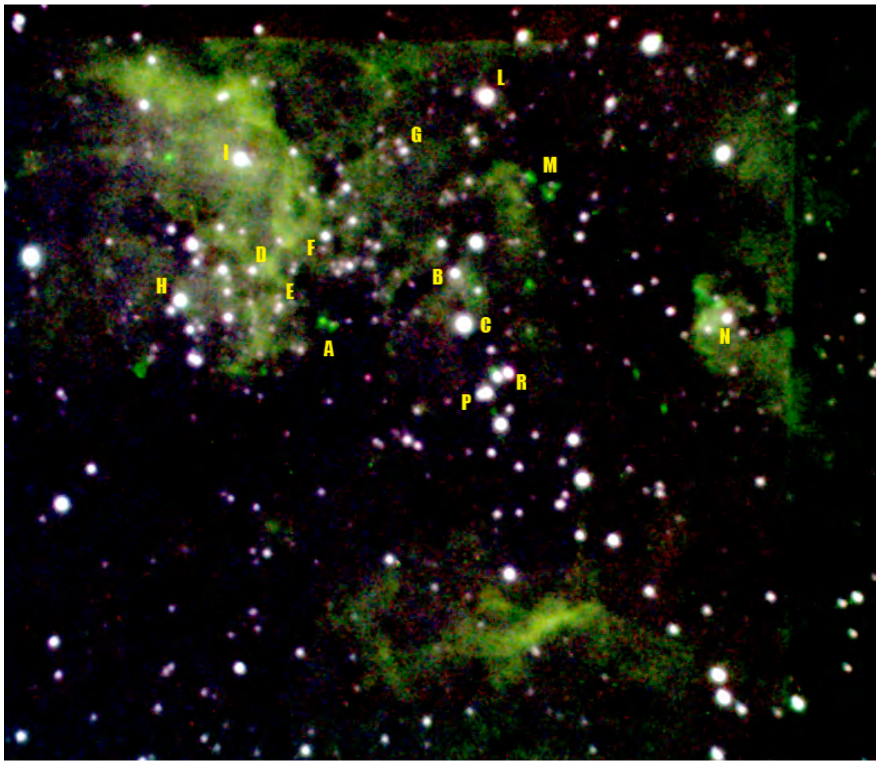
APO 3.5m echelle observations of MARVELS stars

John Wisniewski, Chris Laws and Eric Agol



Protostar outflows imaged with APO 3.5m and NICFPS

Wolf-Chase, Smutko, Sherman, Harper, & Medford



We are preparing a paper for publication that reports the discovery of a bipolar shocked molecular hydrogen outflow from a massive protostar using NICFPS on the 3.5-m. We confirmed the outflow nature of this emission with subsequent CARMA observations. What makes this discovery significant is that few (if any) massive protostars have 2.12 micron detections because these objects are so highly extincted. Implications are that this is a very luminous outflow, which has interesting implications for the earliest stages of massive star formation.

Figure 1.: This is a 3-color cropped NICFPS image of Mol 160 (IRAS23385+6053),roughly 3.5 X 3.5 arcminutes in extent. Objects that show up white are sources of near-infrared continuum emission; green nebulosity and knots represent H2 2.12 micron spectral line emission .Letters represents young stellar objects that are detected as point sources in theSpitzer24 micron MIPS band. For clarity, they are offset slightly from actual source positions, but most are not visible in near-infrared continuum emission. While much of the extended green emission comes from H2 fluorescence associated with Photo-Dissociation Regions (PDRs), the two bright blobs near source A indicate shocked emission associated with a compact bipolar outflow. Source A was previously confirmed as a massive protostar. Note the LACK of near-infrared continuum emission in the immediate vicinity of this object, suggesting high extinction toward this object.

Followup ARC 3.5m Observations of Lensing Arcs

Search for Strong Lensing Arcs in the SDSS

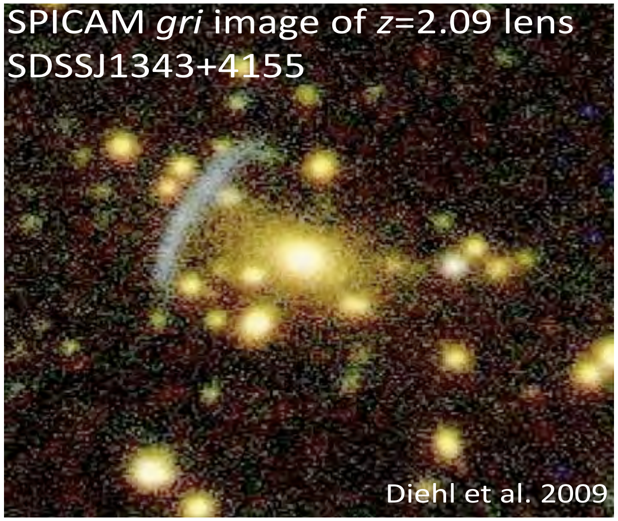
- Purpose: Use SPICAM *g*, *r*, *i* imaging and DIS-III spectroscopy to follow-up and confirm candidate group-scale lenses identified in the SDSS imaging data

- Participants: Josh Frieman (UC faculty sponsor), Sahar Allam, Liz Buckley-Geer, Tom Diehl, Dave Finley, Rich Kron, Donna Kubik, Jeff Kubo, Huan Lin, Douglas Tucker, and others

- Number of half-nights since October 2009: 13

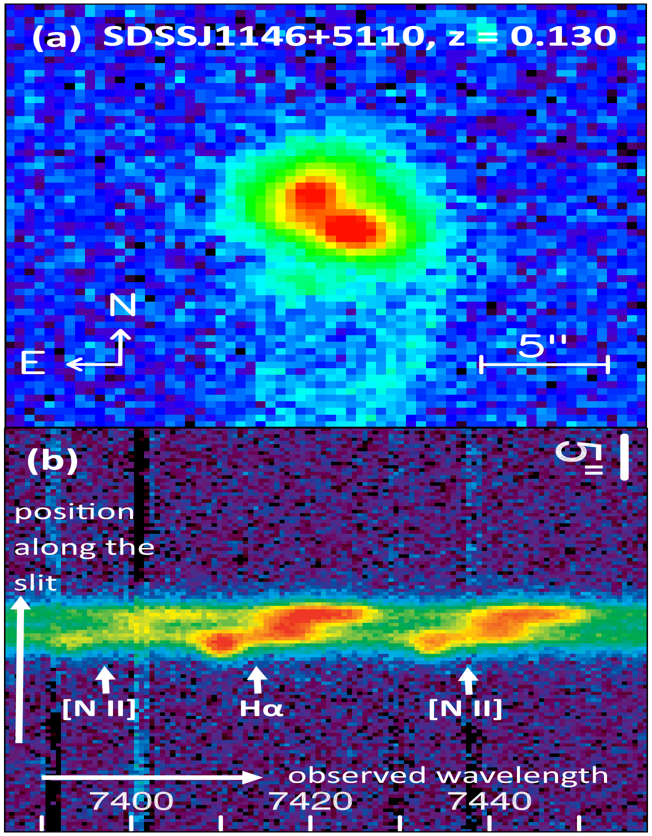
- Number of confirmed lenses: 20, of which 7 have been confirmed since October 2009

- Publications since October 2009:
  1. Diehl, Allam, Annis, et al. 2009, "The Sloan Bright Arcs Survey: Four Strongly Lensed Galaxies with Redshift > 2," *ApJ*, 707, 686
  2. Kubo, Allam, Annis, et al. 2010, "The Sloan Bright Arcs Survey: Discovery of Seven New Strongly Lensed Galaxies from $z = 0.66 - 2.94$" *ApJ Letters*, accepted for publication
  3. West, Diehl, Lin, et al. 2010, "Modeling of Two Strong Gravitational Lens Systems with z > 2," in preparation



