Optimizing science productivity of the new ShaneAO system

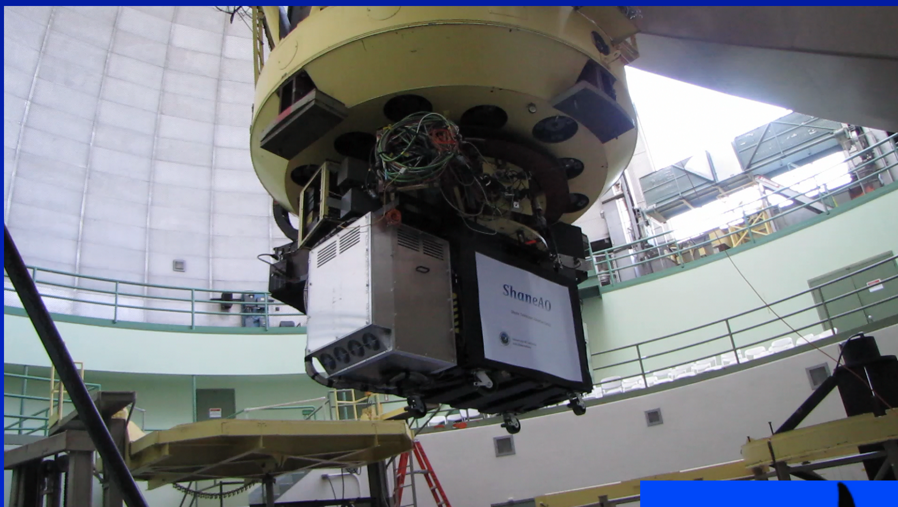
Donald Gavel

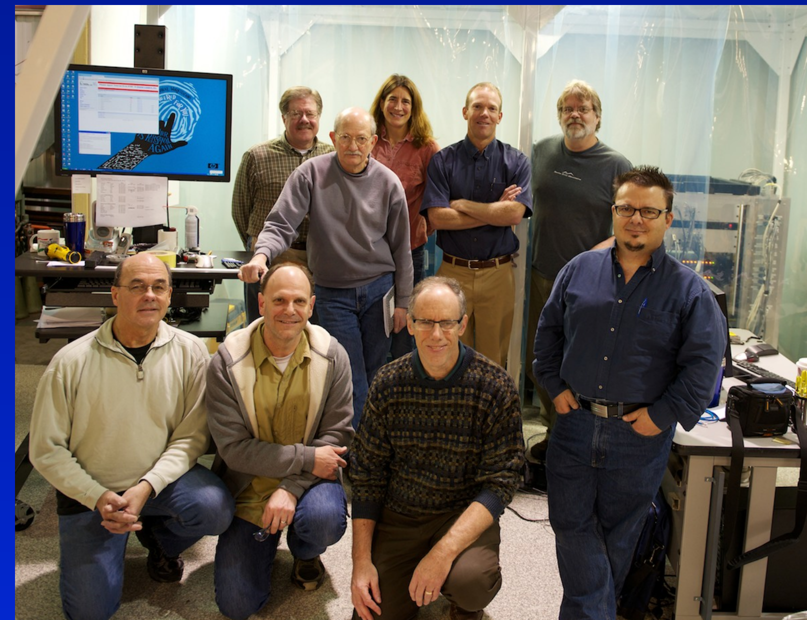
UCO

ShaneAO User's Workshop
17 December 2014
UC Santa Cruz

Lick Observatory
Mount Hamilton, California

ShaneAO - installed at the telescope!
April, 2014





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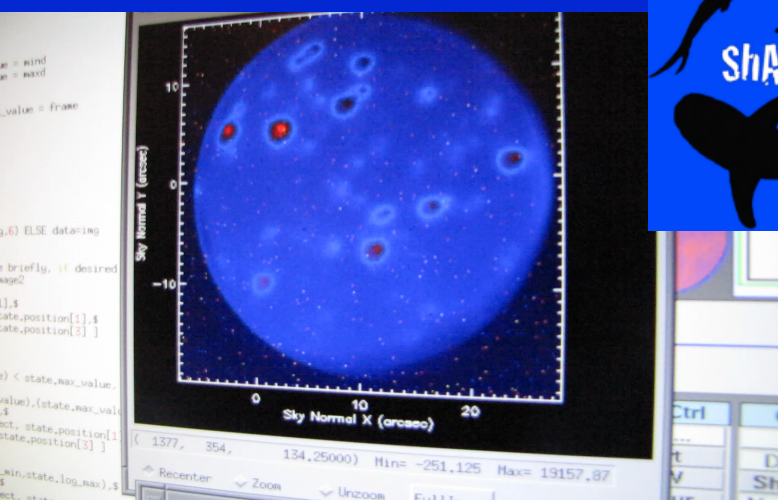

The purpose of this talk and this meeting

- The ShaneAO system saw first light in April, 2014
  - Demonstrated excellent Strehl performance across the near IR bands
  - The next obvious step is to add the new guide star laser, which is planned for the Spring of 2015.
  - There is presently an ongoing effort to improve the ease of operations and expand observational flexibility
- I propose that we take this meeting opportunity to set both near and long-term goals for further collaborative development that will maximize published science output from the system.

