W. M. Keck Observatory
Subaru Users Meeting

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January 16, 2013

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Keck / Subaru Exchange Program

Benefits of Time Exchange

- Expands observing capabilities for each community
  - Subaru's unique wide-field capabilities
  - Keck's powerful spectroscopic & adaptive optics capabilities
- Economical: new instruments are expen$ive
- Brings Keck and Subaru communities closer together
- Contributes to Mauna Kea Observing System
  - As capable as any on Earth

Subaru-Keck Exchange & Capabilities Offered

- Subaru
  - Initiated in semester 2007B
  - Suprime-Cam: wide-field optical imager
  - MOIRCS: IR imager & multi-object spectrograph
  - Expanded to also include FOCAS, HDS, IRCS (with NGS AO), FMOS, and COMICS
  - Up to 6 nights / semester

Subaru-Keck Exchange & Capabilities Offered

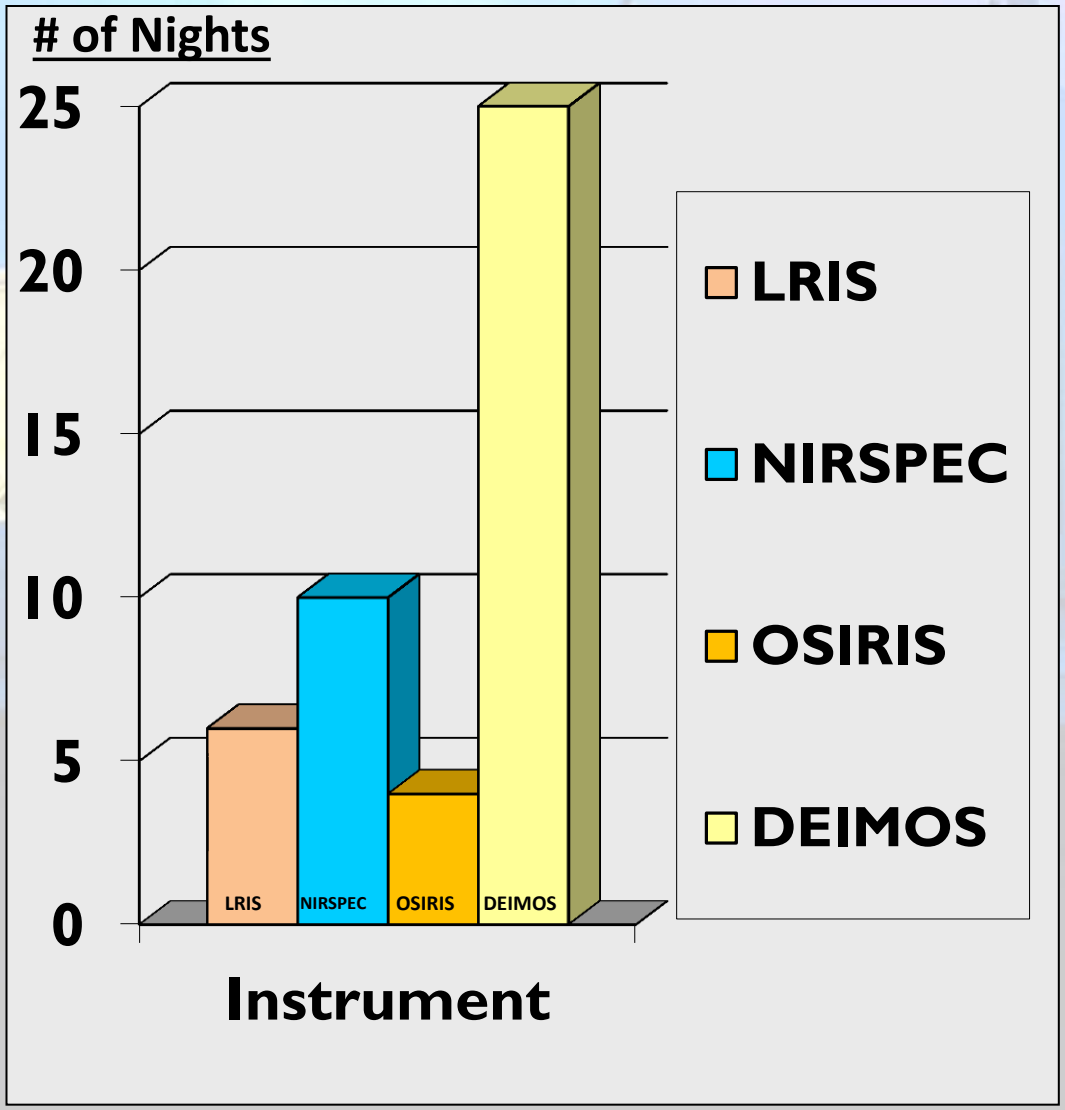
- **Keck I**
  - LRIS: multi-object optical spectrograph
  - OSIRIS: adaptive optics near-infrared integral-field spectrograph
  - MOSFIRE: new multi-object infrared spectrograph
  - maximum of two Keck I nights
- **Keck II**
  - DEIMOS: wide-field multi-object optical spectrograph
  - ESI: moderate-resolution optical spectrograph
  - NIRSPEC: infrared spectrograph
  - NIRC2: adaptive optics infrared imager (& spectrograph)
  - maximum of four Keck II nights
- Maximum of two laser guide star nights

Keck Community Usage of Subaru

Semester	PI	Instrument	# of nights
2007B	Brown	Suprime-Cam	2
2007B	Ellis	Suprime-Cam	2
2008A	Brown	Suprime-Cam	2
2008A	Steidel	MOIRCS	2
2008B	Brown	Suprime-Cam	2
2008B	Brodie	Suprime-Cam	2
2009A	Wilson	MOIRCS	1
2009A	Brown	Suprime-Cam	2
2009B	Stanford	Suprime-Cam	2
2009B	Fraser	Suprime-Cam	1
2010A	Stanford	Suprime-Cam	2
2010A	Brodie	Suprime-Cam	1
2010B	Stanford	Suprime-Cam	1
2010B	Steidel	MOIRCS	2
2010B	Brodie	Suprime-Cam	1