Xin Liu, Yue Shen, Jenny Greene and Michael Strauss

kpc-scale Binary Active Galactic Nuclei (AGNs) Discovered by APO 3.5 m

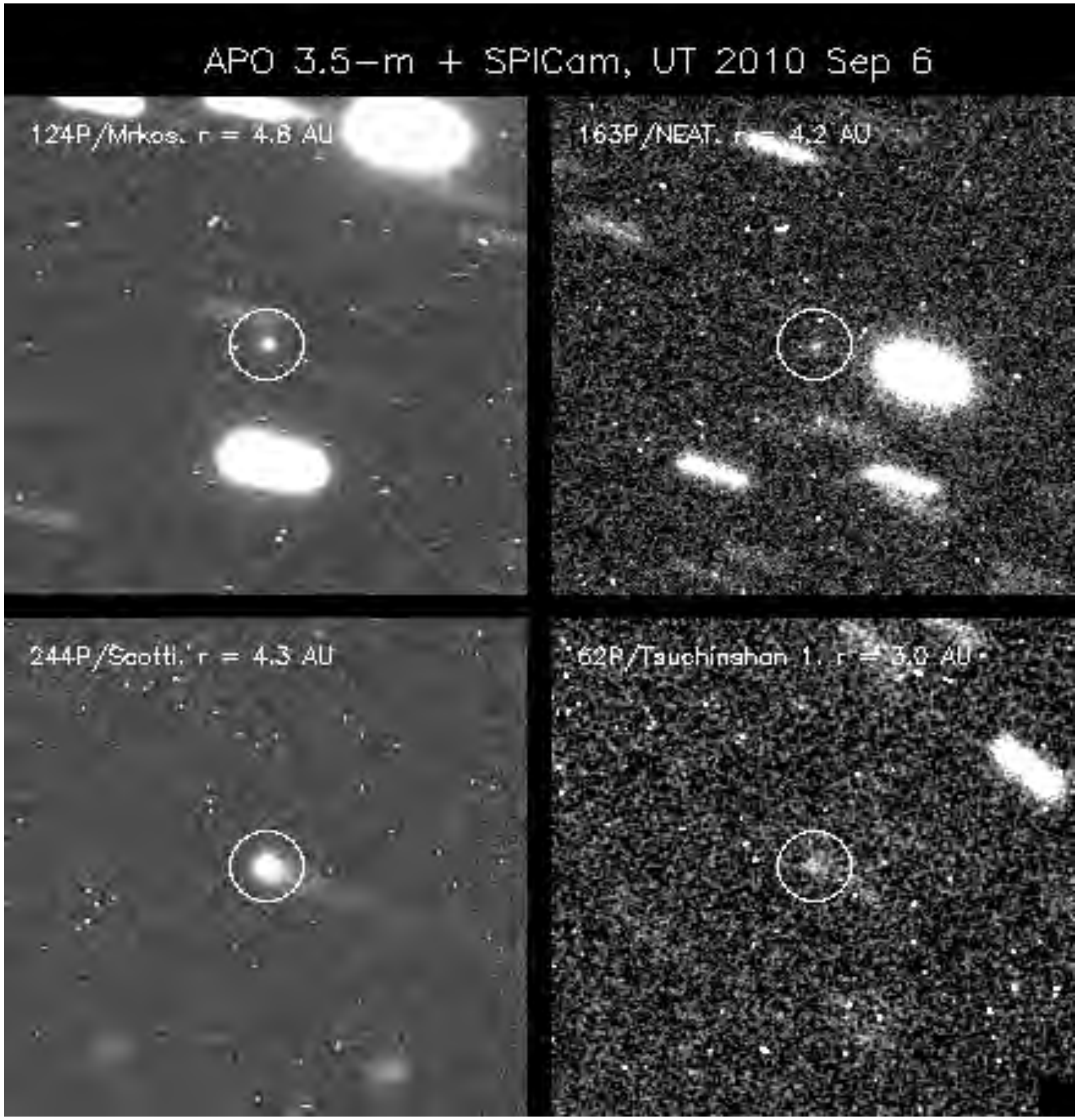


Background: Galaxies are thought to be built up hierarchically via mergers. Since most massive galaxies are believed to harbor a central SMBH, galaxy mergers would result in the formation of binary SMBHs. Despite decades of searching, and strong theoretical reasons to believe they exist, merging active supermassive black holes (SMBHs) remain difficult to find.

Unveiling Merging SMBH pairs from Double-Peaked Narrow-line AGNs: 1% AGNs show double-peaked narrow emission lines. The peculiar profile could result from pairing SMBHs in a galaxy merger, or could be due to bulk motions of narrow-line region gas around a single SMBH. Using deep images and spatially resolved spectroscopy conducted with the Magellan 6.5 m and the Apache Point Observatory 3.5 m telescopes, Liu et al. (2010) have discovered four SMBH pairs from 43 double-peaked AGNs .

Figure explanation: An example merging active SMBH pair discovered by APO 3.5 m. (a) SDSS r-band image. It shows tidal features indicative of galaxy-galaxy mergers and double stellar components with a projected separation of 6.3 kpc; (b) 2D slit spectra obtained using DIS on APO 3.5 m. The slit was oriented to go through the two stellar components seen in its image. The spectra show two Seyfert 2 nuclei spatially coincident with the double stellar components, with a line-of-sight velocity offset of 284 km s^{-1}.

Cometary nuclei observed at APO 3.5m



PI: H.Weaver, JHU/APL
CoIs: C. Lisse, JHU/APL, Y. Fernandez (UCF)

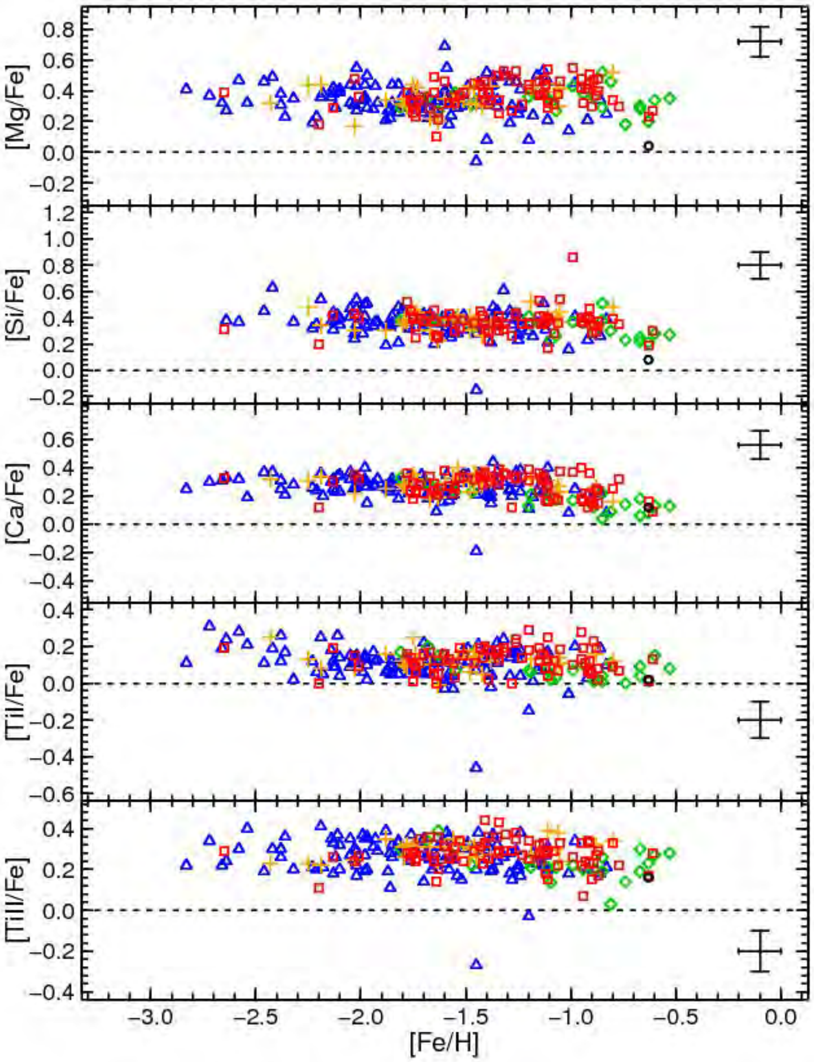
North-up, East-left
R-band; FOV 1.9'

These observations are part of a long-term program to investigate systematically the sizes of all the known short-period comets, by observing them at large heliocentric distance when there is little or no coma contamination.