The Competition

Astronomy Publications

"Know the star, know the planet. IV. Discovery of late-type companions to two exoplanet host stars,"
L. Roberts, A. Tokovinin, B. Mason, R. Riddle, W. Hartkopf, N. Law & C. Baranec
in submission, 2014.

"Characterizing the Cool KOIs. VII. Refined physical properties of the eclipsing brown dwarf LHS6343C,"
B. Montet, J. Joh
Marcy, A. Howar
in submission, 20

"Know the star, k
exoplanet HD867
L. C. Roberts, B.
Bouchez, K. Bui,
Hale, J. Henning,
Ramaprakash, J.
in submission, 20

"Multiplicity of th
companions,"
C. Ziegler, N. M.
in submission, 20

"An ancient extra
T. Campante, T.
Isaacson, E. Quin
Chaplin, J. Christ
S. Hekker, C. Kar
Laerhoven, T. Ar
Sousa, A. Sozzett
in submission, 20

"The Near-Ultrav
M. Ansdell, E. Ga
Riddle, P. Mauas
The Astrophysica

"Characterizatior
companion HAT-I
M. Zhao, J. O'Ro
Baranec, R. Riddl
The Astrophysica

"A survey of the high-order multiplicity of nearby solar-type binary stars with Robo-AO,"
R. Riddle, A. Tokovinin, B. Mason, W. Hartkopf, L. Roberts, C. Baranec, N. Law, K. Bui, M. Burse, H. Das, R. Dekany, S. Kulkarni, S. Punnadi, A. N. Ramaprakash & S. Tendulkar
The Astrophysical Journal, in press, 2014.

"Characterizing the Cool KOIs VI. H- and K-band Spectra of Kepler M Dwarf Planet-Candidate Hosts,"
P. Muirhead, J. Becker, G. Feiden, B. Rojas-Ayala, A. Vanderburg, E. Price, R. Thorp, N. Law, R. Riddle, C. Baranec, K. Hamren, E. Schlawin, K. Covey, J. Johnson & J. Lloyd
The Astrophysical Journal Supplement, 213, 5, 2014.

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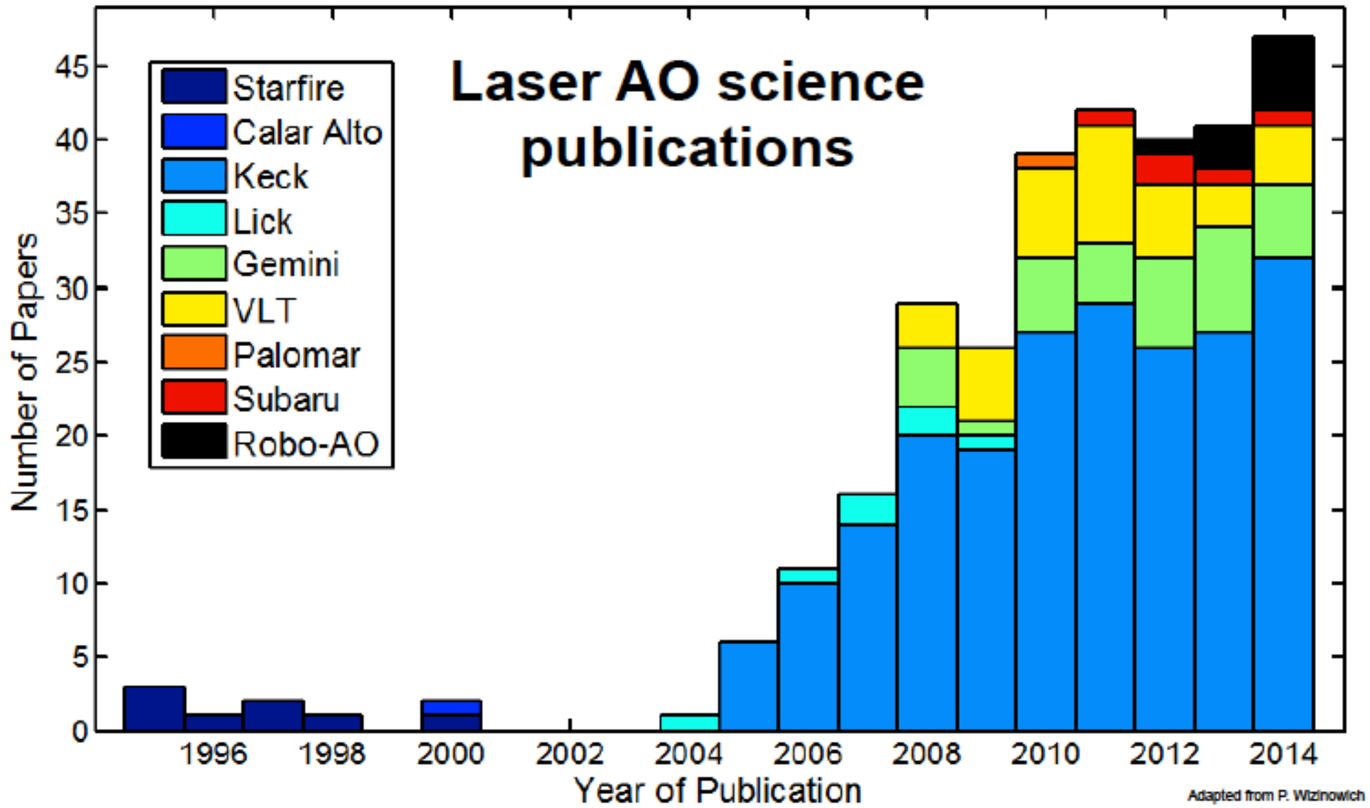
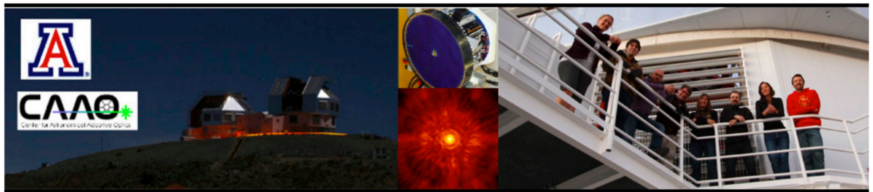


