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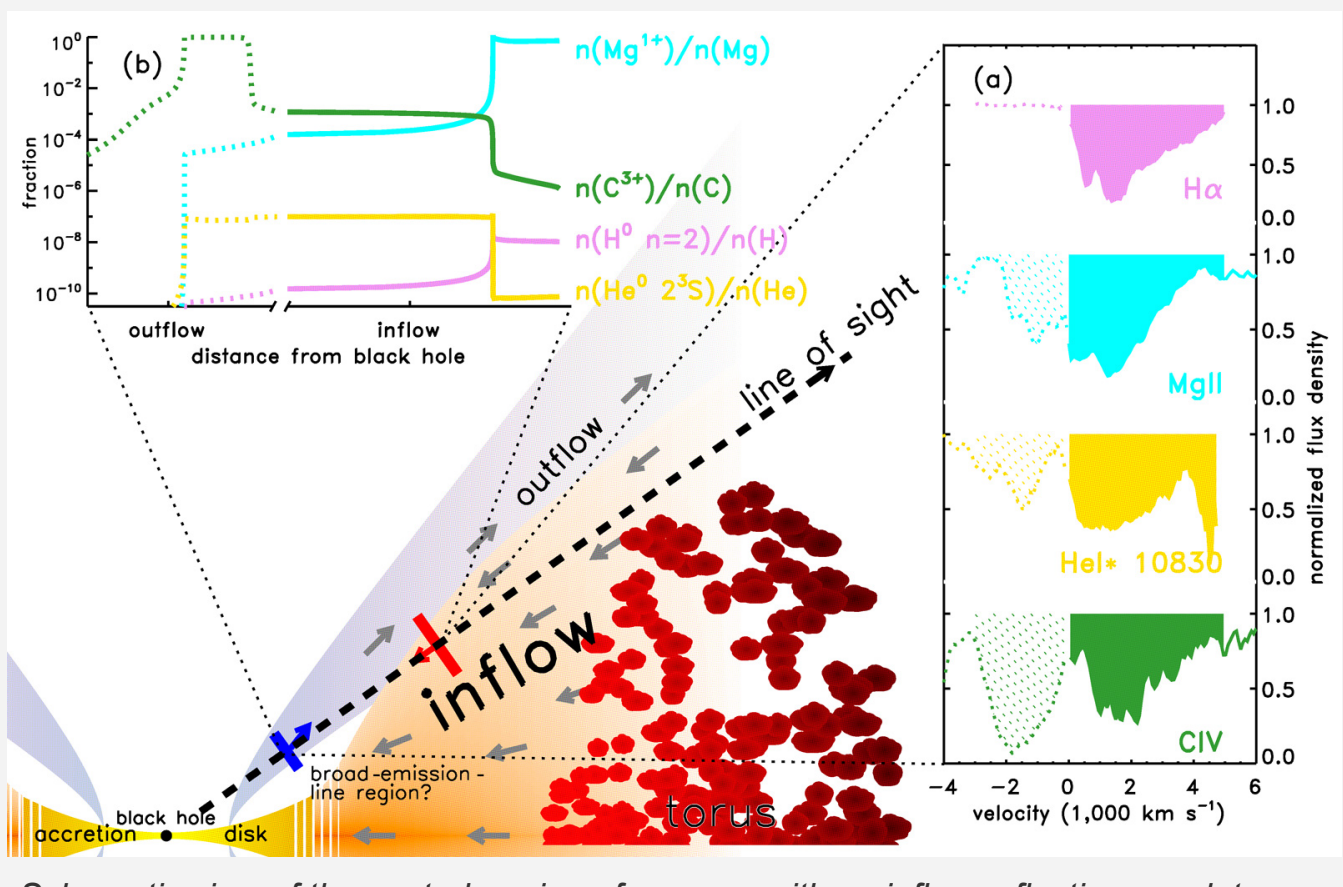
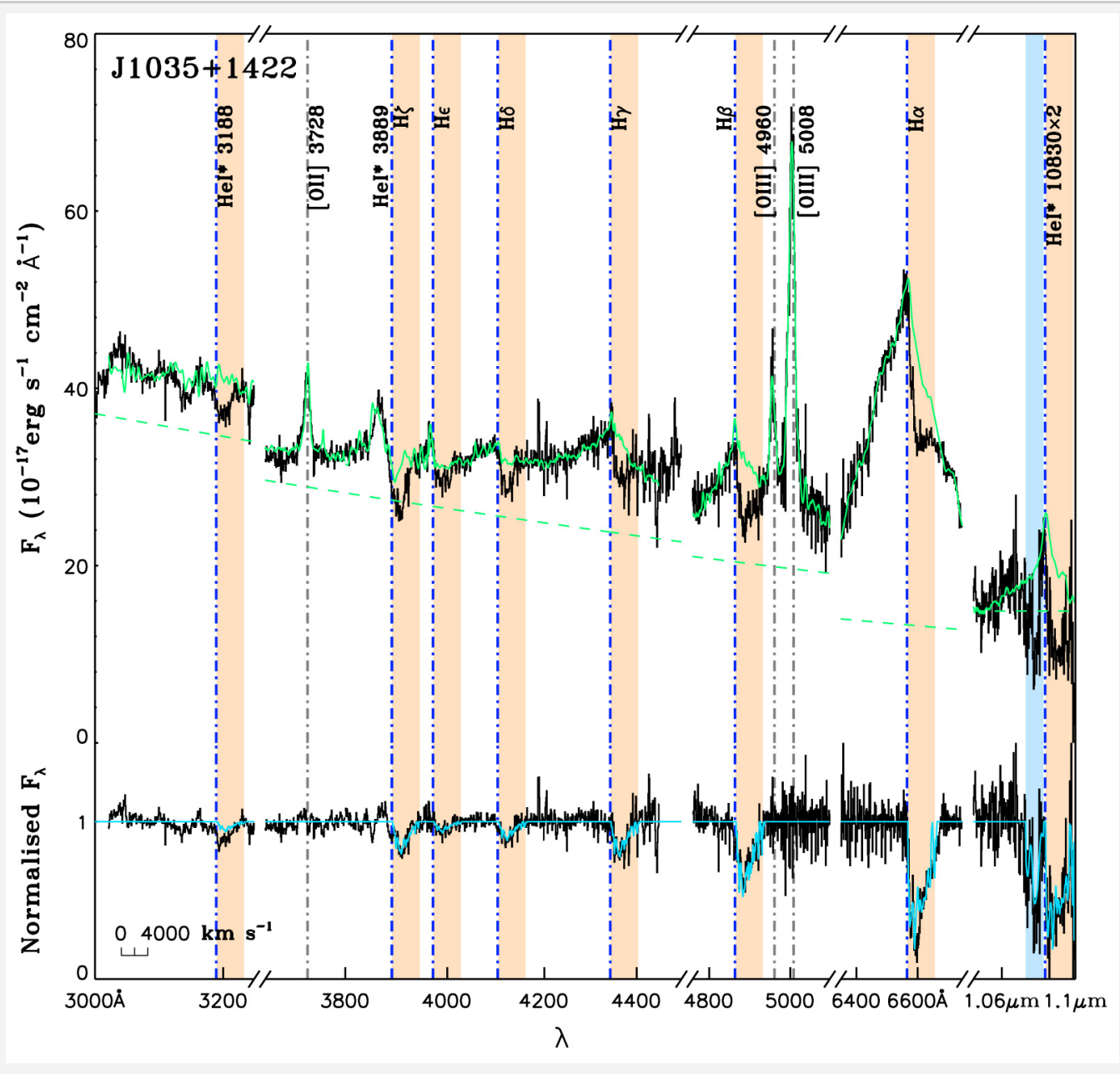
Palomar Science Highlight: Discovery of Inflow Fueling of Supermassive Black Hole Close to the Accretion Disk