APO results are combined with those from the Spitzer Space Telescope and other (non-APO) ground-based observatories.

Four comets were observed our Sep 2010 run, which is typical. In this case, one of the comets (244P/Scotti) had obvious coma, but the others did not, allowing the nucleus sizes to be measured. The faintest (163P/NEAT) had m_R of 23.6, and the smallest nucleus diameter was 1.2 km (for 62P/Tsuchinshan).

Origins of the Thick Disk as Traced by the Alpha-Elements of Metal-Poor Giant Stars



G. Ruchti, J. Fulbright, R. Wyse (JHU)

We have undertaken a study of metal-poor stars utilizing high-resolution echelle spectra from ARCES to establish whether or not there is a significant population of metal-poor thick-disk stars ([Fe/H]<-1.0) and to measure their elemental abundances. We have measured abundances of four alpha-elements (Mg, Si, Ca, Ti) and iron for >200 stars, shown at left. We find that the [alpha/Fe] ratios are enhanced implying that enrichment proceeded by purely core-collapse supernovae. Two stars of note are the halo star at [Fe/H]}~-1.45 with very low alpha-enhancement and the thick disk star at [Fe/H]~-1 with a very high [Si/Fe] ratio.

Computed [alpha/Fe] ratios versus [Fe/H] for our sample of stars. The black circle, green diamonds,
red squares, orange plus signs, and blue triangles correspond to thin disk, thin/thick, thick disk, thick/halo, and halo stars , respectively.

Uranian Satellites in the Near-IR

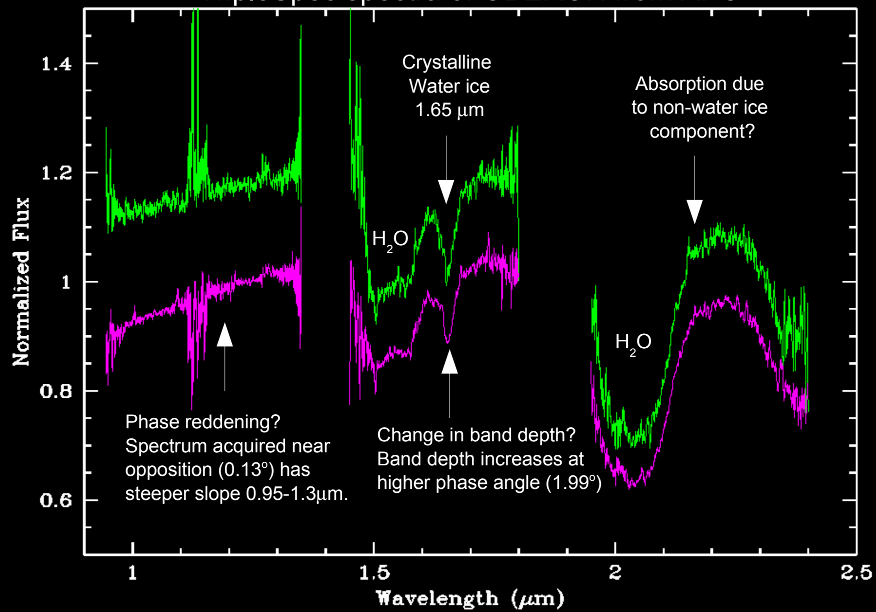
Anne J. Verbiscer (University of Virginia)

- First near-infrared spectra of uranian satellites northern hemispheres. (Uranus equinox was 7 Dec 2007.)

- Two spectra obtained at the same sub-Earth longitude at different phase angles are not identical: different band depths (1.65 µm) and slopes (0.95 – 1.3 µm).

Oberon
Voyager 2

TripleSpec spectra of OBERON from APO



Conclusion:
The spectral determination of constituent grain sizes and abundances must account for phase function (photometric) effects.

31 October 2009	19 September 2010
Phase Angle 1.99°	Phase Angle 0.13°
Longitude 62° W	Longitude 62° W
Latitude 5° N	Latitude 9° N

Both spectra have been normalized to unity at 1.8 µm. The higher-phase spectrum has been offset for clarity. Regions of high telluric opacity are not shown.

APOSTLE: APO Survey of Transit Lightcurves of Exoplanets

P. Kundurthy, A. Becker, E. Agol

Primary Goal: To detect Transit Timing Variations (TTVs).

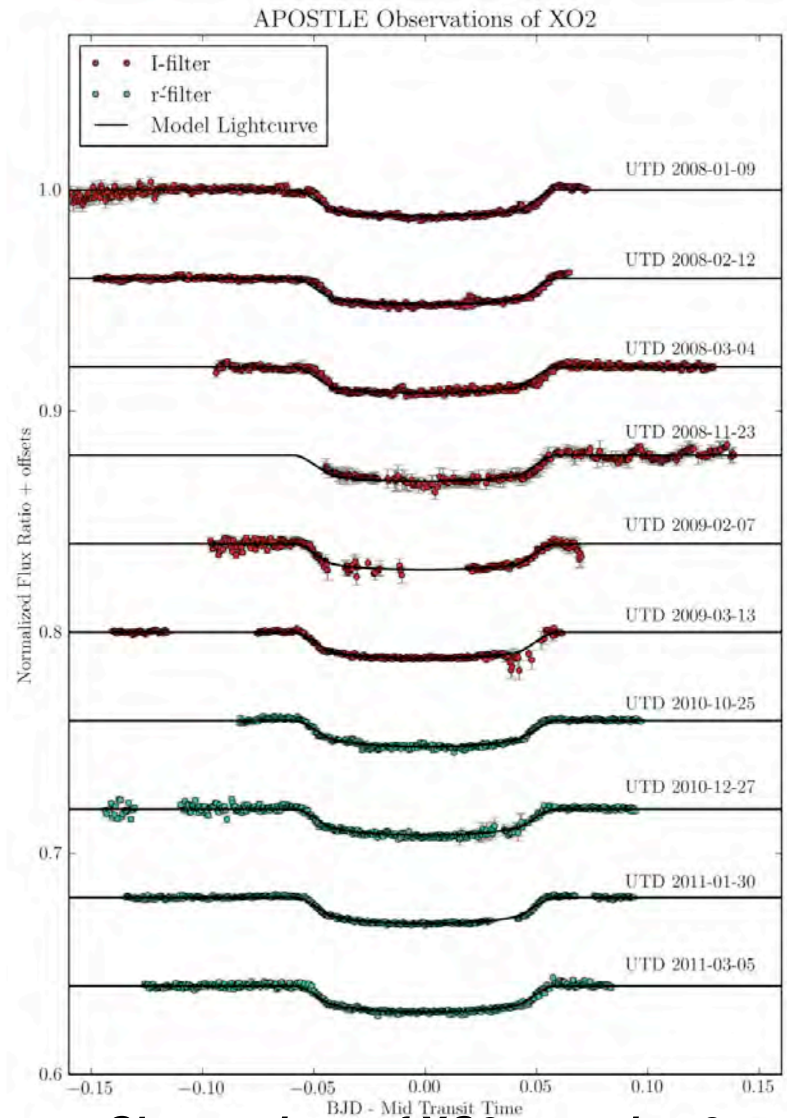
Instrument: Agile

The catalog now has over 35 high-precision lightcurves.