Magellan AO

The Homepage of the University of Arizona MagAO Team



Home | In The News | Results | Publications | Information For Observers | About Us | LCO

2013

Refereed Publications:

Bailey, V., et al. "HD 106906 b: A planetary-mass companion outside a massive debris disk".
ApJL, 780, L4, 2013 ADS preprint [pdf] arxiv preprint

Close, L. M., et al. "Diffraction-limited Visible Light Images of Orion Trapezium Cluster With the Magellan Adaptive Secondary AO System (MagAO)".
ApJ, 774, 94, 2013 ADS preprint [pdf] arxiv preprint

Follette, K. B., et al. "The First Circumstellar Disk Imaged in Silhouette at Visible Wavelengths with Adaptive Optics : MagAO Imaging of Orion 218-534".
ApJ, 775, L13, 2013 ADS preprint [pdf] arxiv preprint

Wu, Y. L., et al. "High Resolution H alpha Images of the Binary Low-mass Proplyd LV 1 with the Magellan AO System".
ApJ, 775, 45, 2013 ADS preprint [pdf] arxiv preprint

Kopon, D., et al. "Design, implementation, and on-sky performance of an advanced apochromatic triplet atmospheric dispersion corrector for the Magellan adaptive optics system and VisAO camera".
PASP, 125, 966, 2013 ADS preprint [pdf] arxiv preprint

IAUS 299 Proceedings:

Close et al. "Visible AO Observations at Halpha for Accreting Young Planets"
pdf

Follette et al. "Visible Light Adaptive Optics Imaging of the Orion 218-354 Silhouette Disk"
pdf

Males et al. "High Contrast Imaging of an Exoplanet with the Magellan VisAO Camera"
pdf

Morzinski et al. "Direct imaging of Beta Pictoris b with first-light Magellan Adaptive Optics"
Talk Slides pdf

2014

Refereed Publications:

Rodigas, T. J., et al. "On the Morphology and Chemical Composition of the HR 4796A Debris Disk"
APJ in press arxiv preprint

Skemer, A., et al. "Directly Imaged L-T Transition Exoplanets in the Mid-Infrared".
ApJ,792, 17, 2014 ADS arxiv preprint

Males, J. R., et al. "Magellan Adaptive Optics first-light observations of the exoplanet β Pic b. I. Direct imaging in the far-red optical with MagAO+VisAO and in the near-IR with NICI"
ApJ, 786, 32, 2014 ADS arxiv preprint

Close, L. M., et al. "Discovery of Hα Emission from the Close Companion inside the Gap of Transitional Disk HD 142527"
ApJ, 781, L30, 2014 ADS arxiv preprint

SPIE 2014:

Morzinski, K. M., et al. "MagAO: Status and on-sky performance of the Magellan adaptive optics system"
SPIE 9148 914804 ADS arxiv preprint preprint [pdf]

Close, L. M., et al. "Into the Blue: AO Science with MagAO in the Visible"
SPIE 9148 91481M ADS arxiv preprint preprint [pdf]

Males, J. R., et al. "Direct imaging of exoplanets in the habitable zone with adaptive optics"
SPIE 9148 914820 ADS arxiv preprint preprint [pdf]