Semester	PI	Instrument	# of nights
2011 A	Stanford	Suprime-Cam	1
2011 A	Bullock	Suprime-Cam	1
2011 A	Spencer	Suprime-Cam	1
2011 B	Stanford	MOIRCS	3
2011 B	Hansen	MOIRCS	1
2011 B	Brown	IRCS+AO	2
2012 A	Hansen	MOIRCS	1
2012 A	Spencer	Suprime-Cam	1
2012 B	Spencer	Suprime-Cam	1
2012 B	Hansen	MOIRCS	1
2012 B	Brown	Suprime-Cam	2
2013 A	Brown	Suprime-Cam	2
2013 A	Wittman	Suprime-Cam	1
2013 A	Zuckerman	Comics	1
2013 A	Weaver	Suprime-Cam	3

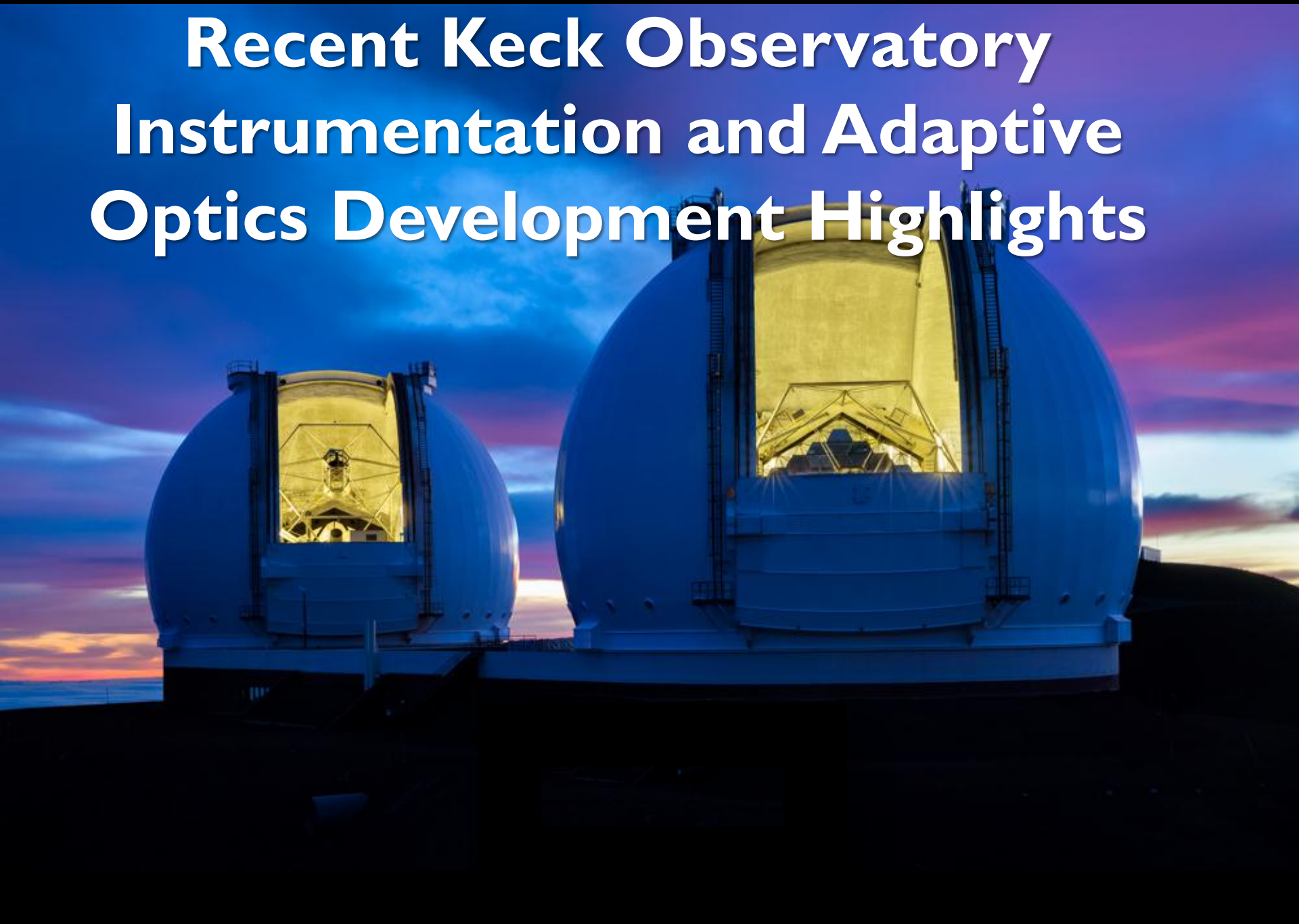
Subaru Time on Keck Instruments
(2007B thru 2013A)



Potential Future Time Exchange Opportunities

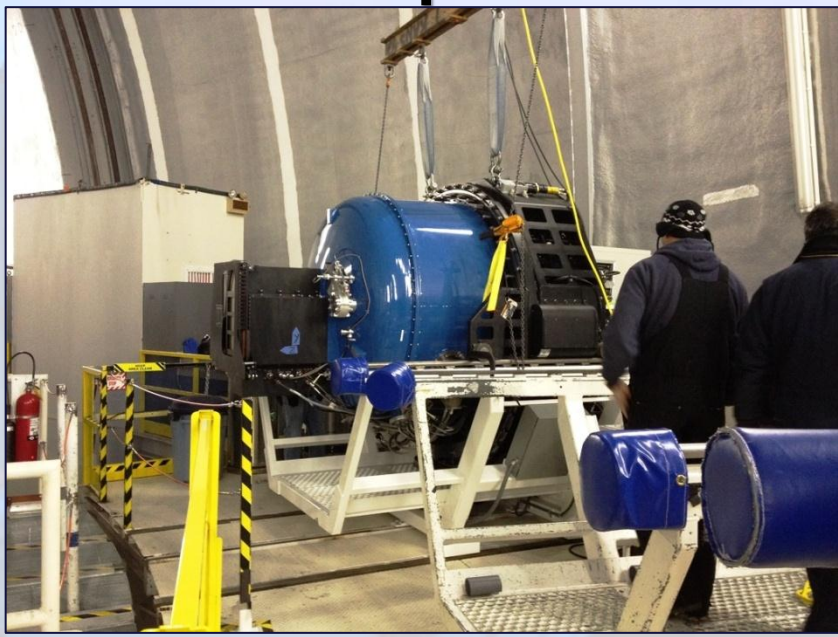
- **Subaru**
  - Hyper Suprime-Cam
  - Prime Focus Spectrograph
- **Keck**
  - NIRES
  - Keck Cosmic Web Imager (KCWI)
  - Performance enhancements to adaptive optics
- Both observatories: could expand to additional nights if there is sufficient interest