Best photometric precision achieved ~380 ppm* for XO2 on 2011-01-30.

We have achieved transit timing precisions on the order of 60 sec or better. This is sufficient to detect minute-level perturbations induced by unseen planetary companions.

We caught a planetary spot-crossing event and a possible low intensity stellar flare on GJ 1214 (Kundurthy et al. 2011, ApJ, 731, 123).



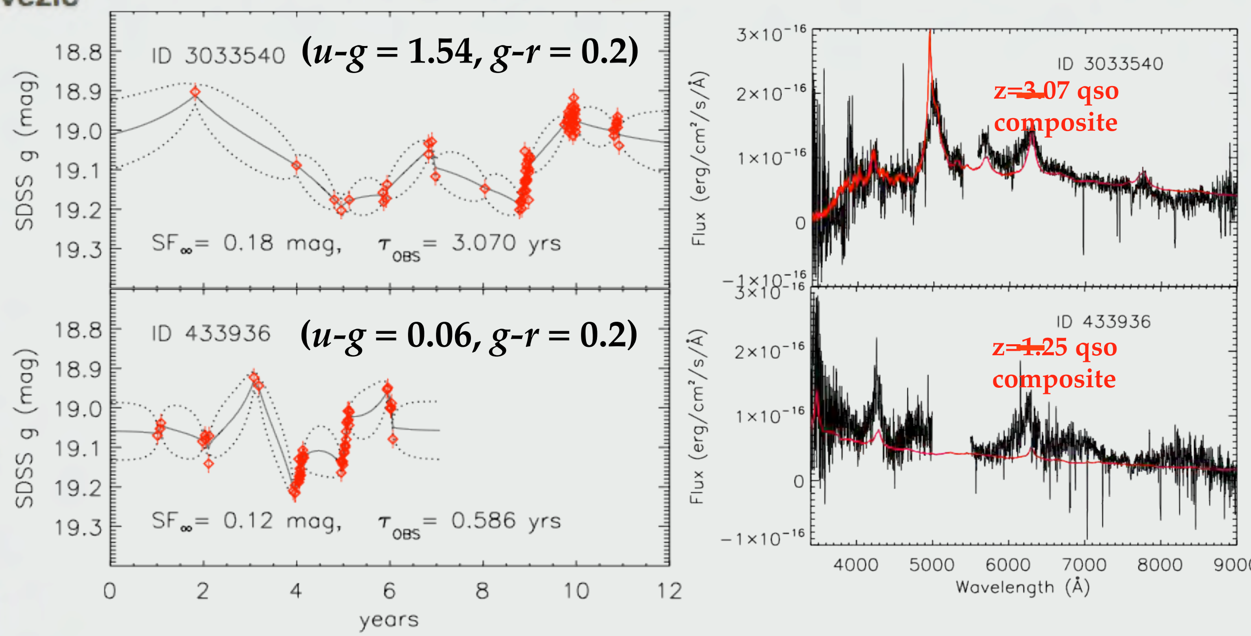
*ppm = parts per million

Lightcurves from our Observations of XO2 spanning 3 years.

Spectroscopic Follow-up with APO DIS

Aaron Meisner, C. MacLeod, Z. Ivezic

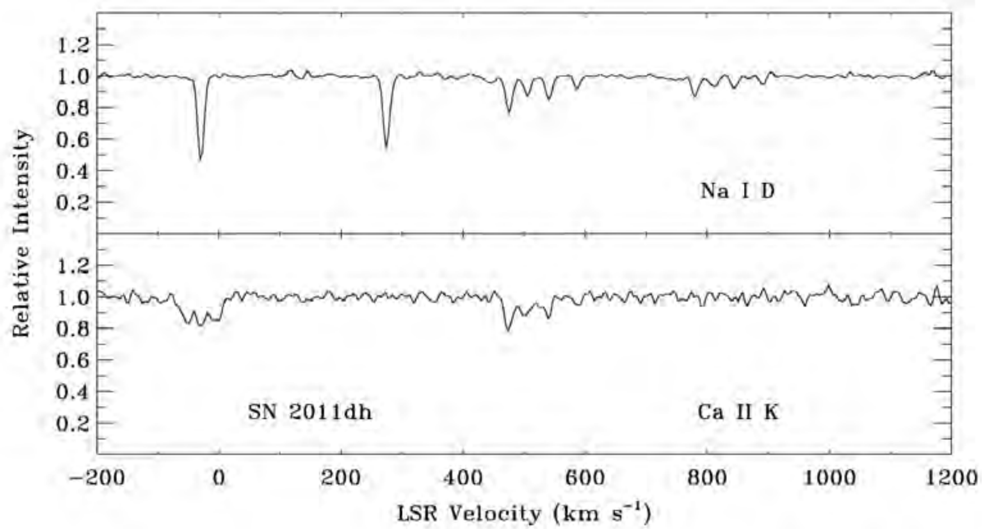
In Q4 of 2010, we obtained 35 spectra of quasar candidates based on their variability in SDSS stripe 82 (i <19, τ >100 days) using DIS on the ARC 3.5m at APO. We have confirmed several as quasars.



Two examples along with their light curves are shown here. Based on the Vanden Berk et al. (2001) composite spectrum (in red), one is a z=3.07 quasar missed by the SDSS due to its stellar-like colors.

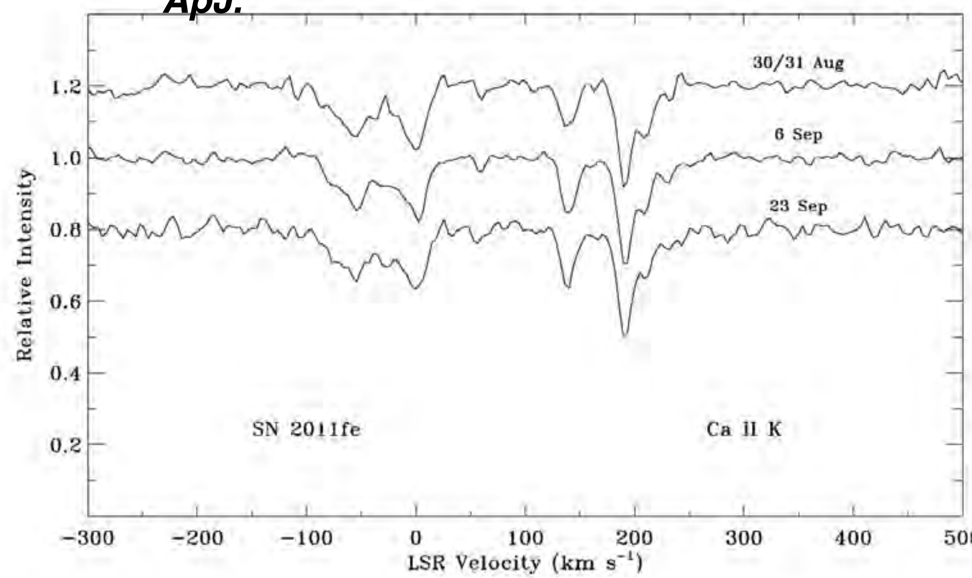
APO Echelle Observations of Bright Supernovae

Adam Ritchey (UW) · George Wallerstein (UW)



SN 2011dh in M51: APO Echelle spectra acquired near maximum brightness reveal multiple absorption components in Na I D and Ca II K arising from gaseous material in the Galactic disk (or low halo) and in the disk and halo of M51. The M51 components span a velocity range of over 140 km/s, with most of the absorption being redshifted with respect to the M51 systemic velocity of about 480 km/s, indicating that the clouds are falling onto the disk. A paper describing these observations has been submitted to ApJ.

SN 2011fe in M101: APO Echelle spectra obtained at three epochs near maximum brightness reveal multiple Ca II absorption components arising from the Milky Way and M101. The data are being analyzed to determine whether any of the components show evidence of variability. Time-variable absorption toward Type Ia supernovae may trace circumstellar material associated with a red giant companion to the white dwarf progenitor. The absence of variability can help place robust constraints on the nature of the progenitor system.