By Xiheng Shi (Polar Research Institute of China)



Schematic view of the central engine of quasars with an inflow reflecting our data on redshifted hydrogen and helium broad absorption lines. The parsec-scale inflow (grey arrows pointing towards the central black hole; positioned at few thousand gravitational radii, Rg, from the black hole) is located between an accretion disk and a dusty torus. The velocity of infalling gas (not shown) along the line of sight span from zero to as high as 5,000 km/s (roughly the freefall speed just beyond the outer radius of the accretion disk), indicating that the flow is being accelerated under the pull of the central black hole. A large amount of cold, dense and high-column-density gas, inferred from our absorption-line modelling, provides a direct and sufficient mass supply to feed the accretion disk. The inflow probably originates from the dusty torus, formed by materials therein that lose a substantial fraction of their angular momentum through various processes and hence fall inwards. Viewed at a modest inclination angle, the line of sight may intercept both the inflow and outflow (shown between the red and blue bars), leaving imprints as both redshifted and blueshifted broad absorption lines that are observed in J1035 + 1422 as an example. Four representative lines are shown at the top right in their common velocity space (cyan line, Mg II; green, C IV; pink, Hα; yellow, He I λ10,830). The left inset shows the fraction of the corresponding ions (atomic levels) as a function of distance from the black hole. (X.Shi/PRIC)*

A research group from Polar Research Institute of China (PRIC) recently identified a fast gaseous inflow fueling the accretion disk around a supermassive black hole in the quasar J1035+1422. The discovery is based on the spectra obtained using the Palomar 200-inch telescope. The inflow is traced by a redshifted broad-absorption-line system. Located at the outer radius of the accretion disk, this inflow is the first case reported actually reaching the disk. The result is published in a Letter to Nature on September 4, 2019.