Plans

ShaneAO Near Term Development Plans

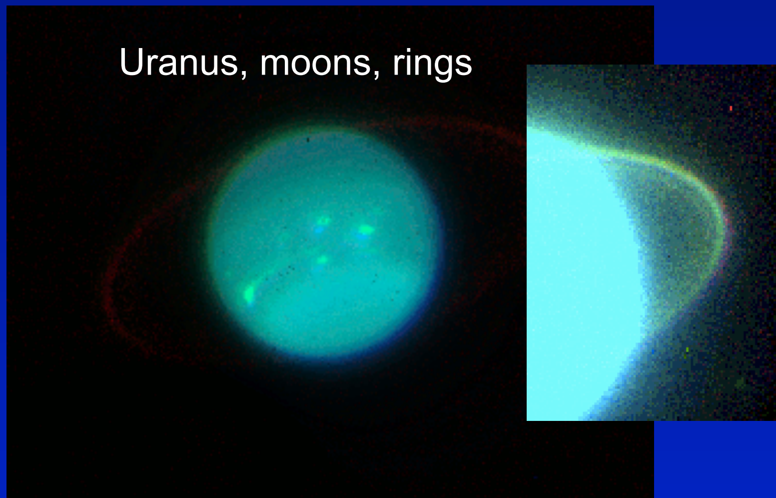
- Laser Guide Star – by mid semester A 2015
  - Funded project to deploy a fiber laser to replace the dye laser
  - 5-10x brighter guide star.
- "Wind-Predictive" Control
  - Enhance wavefront control by incorporating atmospheric wind models.
  - Two grad students involved: Alex Rudy, Srikar Srinath; in collaboration with Lisa Poyneer at LLNL
  - Leading to 30x mode - pressing to visible λ AO

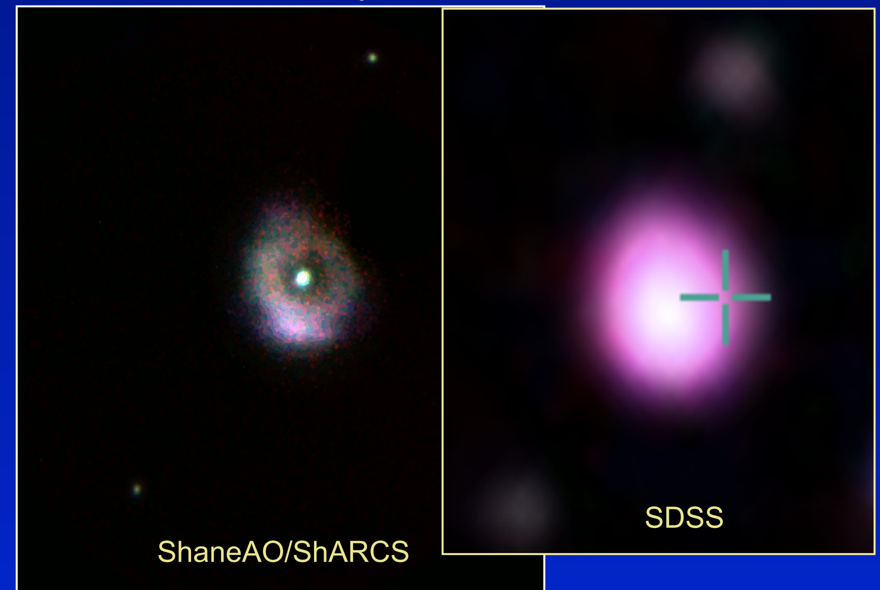
The objective is reliable and efficient science output

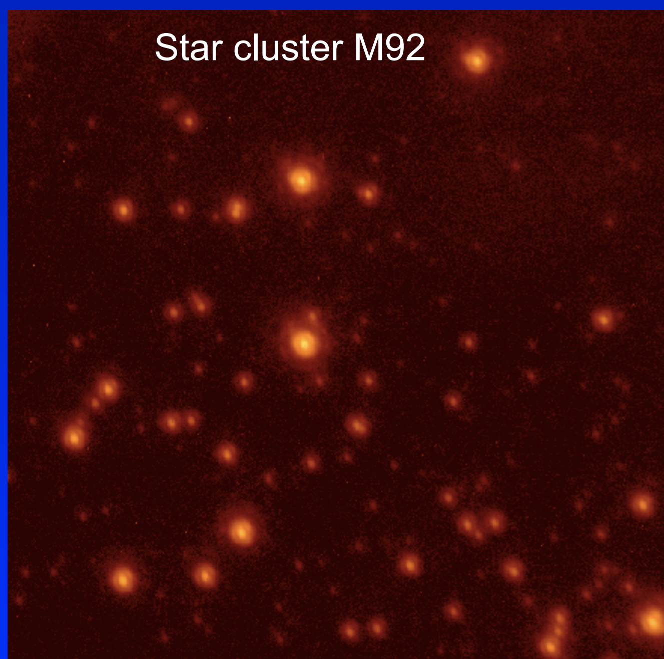
1. Observing prep
   – Exposure calculator
   – NGS selector
2. Data pipeline
   – Bad pixels remediation
   – Field distortion compensation
   – Photometric calibration
   – Help pages, software distribution and sharing
3. Operation
   – Efficient acquisition and lock on target
   – Field steering accuracy
   – Nod along slit accuracy
   – Long exposure track accuracy
4. Repairs need to be done
   – Various items need attention
     - ShARCS aperture wheel
     - NGS field steer mechanisms
     - TTS filter wheel
5. Improving access
   – Remote ops including LGS mode
   – Lower zenith angle limit
   – More nights assigned to LGS