APO 3.5m science highlight

The Star Formation History of Luminous Red Galaxies Hosting MgII Absorbers

Jean-René Gauthier
Hsiao-Wen Chen
UChicago/KICP

We present a spectroscopic sample of z≈0.5 luminous red galaxies (LRGs) that are located within physical projected distances ρ ≤ 350 kpc/h of a QSO sightline. Of the 37 LRGs in our sample, eight have associated MgII absorbers with rest-frame equivalent width $W_r(2796)$>0.3Å and velocity separation |Δv| ≤ 350 km/s and 29 do not have associated MgII absorbers to a 2-σ limit of $W_r(2796)$=0.3Å. We perform a stellar population synthesis analysis using stacked spectra of the MgII absorbing and non absorbing LRG subsamples. We find that LRGs with or without associated MgII absorbers share similar star formation histories and are best described by old stellar population models (≥1 Gyr). Younger stellar populations (< 1Gyr) fail to reproduce their spectra. These findings are consistent with the lack of [OII] emission features in the LRG spectra. The primarily old stellar populations in the LRGs indicate that starburst driven outflows are unlikely to explain the observed MgII absorbers at large distances from the LRGs. In addition, the spectroscopic LRG sample allows us to derive a sensitive constraint for the cool gas covering fraction of ⟨κ⟩ =14±6% in the LRG halos for absorbers of $W_r(2796)$>0.3Å.

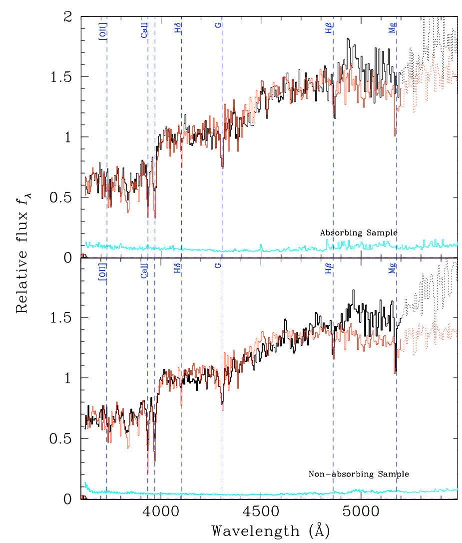
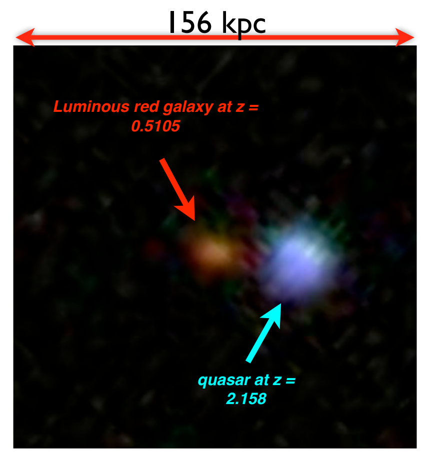


Figure 1. Comparisons of the observed LRG spectra and best-fit models from a stellar population synthesis analysis. The top panel shows the stacked spectrum of eight LRGs with associated Mg II absorbers at projected distances $< 350\ h^{-1}$ kpc along with the best-fit synthetic model displayed in red. The data points and associated model predictions shown in dotted lines have been excluded from the stellar population synthesis analysis. The bottom panel shows the stacked spectrum of 29 LRGs without associated Mg II absorbers down to a 2-σ limit of $W_r(2796) = 0.3$Å , in comparison to the best-fit model displayed in red. Spectral features such as Ca II H&K, G-band, and Mg I are prominent in both stacked spectra, while [O II] emission features are not seen. The 1-σ error spectrum of each stack is shown at the bottom of each panel.



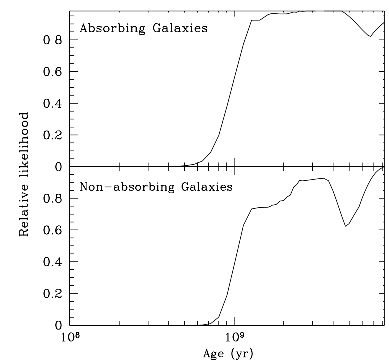
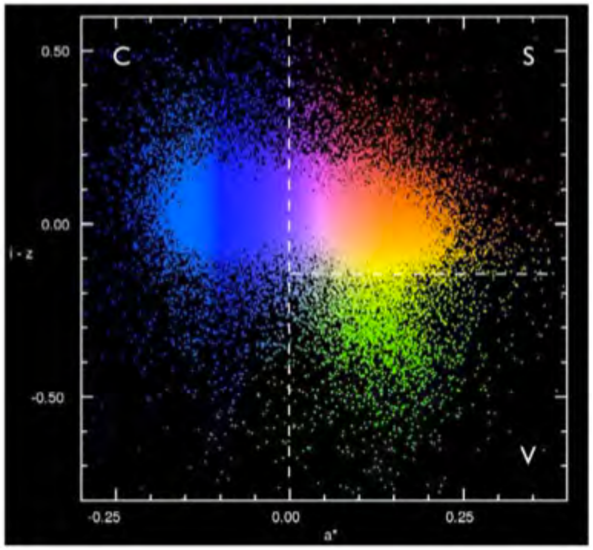


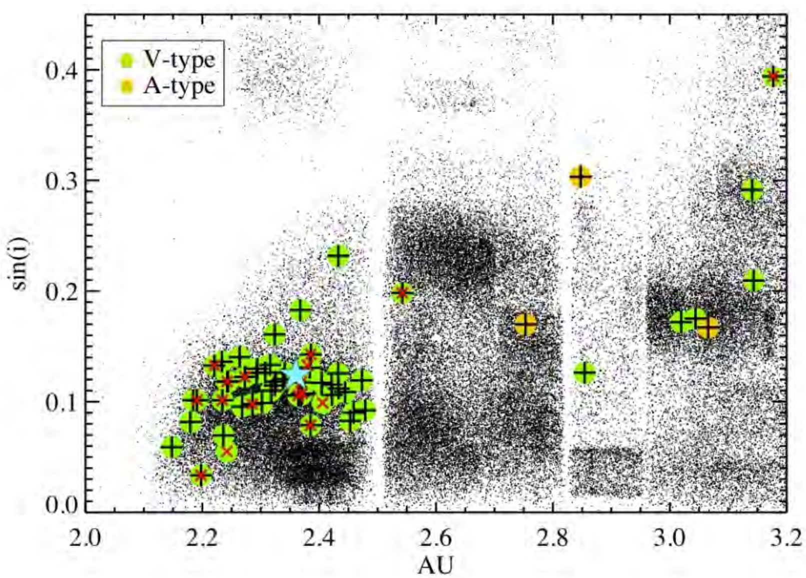
Figure 2. Relative likelihood functions of the stellar age of LRGs with and without associated Mg II absorbers. The stellar age distribution shows that both galaxy samples are characterized by an evolved stellar population of age $\gtrsim 1$ Gyr. The model spectra are shown in Figure 1. The Mg II absorbing LRG sample is best characterized by a τ model of $\tau = 0.15$ Gyr, age $t = 3.25$ Gyr, and solar metallicity, while the non-absorbing LRGs are best-characterized by a single burst of age $t = 8.25$ Gyr and metallicity 0.2 solar. At $\lesssim 1.6$ Gyr, the LRGs can be characterized by a single burst of metallicity 2.5 solar. At $1.6 \lesssim t \lesssim 5$ Gyr, the LRGs can be characterized by an exponentially declining SFR model of $\tau = 0.2$ to 0.5 Gyr and metallicity of solar or 2.5 solar. At older ages ($\gtrsim 5$ Gyr), the best-fit models are either single burst of sub-solar metallicity (0.2 solar) or exponentially declining models of $\tau = 0.5$ Gyr and solar metallicity.