Recent Keck Observatory Instrumentation and Adaptive Optics Development Highlights

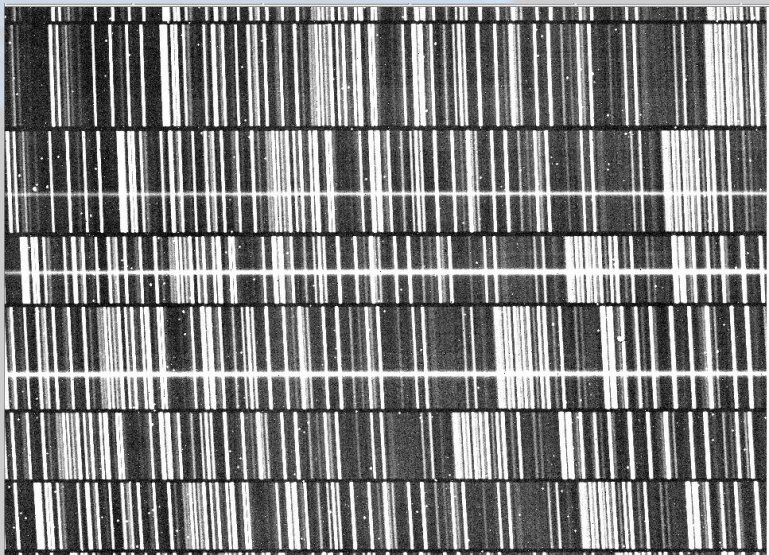


MOSFIRE

Multi-Object Spectrometer For InfraRed Exploration

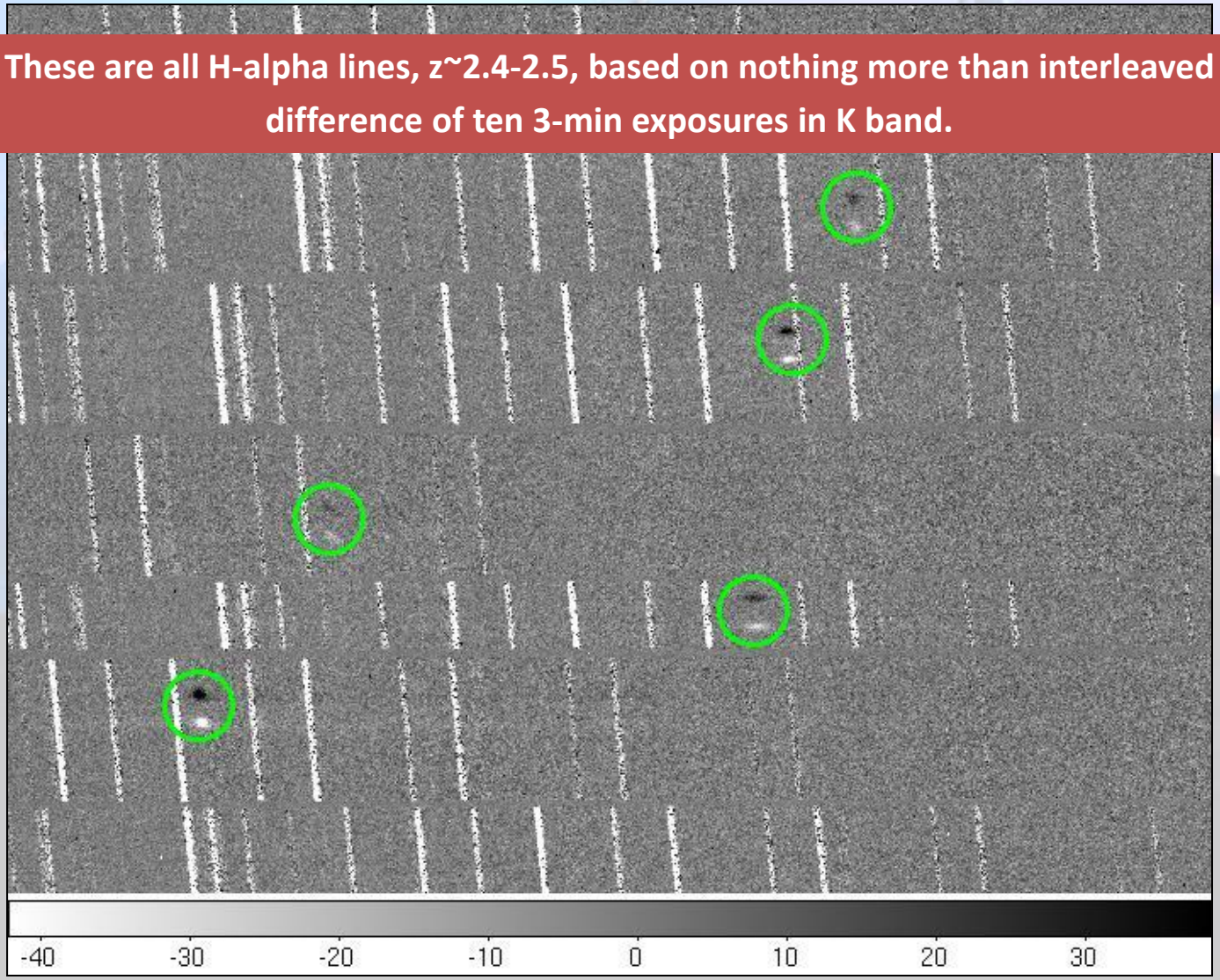


- Near-IR Multi-Object Imaging Spectrometer
  - 0.97 to 2.45 μm
- Keck I + MOSFIRE provide:
  - R = 3,270 for a slit width of 0.7"
  - 46 slits over 6.1' x 3' FOV using a remotely configurable slit mask unit
  - Imaging FOV 6.14' diameter with 0.18" pixels
- Unique capability worldwide
- Commissioning complete
- Over 50 nights of science observing in semester 2012B
- Now WMKO's most popular instrument