Top: The observed spectrum of J1035+1422. The black line shows the observed flux; the green solid line represents the unabsorbed quasar template spectrum and the green dashed lines are the underlying power-law continuum. Bottom: Normalized broad-absorption-line spectrum (dark grey line). The redshifted broad absorption lines are normalized to the continuum only. By contrast, the blue-shifted He I λ10,830 line is normalized to the total flux of the modelled template. The cyan line represents the best-fit model of broad absorption lines. The blue dotted-dashed lines mark the rest wavelengths. The quasar systemic redshift is determined from narrow emission lines including [O II] (grey dotted-dashed vertical lines). (X.Shi/PRIC)

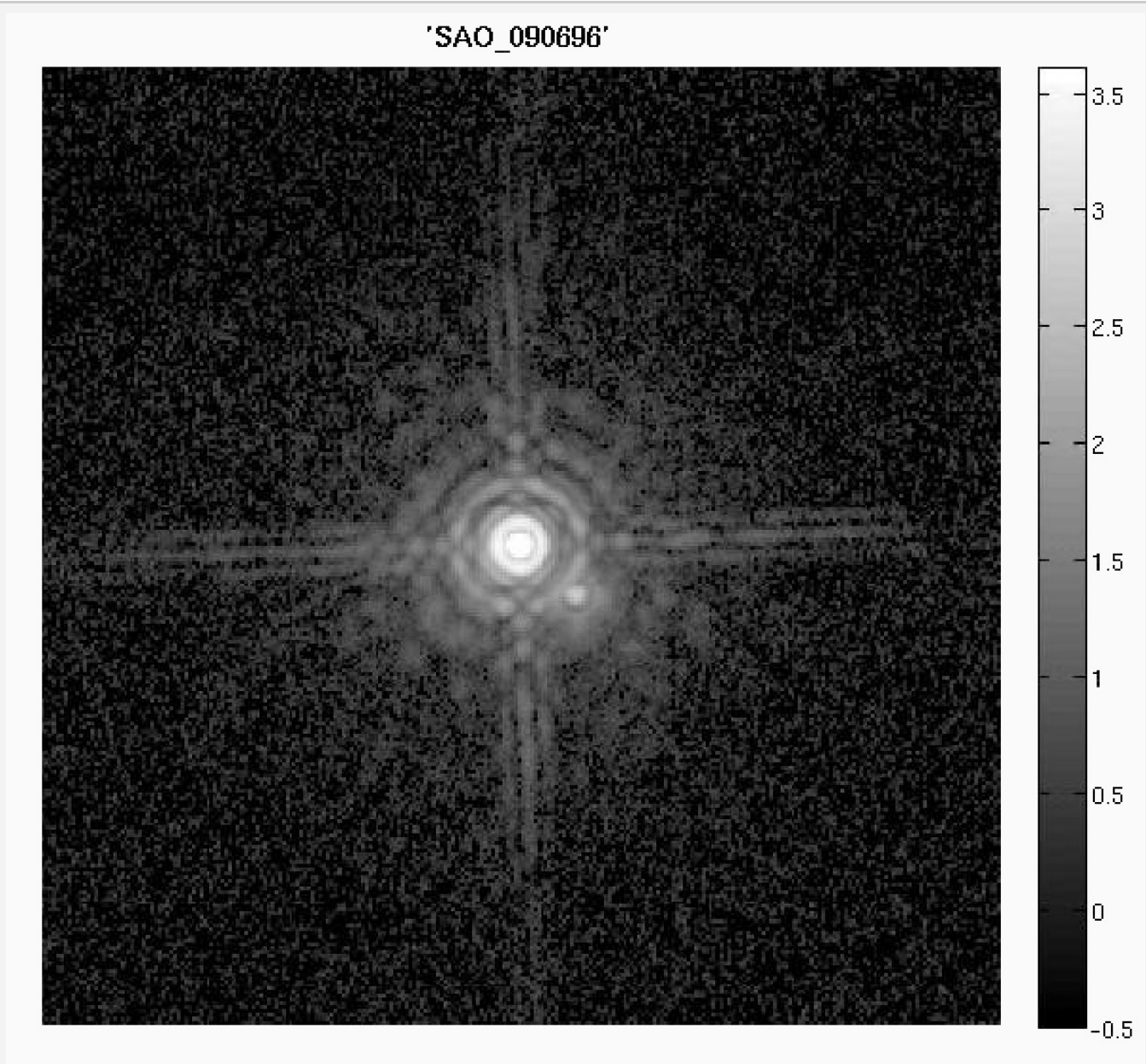
The absorption-line system was originally detected through a systematic search in ~105 SDSS quasars with $z < 1.3$. In the follow-up campaign with the DBSP and TripleSpec spectrographs, the system was confirmed using H I Balmer absorption from H-α to H-η and metastable He I multiplets He I* ll3,188,3,889,10,830A in the optical and near-infrared spectra. The absorption trough spreads 0 - 5,000 km/s redshifted to the quasar's rest frame. This is the fastest and broadest among the sample of absorption line systems. This large velocity width implies a fast inward motion. Our photoionization simulation presented in the paper suggests that the inflow reaches 1,100 gravitational radii from the central engine, overlapping with the outer accretion disk. The inflow could originate near the inner surface of the dusty torus, and the mass flux rate is therefore about 15 – 36 solar masses per year, sufficient to power the quasar radiation and the outflow.