The Adler V-type Asteroid Survey (AVAST): Identifying fragments of differentiated objects (M. Hammergren, G. Gyuk, M. Solontoi)



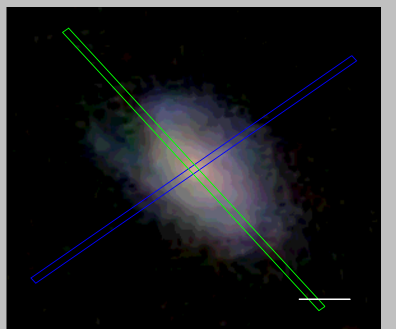
Evidence from meteorites (supported by theoretical models) suggests that there must have been scores of large, differentiated planetoids in the asteroid belt region, but only one such body (Vesta) remains.

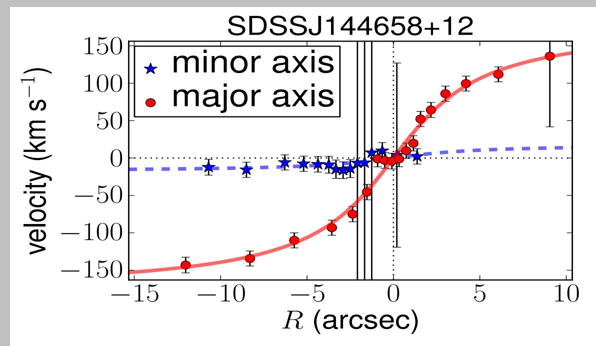
SDSS colors are used to select candidates that show a strong spectral absorption signature of pyroxene (characteristic of basalt, i.e. solidified lava). These are commonly known as V-type asteroids or “Vestoids.” Confirmation is provided through reflectance spectroscopy using DIS and Triplespec.

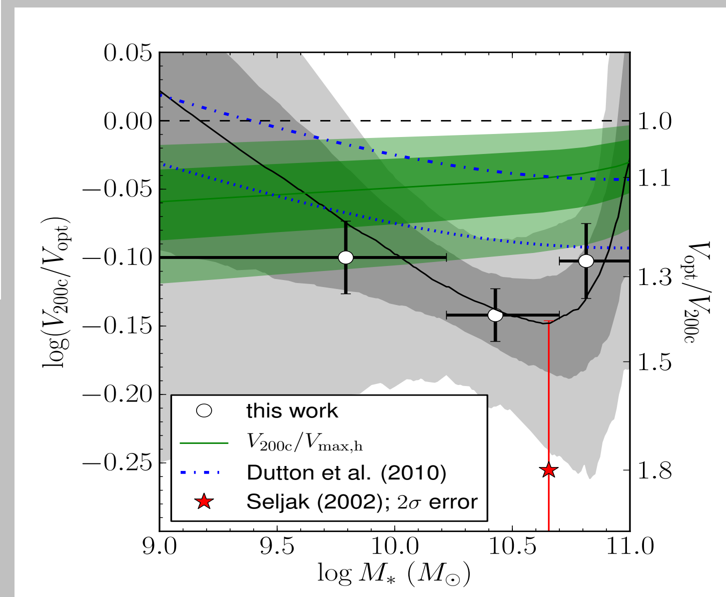


- **We have identified 57 “Vestoids”, including 7 that orbit on the opposite side of the 3:1 mean motion resonance – a strong dynamical barrier – from Vesta**
- **7 other “Vestoids” have orbital inclinations lower than 5 degrees, a significant dynamical separation from Vesta**
- **These objects may be fragments of lost large parent bodies, independent of Vesta**

ARC 3.5m DIS observations of galaxy rotation curves





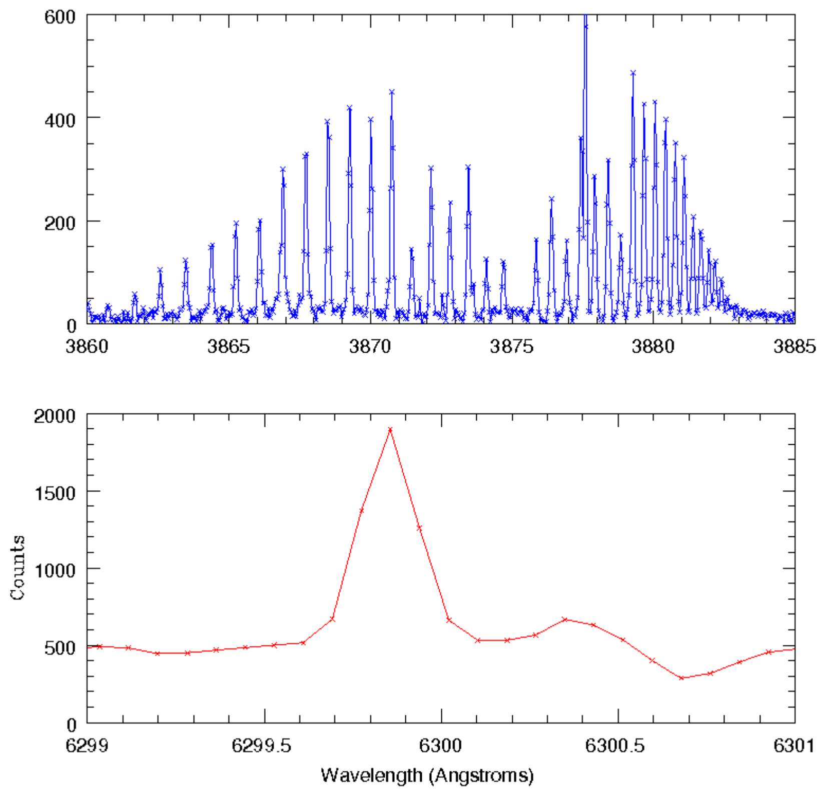


Rotation curves for 189 SDSS disk galaxies were extracted from Hα long-slit spectra taken with DIS at APO to determine the optimal Tully-Fisher relation (**V_{opt}** vs. **M_{star}**) for estimating V_{rot} for a sample of ~10^5 SDSS disk galaxies.

Combination with **weak lensing** yields a key constraint on the mass distribution (and formation scenarios) of disk galaxies: **$V_{opt}/V_{vir} \approx 1.3$**-- the ratio of the circular velocity at the optical radius (~10 kpc) to that at the DM halo virial radius (~150 kpc).

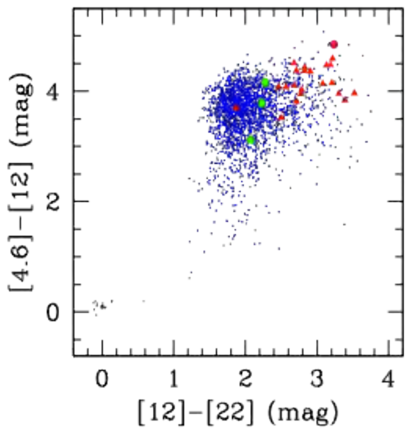
R. Reyes,
R. Mandelbaum,
J. Gunn et al. (2011a,b)

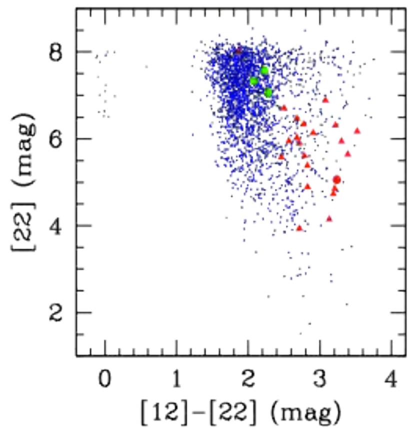
Volatile Composition of Comets Using APO 3.5m and echelle spectrograph