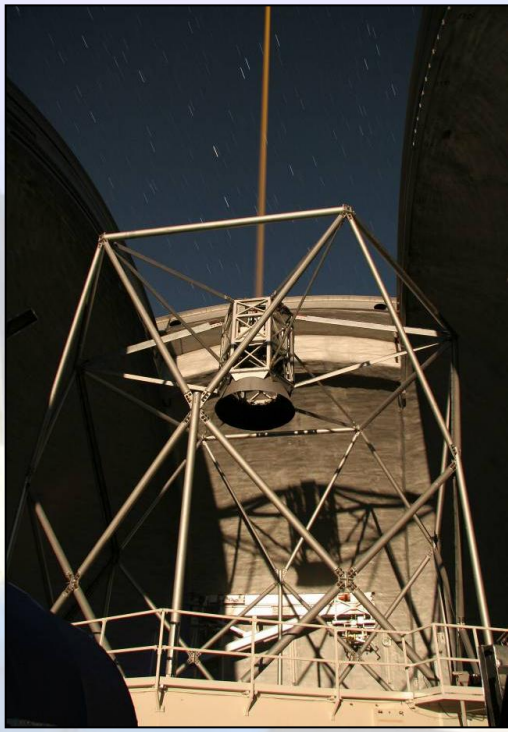
Example spectra: nodded pair in K-band

These are all H-alpha lines, z~2.4-2.5, based on nothing more than interleaved difference of ten 3-min exposures in K band.

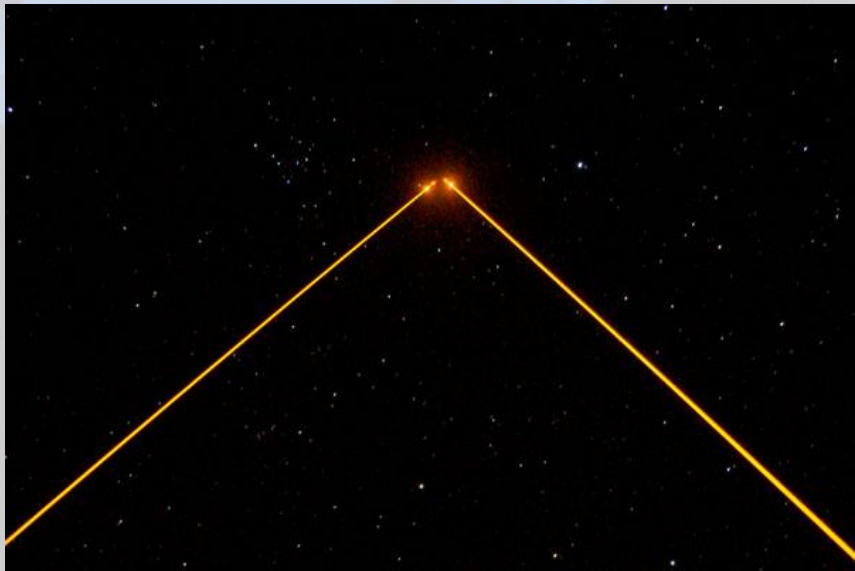


Keck I
Laser Guide Star Adaptive Optics

Keck I Laser Guide Star Adaptive Optics

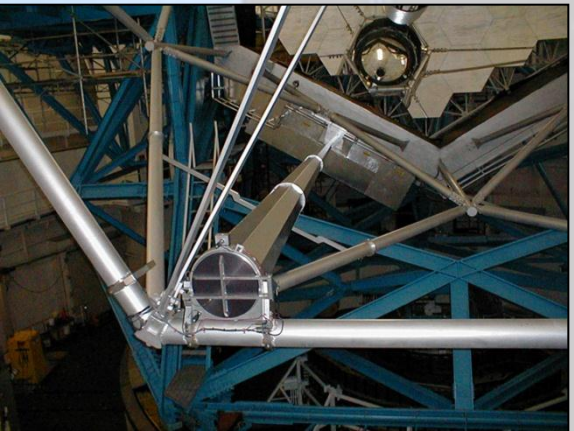


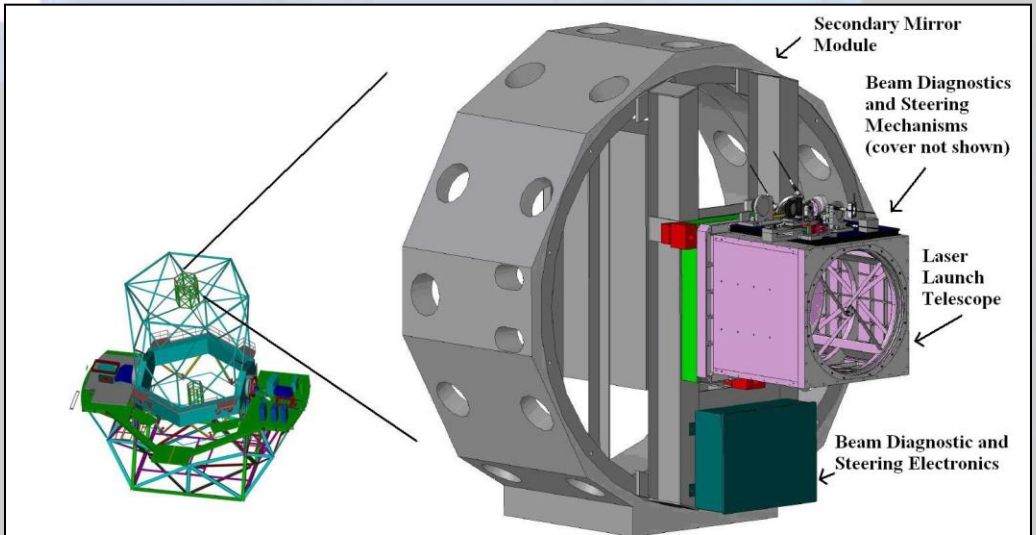
- Motivation
  - Improved performance relative to K II LGS AO
  - Redundancy
- Brighter LGS AO spot
  - New solid-state laser
  - Spot 44% brighter than K II on dual LGS night
- Better performance from center projection (vs. side projection)
  - Spot elongation reduced
  - 37% smaller spot than K II on dual LGS night
- OSIRIS moved from K II to K I
  - NIRC2 remains with K II LGS-AO system
- Shared risk science commenced as planned in May 2012
  - Positive observer feedback
- New OSIRIS grating installed recently
  - Higher efficiency, particularly at shorter wavelengths