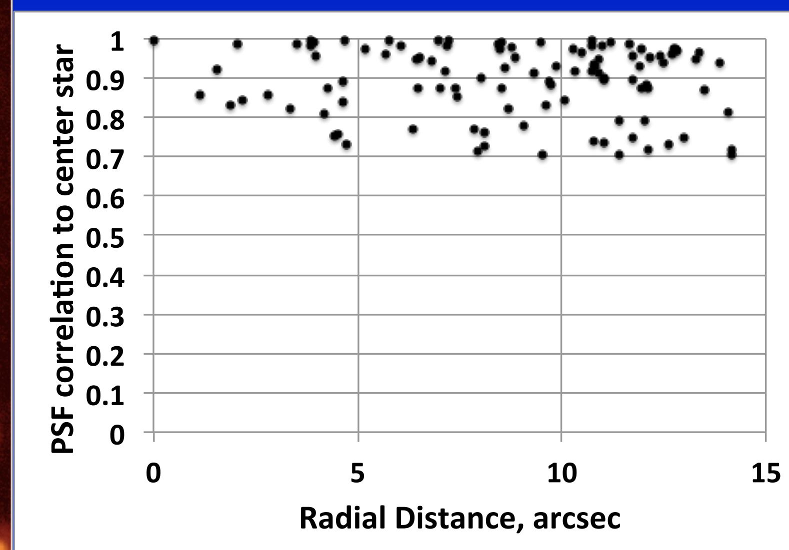
First Light Pictures
and PSF performance

Planetary Nebula IC 2003





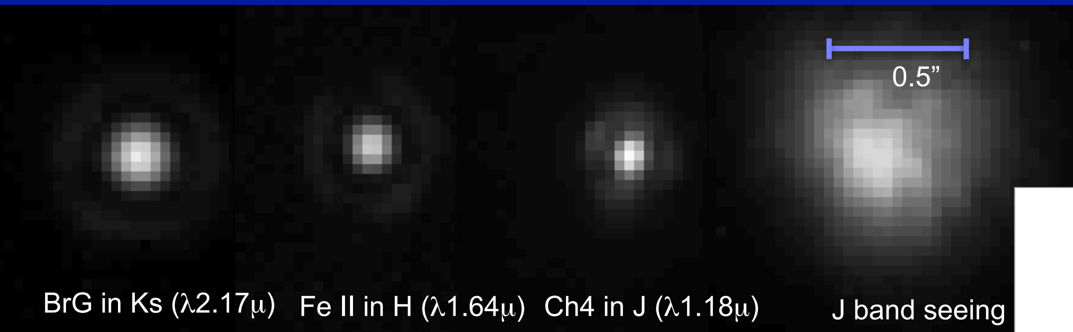




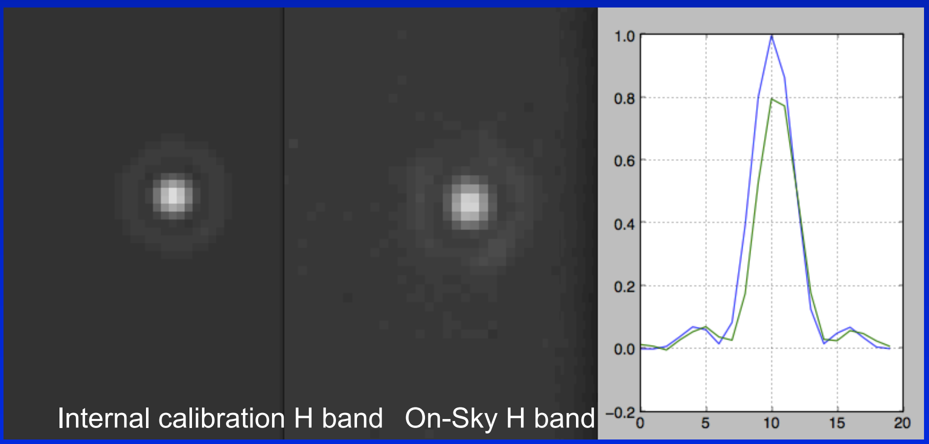
Diffraction-limit (note the Airy rings) everywhere in this 28 arcsec field
Hundreds of stars