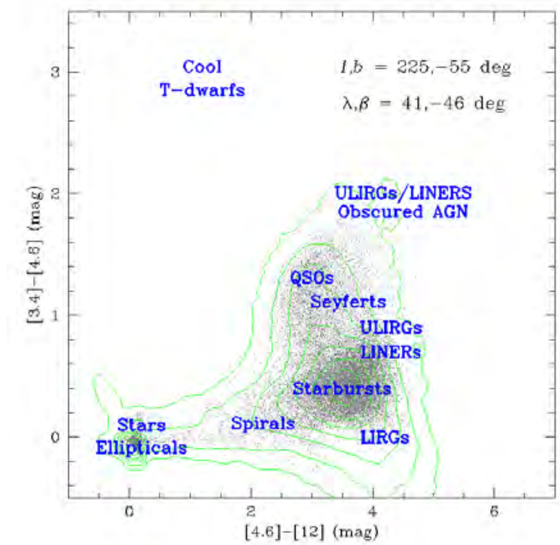


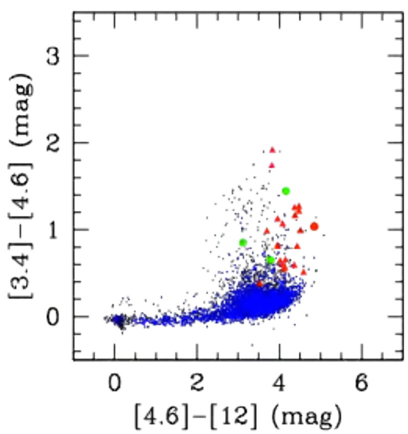
- Understanding cometary composition is key to understanding planetary formation due to the primitive composition
- Using ARCES in collaboration with Keck NIRSPEC and IRTF CSHELL observations to characterize the volatile composition of comets 103P/ Hartley and C/2009 P1 Garradd
- Preliminary results presented at Lunar and Planetary Science Conference in March 2011 and the Division of Planetary Science Meeting in October 2011
- Figures: Top: CN emission in 103P/ Hartley. Bottom: [OI] 6300 emission in C/2009 P1 Garradd

OH Megamaser Hosts in WISE Space
Jeremy Darling









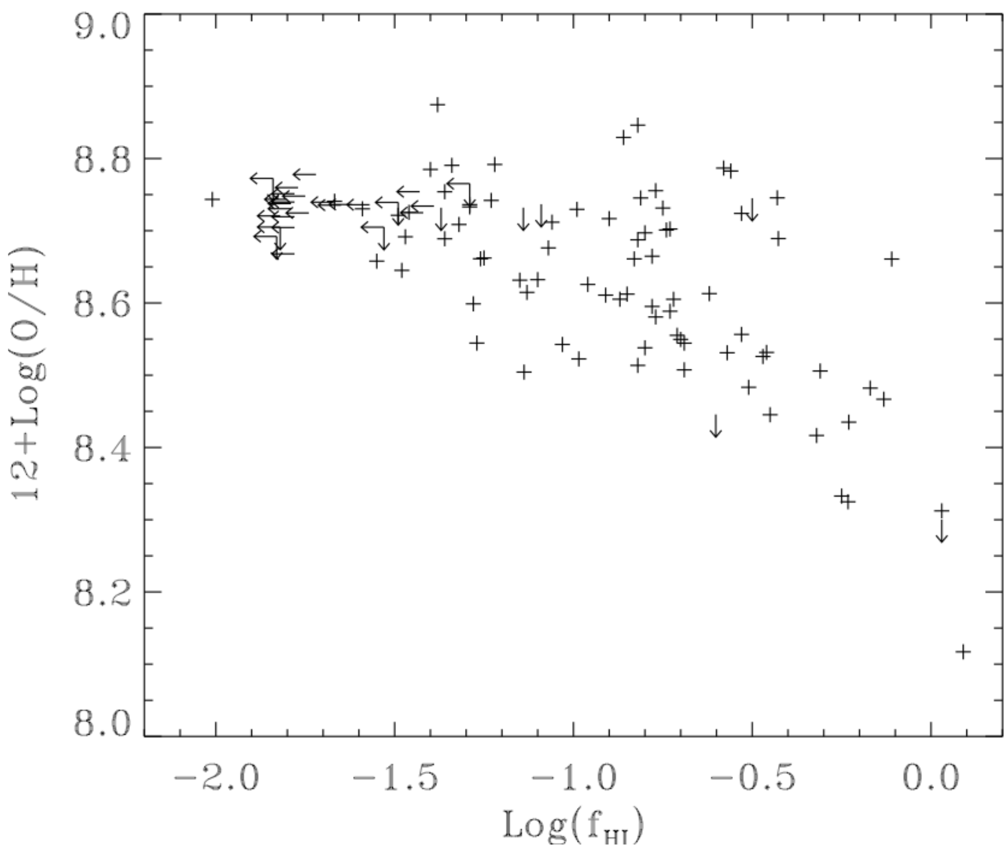
Mergers/ULIRGs (OH)
New OH
Disks (HI)

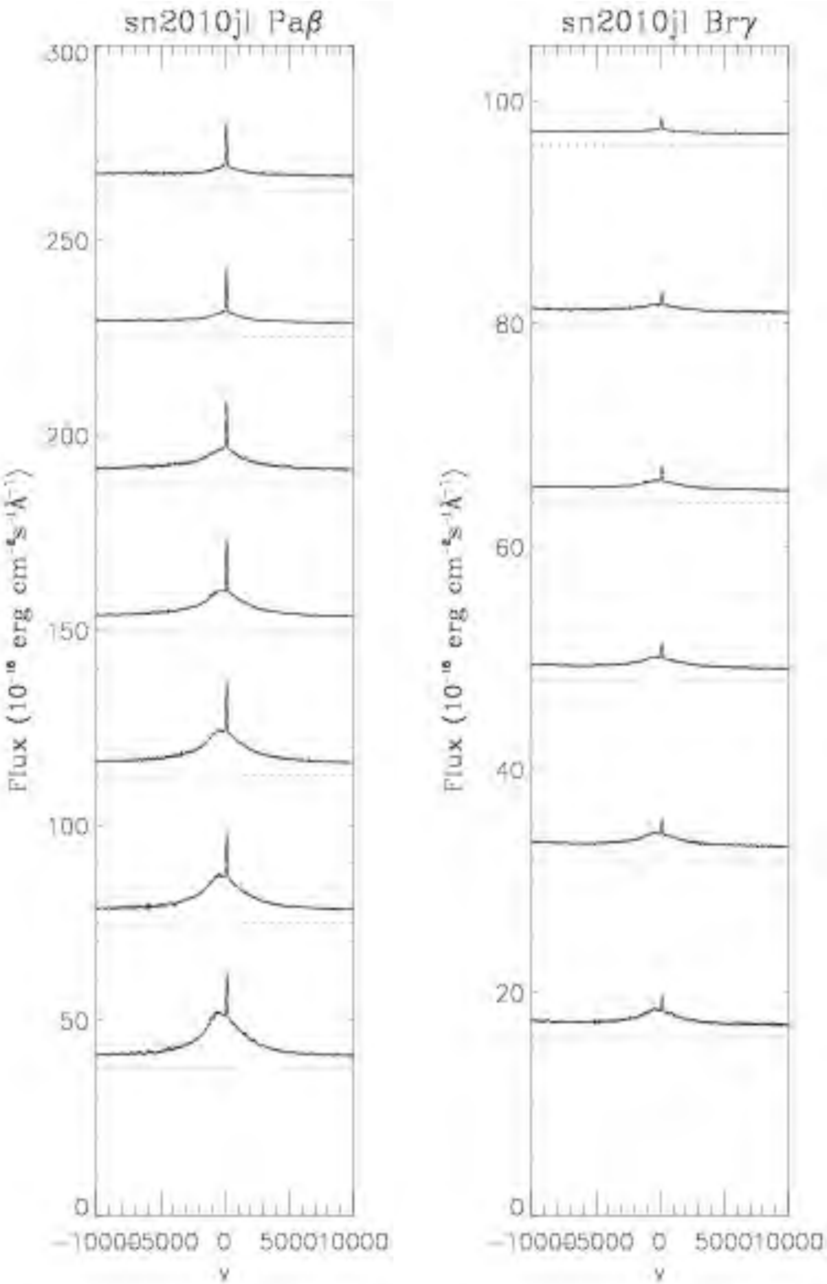
We're using WISE to identify major mergers (via OH 18 cm maser lines) in ALFALFA that have been mis-identified as disks (via HI 21 cm lines). Shown are mid-IR color-color and color-magnitude plots of WISE-identified ALFALFA sources. There is a single-line redshift ambiguity between 21 cm HI lines and 18 cm OH lines that can be resolved with optical spectroscopy (to obtain redshifts). Red points are known OH megamaser galaxies (which are also major mergers and ULIRGs); the green points are newly identified OH megamaser hosts using DIS on APO. Only about 110 OH megamasers are known, but in one clear half-night we found three more.