Implement Center Laser Launch for Keck II LGS-AO

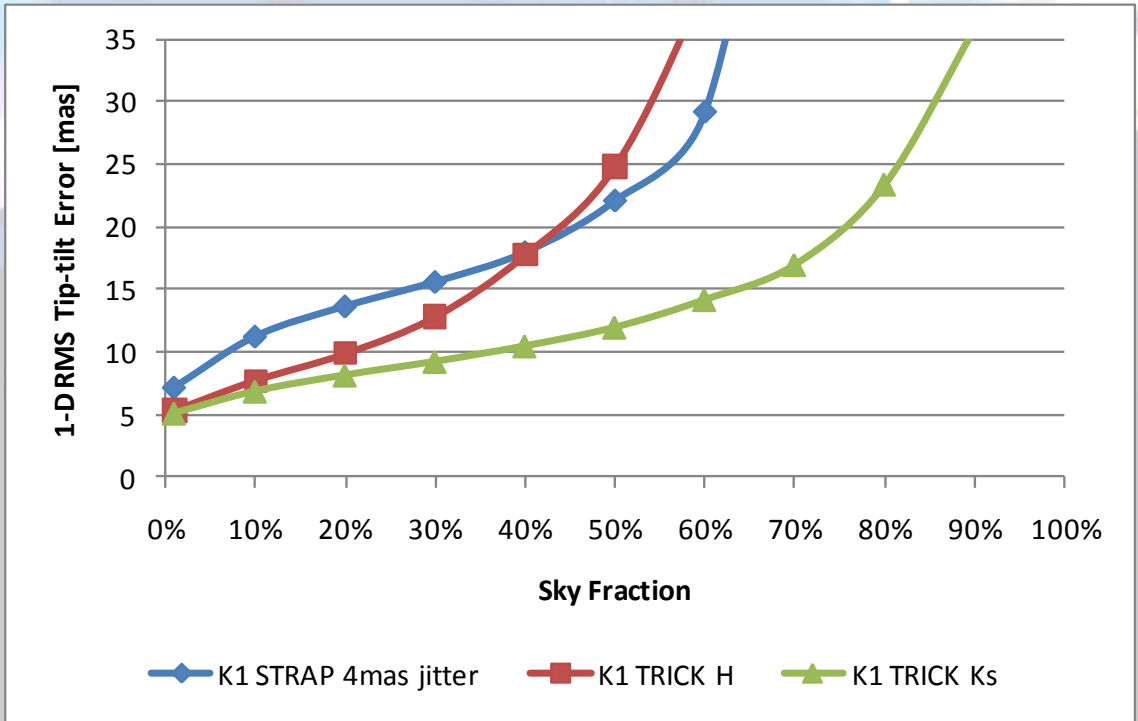
- Improve Keck II LGS AO performance
- Serve as launch telescope for NGAO
- First light planned for early 2014
- Funded by public-private partnership





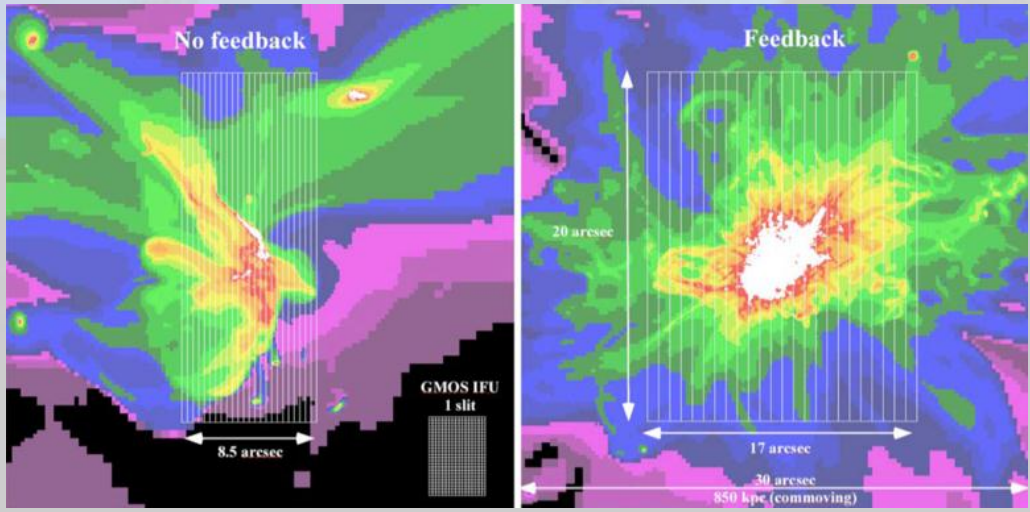
Keck I AO IR Tip-Tilt

- Implement near-IR tip-tilt sensor for KI LGS AO
  - Dramatically increases sky coverage and improves Strehl by decreasing contribution of tip-tilt errors
    - particularly in absence of optically bright tip-tilt star
  - Passed Detailed Design Review in February 2012
  - Supported by NSF ATI program
  - First light: semester 13B