Strehl

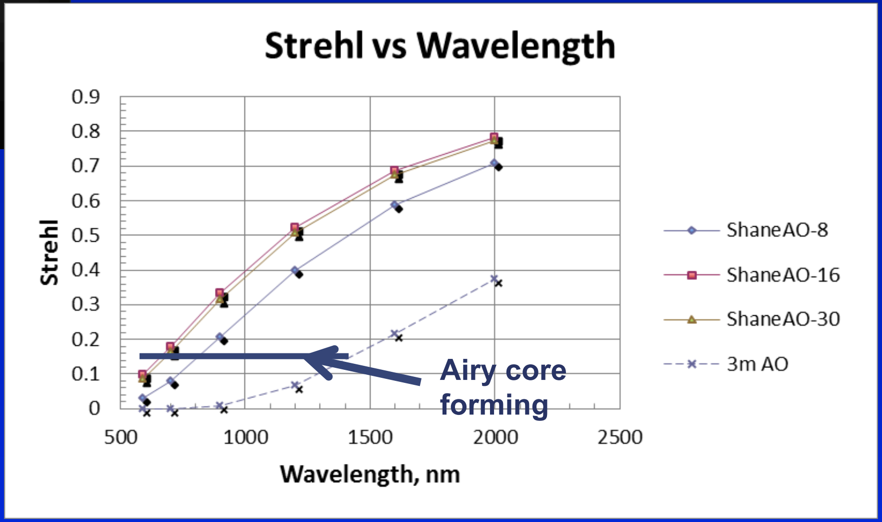
Ks H J



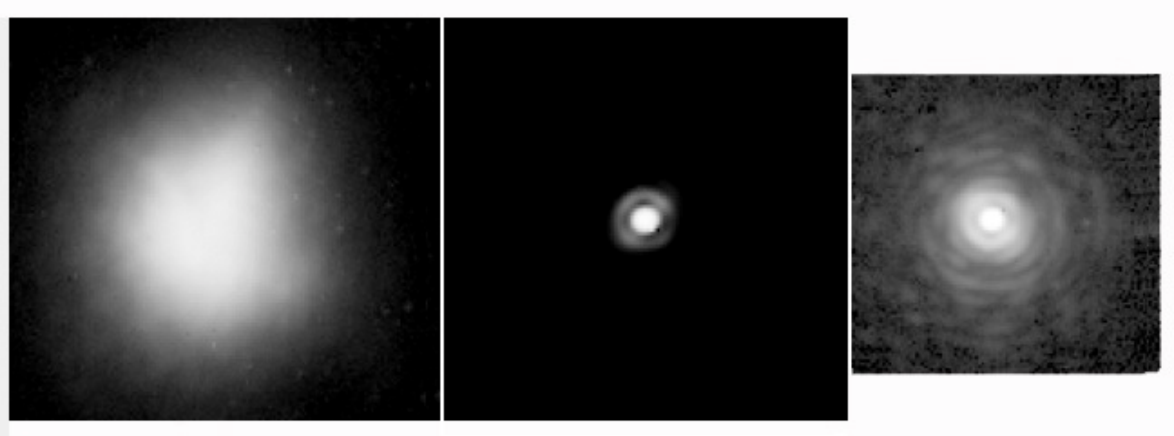
0.5”
BrG in Ks (λ2.17μ)
Fe II in H (λ1.64μ)
Ch4 in J (λ1.18μ)
J band seeing



Internal calibration H band
On-Sky H band
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
0
5
10
15
20



Strehl vs Wavelength
Strehl
Wavelength, nm
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
500
1000
1500
2000
2500
ShaneAO-8
ShaneAO-16
ShaneAO-30
3m AO
Airy core forming