Such inflow directly feeding the accretion disk is considered the last piece of the puzzle of quasar black hole accretion. Because of potential dust obscuration, such inflow around supermassive black hole could be much more common in quasars than as suggested by ultraviolet and optical spectra. Absorption/emission lines in the infrared, (sub)millimetre and radio wavelengths, where dust obscuration is small or negligible, could be more powerful means to study these disk-feeding inflows.

Upgraded P3K Returns to Science Operations

By Seth Meeker (JPL)

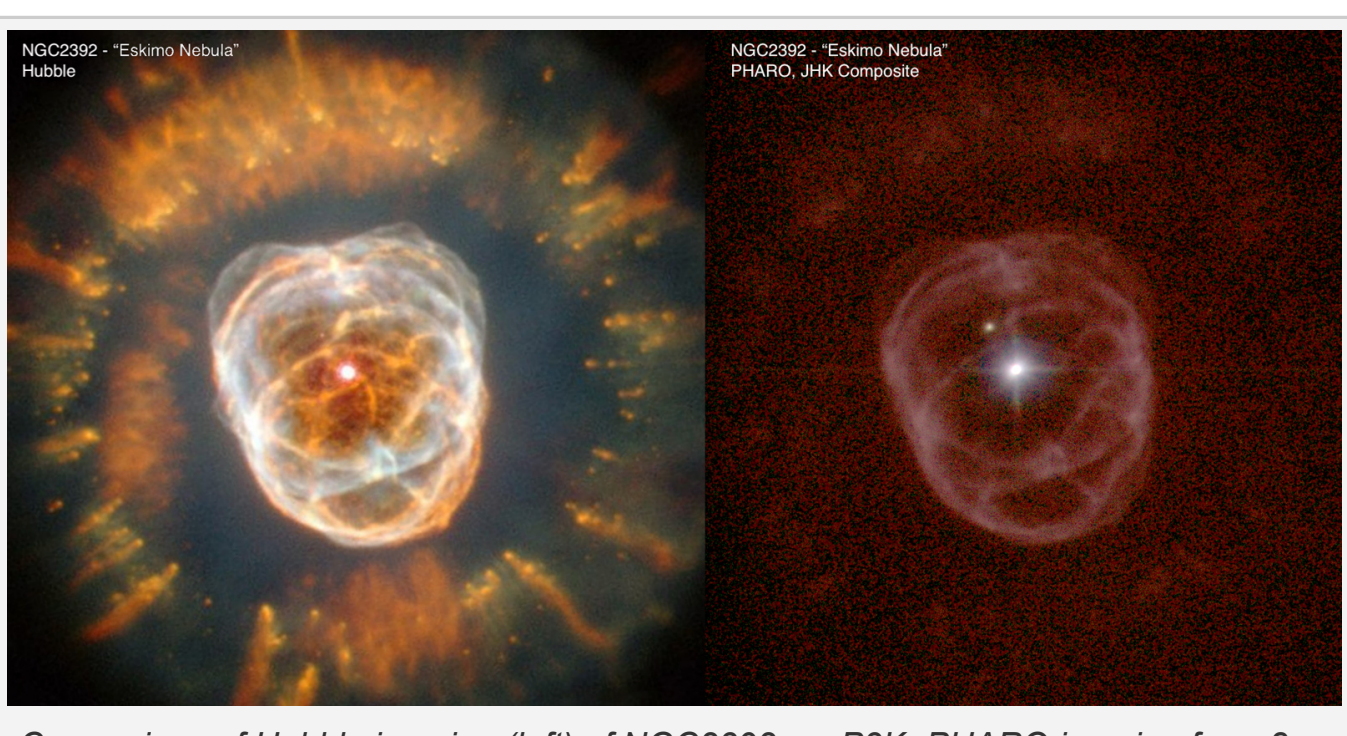
PALM-3000 (P3K), the Palomar 200-inch facility adaptive optics system, has undergone a significant upgrade during the 2019B observing semester, concluding with a successful re-commissioning phase in September/October 2019 and a return to science operations as scheduled on 08 November 2019. The main features of this upgrade are: 1) the original frame-transfer CCD wavefront sensor (WFS) is upgraded to an OCAM2K EMCCD capable of 3.5 kHz framerates; 2) new real-time control (RTC) hardware and software based on advanced Digital Signal Processor (DSP) boards has replaced the aging GPU based RTC system.