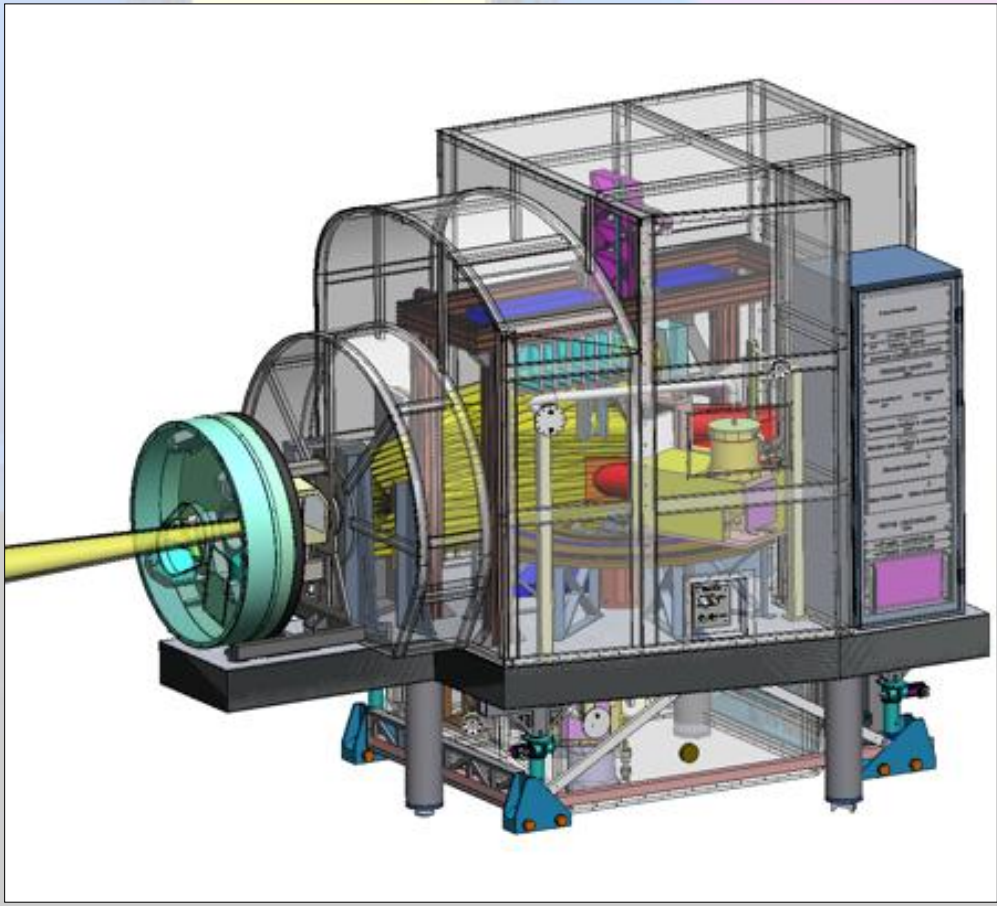
KCWI
Keck Cosmic Web Imager

- KCWI: optical integral-field spectrograph for Keck II
- Example science drivers
  - Low-surface-brightness galaxies
  - Galaxy kinematics
  - Galactic superwinds / feedback
  - Circum-galactic medium 2<z<7
  - Circum-QSO medium
  - z~6 reionization bubbles
  - Strong lens systems
  - Jets from young stars
  - Supernova light echoes



KCWI Design & Progress

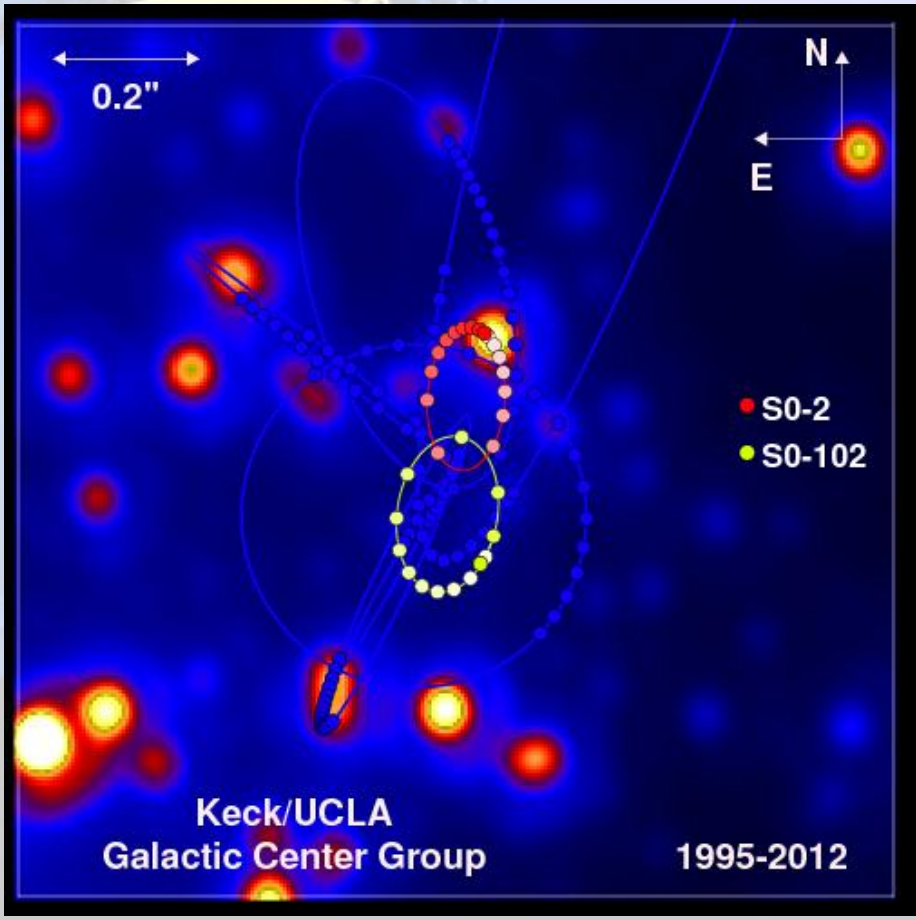
- (8-30) arcsec x 20 arcsec field
- R~1000-20,000
- 2 channels, 0.35-1.0 μm
- Flexible sampling, FOV, resolution
- High efficiency (~30%)
- Designed for precision sky subtraction
- Funded primarily by TSIP
- Detailed Design Review: November 19-20, 2012