Sensitivity

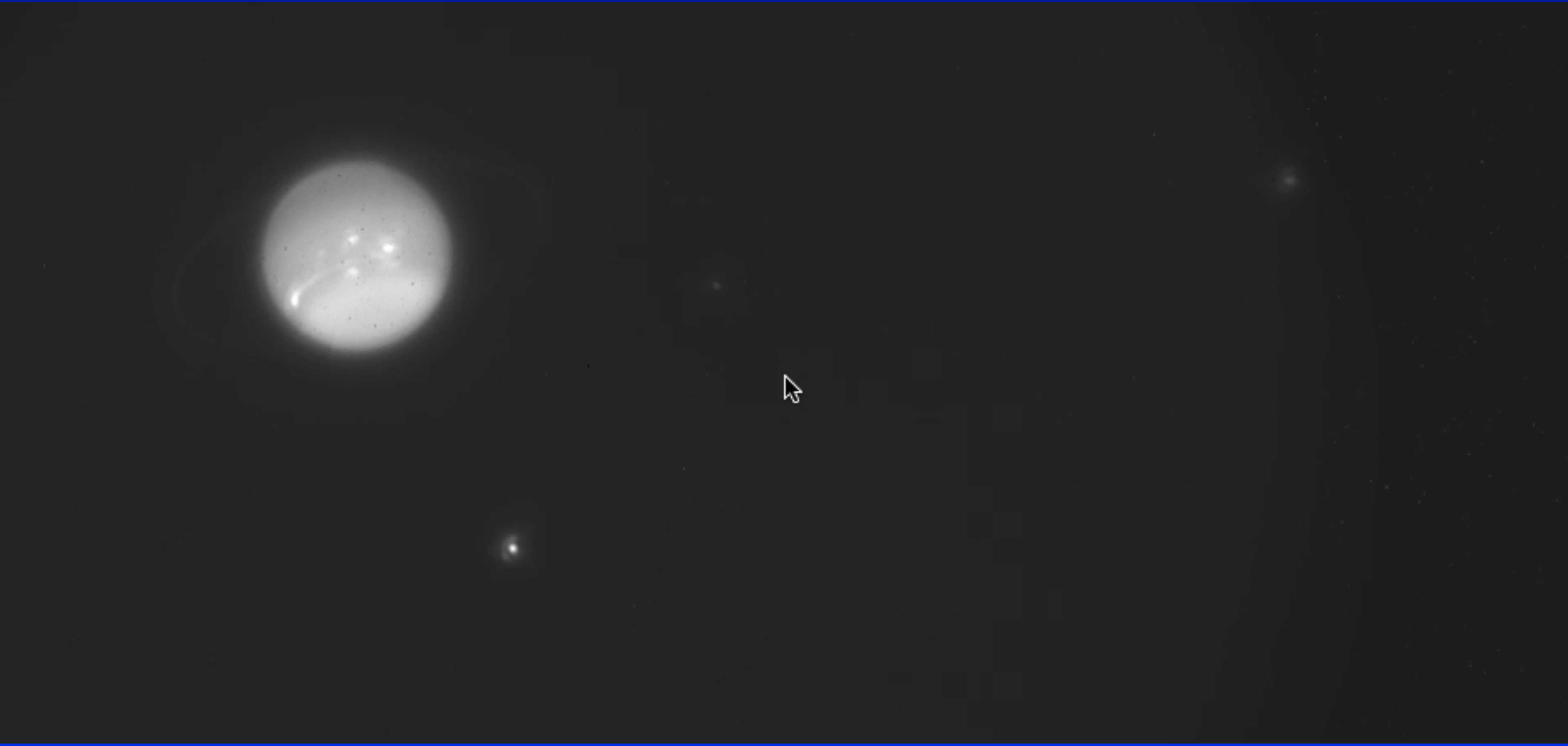
Summary of performance, current system	J-band	H-band	Ks-band	
Summary Throughput	16.6%	14.7%	16.9%	top of atmosphere to detected photons
Summary Emission	16.5	16.2	12.0	mag/band/as^2
Point source sensitivity SNR=5 t=300s	21.31	20.9	18.77	mag
Strehl	0.1	0.2	0.3	

Summary of performance, proposed new system		J-band	H-band	Ks-band	
Summary Throughput		18.4%	20.3%	23.0%	top of atmosphere to detected photons
Summary Emission		16.5	16.3	12.2	mag/band/as^2
Point source sensitivity SNR=5 t=300s		22.93	22.49	20.10	mag
Strehl		0.4	0.6	0.7	
Speed improvement	(exp time to same mag pt src)	18	16	12	times faster than current system

Keys to AO science performance

- High Strehl
  - 32x32 MEMS DM
  - choice of 10 or 20 cm subaps with brighter LGS
- High optical throughput
  - "Holy Grail" silver coatings
  - Note: we're ignoring K-long for now, which may require cooling. Cooling will require windows and throughput loss, plus additional expense.
- Improved QE of Hawaii RG detector: 80% vs 62%
- Very efficient observing sequences – open shutter time with the loop closed
- Reliable and consistent system
  - Stable components and software system – high % uptime
  - High mechanical stiffness – long exposures at the diffraction limit
  - Graceful degradation and adaptive to changing seeing conditions

Uranus, Rings, Moons



Click on the image - it's a movie

Note the motion: rotating planet and orbiting moons

3 rings are resolved

Star cluster M92

Diffraction-limit (note the Airy rings) everywhere in this 28 arcsec field

Hundreds of stars

Mt Hamilton Seeing

- Mt Hamilton seeing is anecdotally 1.25 to 1.5 arcseconds FWHM of star in mid visible (V-band)
- Years of data collection (from telescope guider cameras) seem to support this