Outer Metallicity and the HI Content of Galaxies

Sean Moran, Tim Heckman & GASS Team, JHU (Moran et al. 2011)

- APO DIS spectra have allowed us to measure radial profiles of gas-phase metallicities for galaxies in the GASS sample, a mass-limited set of galaxies with HI measurements
- Surprising result has been that metallicity at outer edge of galaxy disk is related to *total* HI content
- Possible explanation is that metals are diluted at edge because gas-rich galaxies sit in a gas reservoir that is more extended than the optical disk





Broad Emission in SN 2010jl

Jake Borish, U. Virginia

- Six Triplespec observations spanning first 7 months after discovery, including time contributed by other institutions.
- Broad emission becomes stronger and shows an evolution towards the blue.
- We are currently investigating electron scattering models to explain the broad line behavior.

Detecting Binarity in the Kuiper Belt

Anne J. Verbiscer (University of Virginia)
Nancy Chanover, Jon Holtzman (New Mexico State University)

Most particulate surfaces exhibit a dramatic increase in reflectance at opposition, a phenomenon known as the opposition effect or surge.

Few Kuiper Belt Objects (KBOs) have been observed at true opposition (in perfect alignment with the Earth and Sun), but among those which have, so far *only binary objects exhibit strong opposition surges (> 1 magnitude/degee).*

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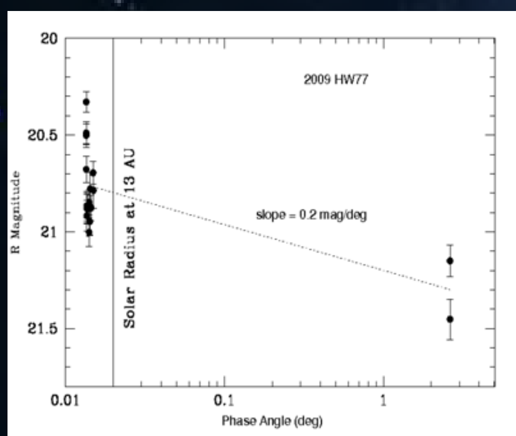
Using SPIcam at APO in 2011Q2, we observed 2009 HW77 at true opposition (smallest phase angles below) and measured its opposition surge: 0.2 mag/deg. If our hypothes is correct, 2009 HW77 is not a binary. In 2010 Q4, NMSU students measured the opposition surge of binary 1995 TL8.



The opposition surge of many more KBOs need to be measured to confirm any correlation between binarity and surge strength; however, if the theory holds, then *measurement of the opposition surge could become a tool for detecting KBO binarity* without resolving individual components using large aperture (>8-m) or space-based (HST) telescopes. Ultimately, the technique could provide a more accurate, revised assessment of the binary fraction of the Kuiper Belt population.

Work supported by NASA Planetary Astronomy Grant No. NNX09AD06G
Results presented at New Horizons Workshop, Flagstaff AZ, August 2011 and EPSC-DPS, Nantes, France, October 2011

Engaging Tomorrow's Scientists In Astronomical Research

A collaboration between Graduate Students and High School Students

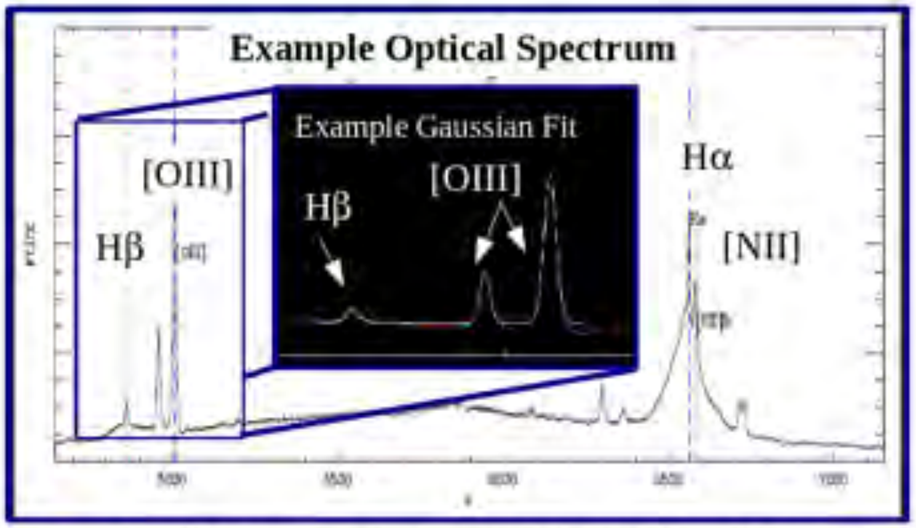
Rachael Beaton, Joanna Corby, William Dirienzo and Gail Zasowski

2010 Group at NRAO- Green Bank

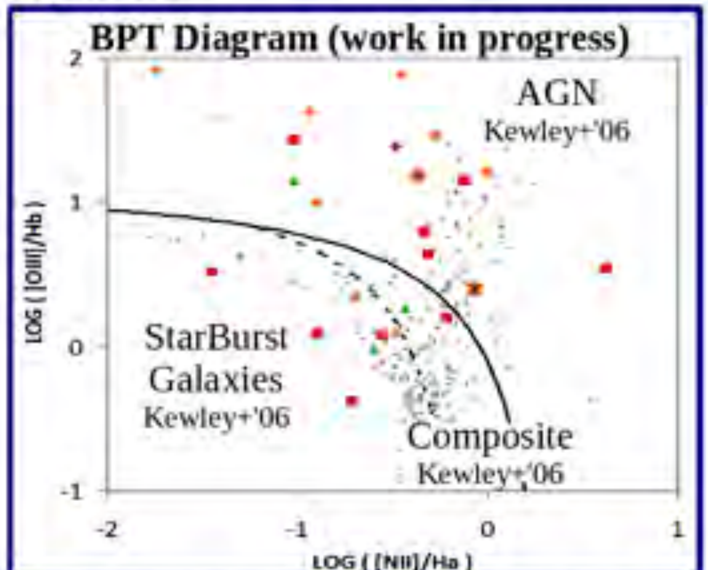
Since 2009, UVA Astronomy graduate students have led scientific mentoring partnership with the Central Virginia Governor's School on a variety of projects. One such project is a partnership with a long standing NRAO campaign to discover 22GHz megamasers with the GBT.

High school students are studying the properties of megamaser host galaxies using a combination of literature data and optical spectroscopy from APO+DIS to better understand the hosts of 22GHz megamasers.

Artist Conception of a Megamaser



In a series of tutorials, students are taught how to identify lines and fit multiple Guassians to emission lines using GBTIDL. The students then convert these measurements to line ratios using Excel.



The students then compare their measurements to literature values (Kewley et al. 2001, 2006) as a BPT diagram in order to interpret the AGN optical spectrum.