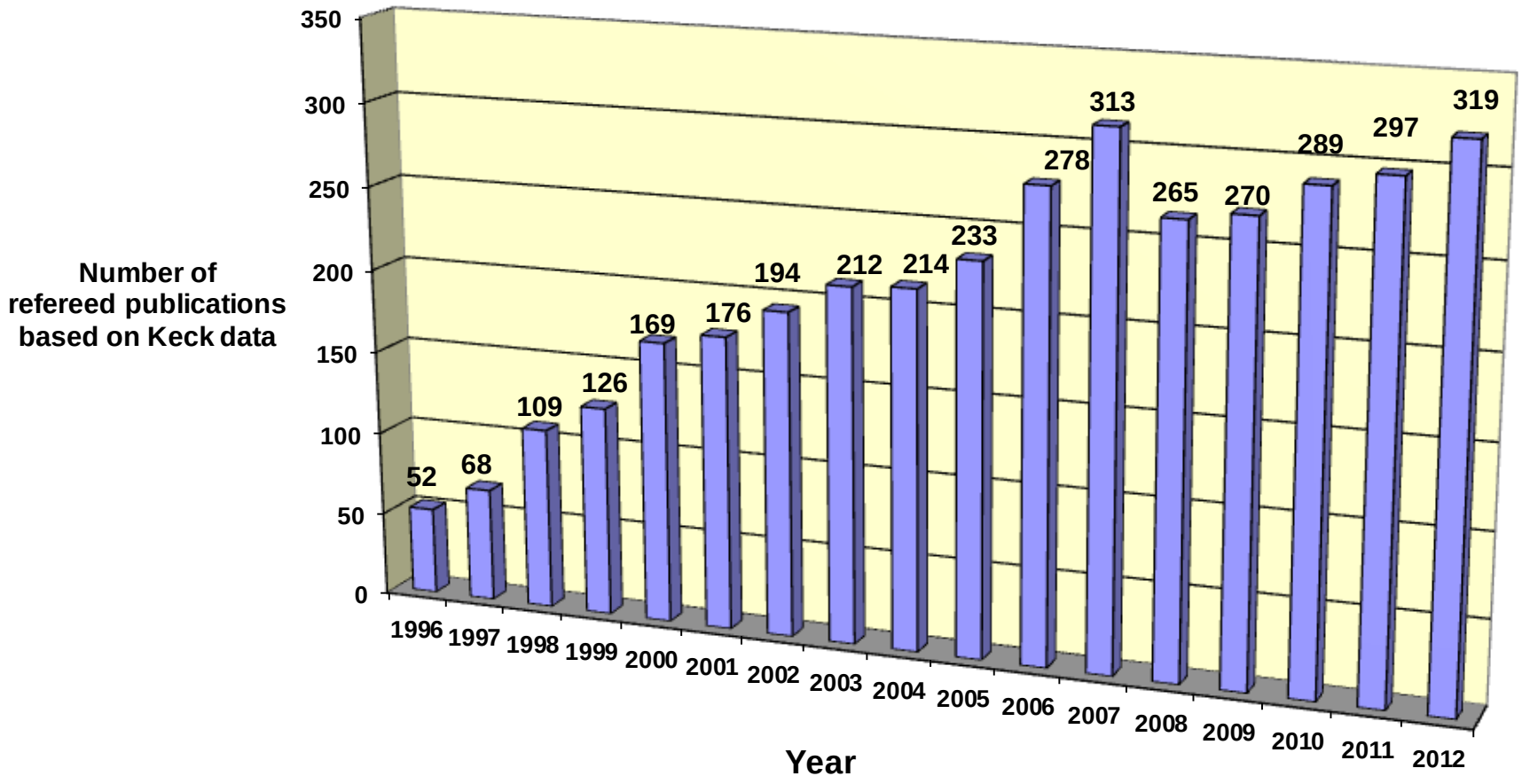
Scientific Productivity

Keck Adaptive Optics Discovers Pivotal Star to Test General Relativity

- S0-2 is previously known star closest to Galactic Center black hole: 16 year period
- S0-102 is newly discovered star with 11.5 year period
- Improvements in Keck AO enable fainter stars to be discovered and studied
- Meyer, Ghez, et al. 2012, Science **338**, 84