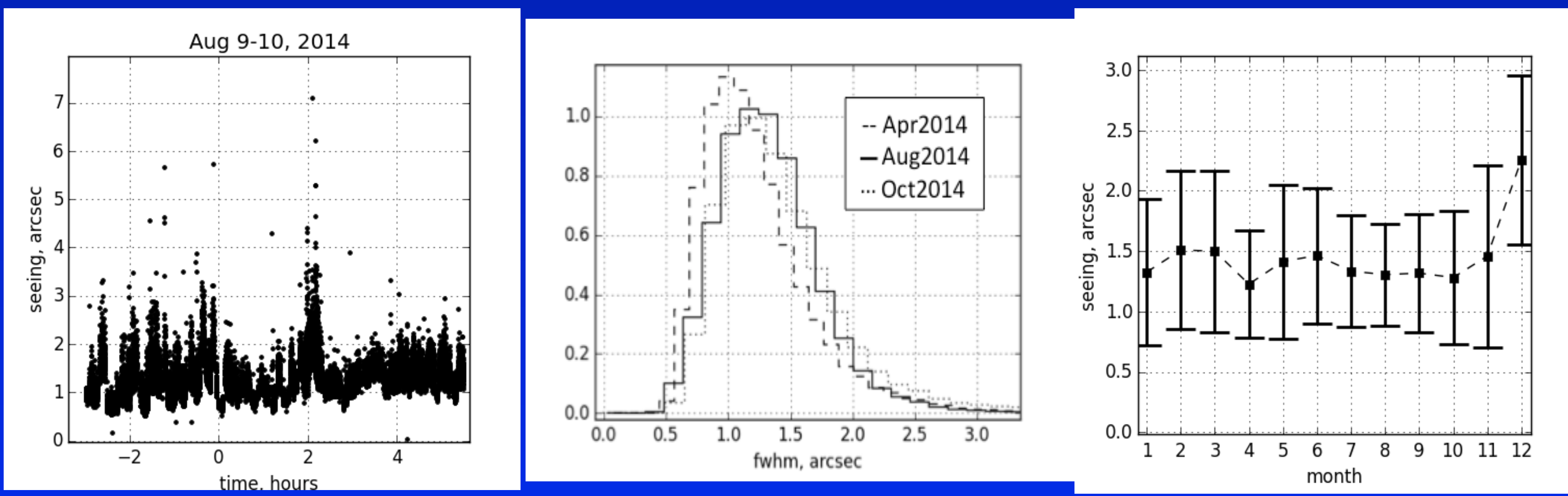
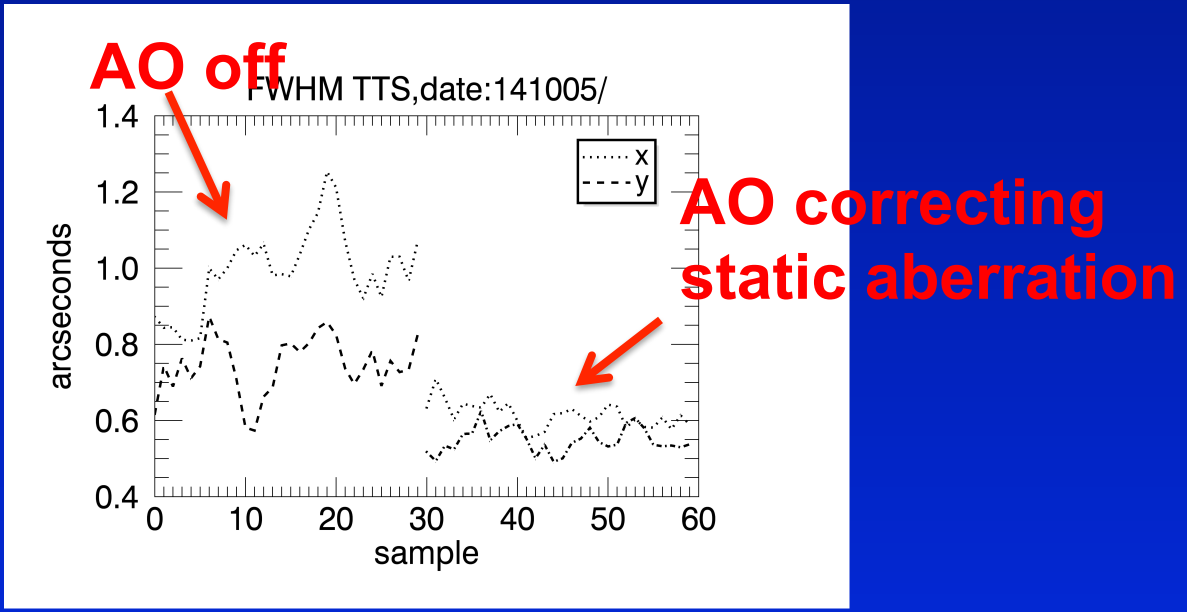


Figure 1 Seeing data from the APF guider. Left, time series from one night's observing with data taken every few seconds. Histogram of seeing for several months. Right average seeing on a monthly basis over the past year.

ShaneAO can measure "free-seeing"
independent of telescope and dome



- There is evidence that free seeing of the Mt. Hamilton site is ***much better*** than 1.25 arcsec, more like 0.7 arcsec
- We will be collecting seeing data every AO night
- Submitted a proposal to construct a seeing monitor – this will complement observing programs (e.g. PSF estimator)
- Future AO development at Lick may be impacted by results
- Future Mt Ham site use may be impacted by results

Bottom line: We want to work with you to make ShaneAO/ShARCS a productive science instrument