85% K-band Strehl achieved on SAO 090696, mV=7.88 M3, on 8 October 2019. The diffraction limited core has a FWHM of 3.4 pixels or 85 mas. The ghost to the lower right of the PSF core is from the ND filter in PHARO. (S.Meeker/JPL)

Similar to the pre-upgrade system, P3K's Shack-Hartmann WFS supports multiple pupil sampling modes using a motorized lenslet stage, and these pupil sampling modes are being released to general observing in phases. The default sampling mode with 64×64 sub-apertures was the first to be tested on-sky during the September/October re-commissioning, and is now available for normal science observations. In 64× mode the upgraded P3K is already achieving K-band Strehl ratios-the ratio of PSF core intensity vs. a theoretically perfect PSF—up to 85% on-sky and can lock on natural guide stars (NGS) as faint as m_V=16, rivaling or exceeding the natural guide star capabilities of facility NGS systems on much larger telescopes. The clearest improvement is in the quality of correction for a given guide star magnitude. Compared to the old system, the new system offers the same level of performance for guide stars that are 2 or 3 magnitudes fainter. For example, the upgraded system achieved Strehl ratios of 35% on a m_V=14 guide star on a *good* night (in terms of atmospheric conditions) during re-commissioning. The previous system could achieve that on an m_V=11 guide star on an *excellent* night. This is directly thanks to the new EMCCD wavefront sensor with its sub-electron read-noise, compared to the several-electron read-noise of the old camera. Early results from this upgrade can be found on the P3K observer webpage to aid in observation planning with these new capabilities.

The next phase will be the 16×16 subaperture mode, which is scheduled for on-sky commissioning in January 2020 and science use starting in the 2020A semester. This mode is expected to extend the system's faint limit by two more magnitudes, while offering superior correction to the 64× mode for targets fainter than ~11th magnitude.



Comparison of Hubble imaging (left) of NGC2392 vs. P3K+PHARO imaging from 8 October 2019. The PHARO image is a false color composite of J, H, and K band images covering the full 40"×40" PHARO field of view. AO correction was made by locking onto the m_V = 9.68 guide star at the center. (S.Meeker/JPL)

Meet Our Support Astronomers and Palomar Staff: Carolyn Heffner

Support Astronomer Carolyn Heffner. (Palomar/Caltech)

Every successful night at the Palomar 200-inch telescope relies on excellent support from many staff members at Palomar mountain. With this series, we introduce these dedicated people to our P200 user community. Our first profile is on Support Astronomer Carolyn Heffner.

Carolyn Heffner, from Cleona, Pennsylvania, is a support astronomer at Palomar Observatory. She became interested in astronomy while studying physics at Lafayette College and continued her education by completing a master's degree in astronomy at San Diego State University. As a student at SDSU, Carolyn worked at Mount Laguna Observatory with former director Paul Etzel. Her experiences there gave her a great foundation for a career working at observatories, and she became a Palomar staff member in 2011.

As a support astronomer, Carolyn helps visiting astronomers with their observations on the 200-inch Hale Telescope by training them how to use instrument software and by ensuring their telescope time goes smoothly. The instrumentation she works with includes optical and infrared spectrographs and direct imaging cameras, as well as the 200-inch adaptive optics system. She also supports work being performed at the 48-inch and 60-inch telescopes. Her additional duties include mirror aluminizing, mirror quality assessment, on-site computer and networking support, and various other projects as they arise.

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