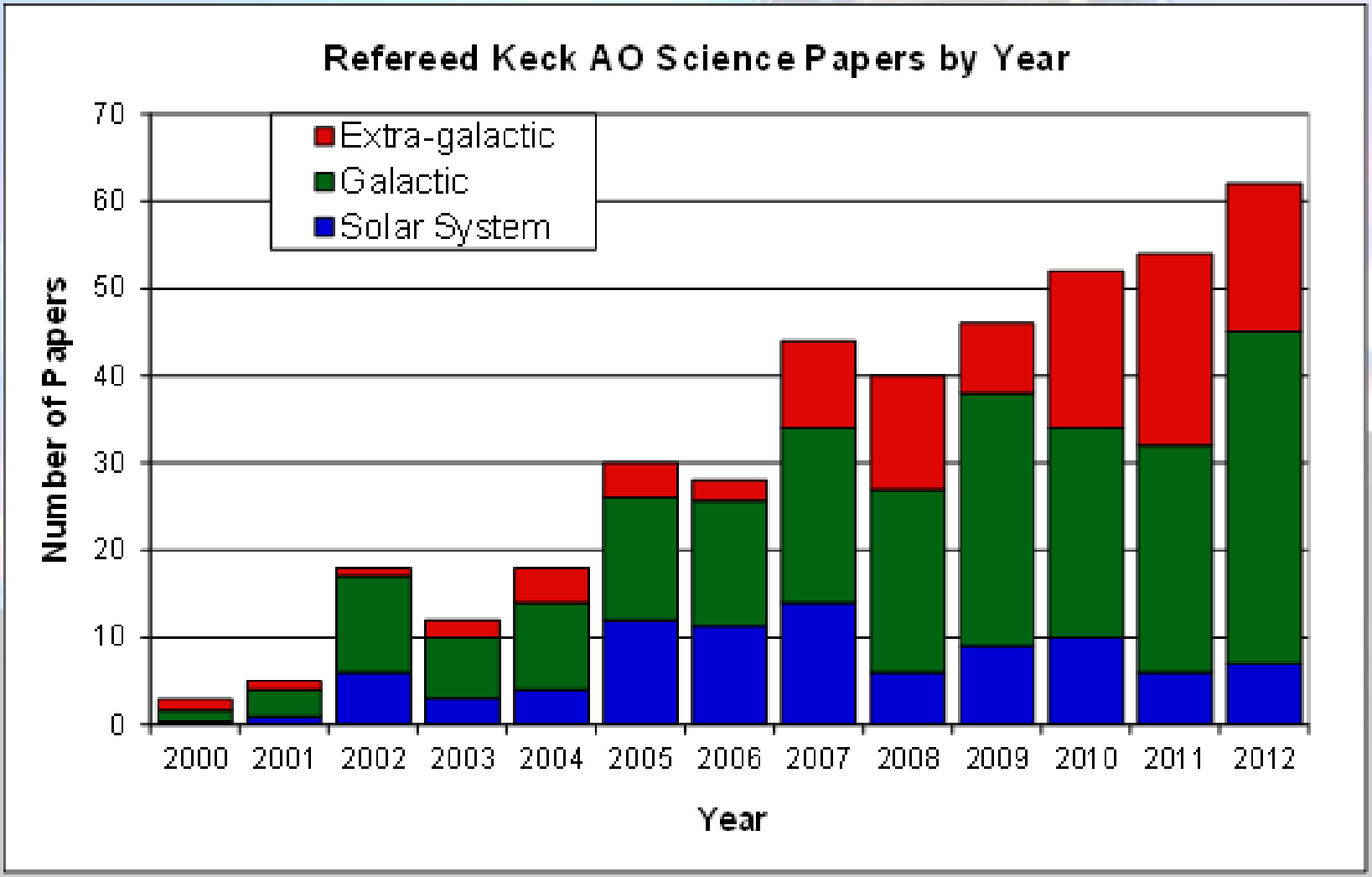


Number of Publications per Year

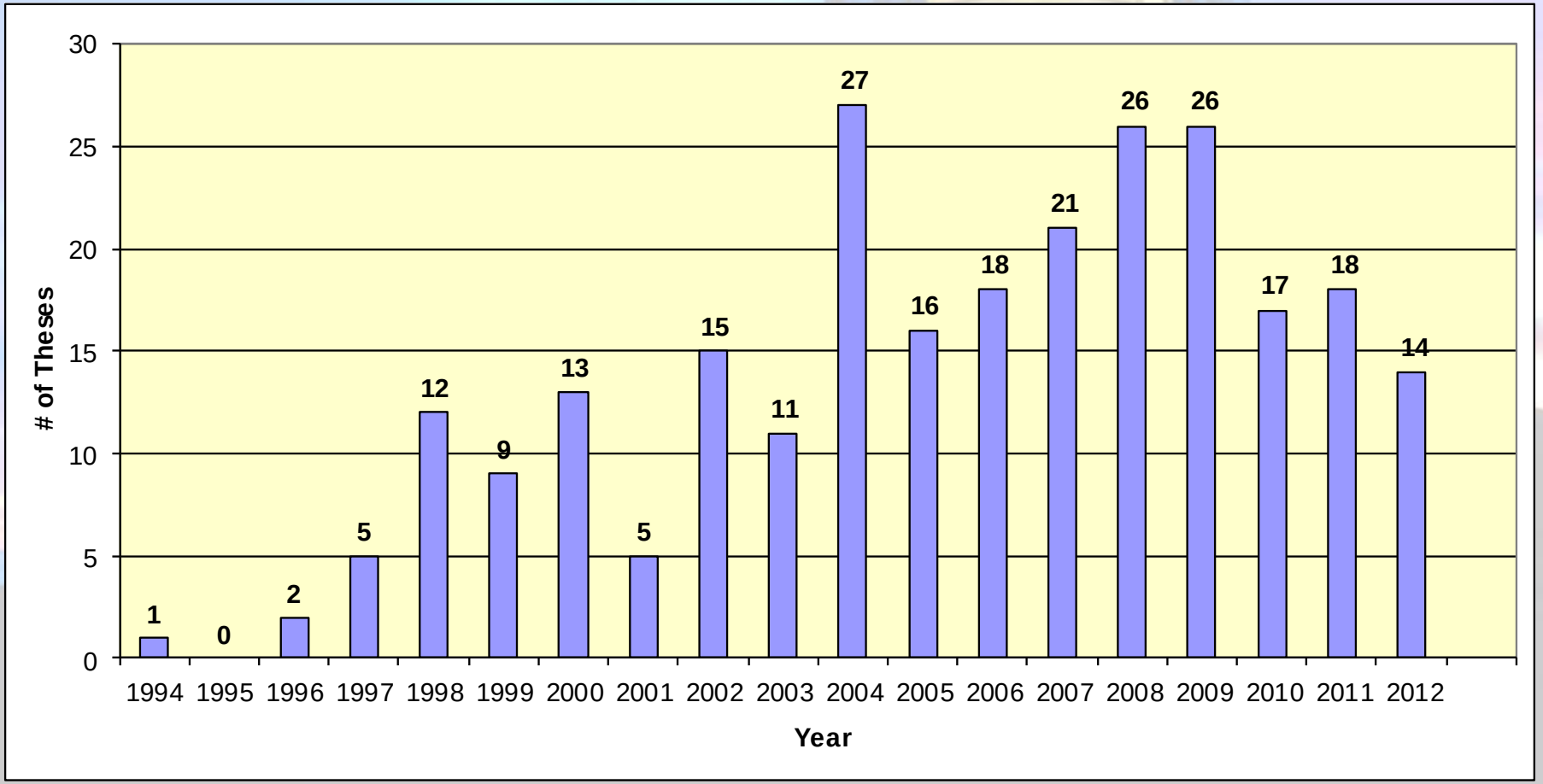


Number of refereed publications increasing over time

Adaptive Optics Publications Per Year



Ph.D. Theses Based on WMKO Observing



- Strategic Goal: Training the future leaders of the field

Keck Observatory and our science community strongly value our collaboration with Subaru