IRCS+AO188 decommission?

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IRCS

- AO assisted NIR imager and spectrograph
- Wavelength coverage:
  - 1-5 micron (Aladdin III 1024x1024 InSb array)
- Observing mode
  - Imaging (20mas, 52mas), FOV~20”x20” or 53”x53”
  - Low-resolution grism spectroscopy (20mas, 52mas, R<2000)
  - High-resolution echelle spectroscopy (55mas, R~5,000-20,000)
- History
  - 2000 : First light
  - 2001~2005: AO 36
  - 2005: Moved to NsIR and used w/o AO until 2008
  - 2008~: AO188
  - 2011~: LGS mode
  - 2013: spectro-polarization mode
- Stably operated without major problems so far

IRCS: Science Case

- AO assisted high-resolution images
  - Resolve high-z galaxies
  - High-contrast imaging with ADI mode
- Thermal infrared (L, M) band imaging/spectroscopy
  - SEEDS follow-up --- low-resolution spec.
  - Dust obscured AGN --- low resolution spec.
  - ISM (or IGM) --- high-resolution spec.
  - Radial Velocity measurement with NH3 gas-cell
- Fast readout imaging mode (up to ~160 Hz)
  - Lucky imaging
  - High temporal resolution (pulsar, flare from SgrA*)

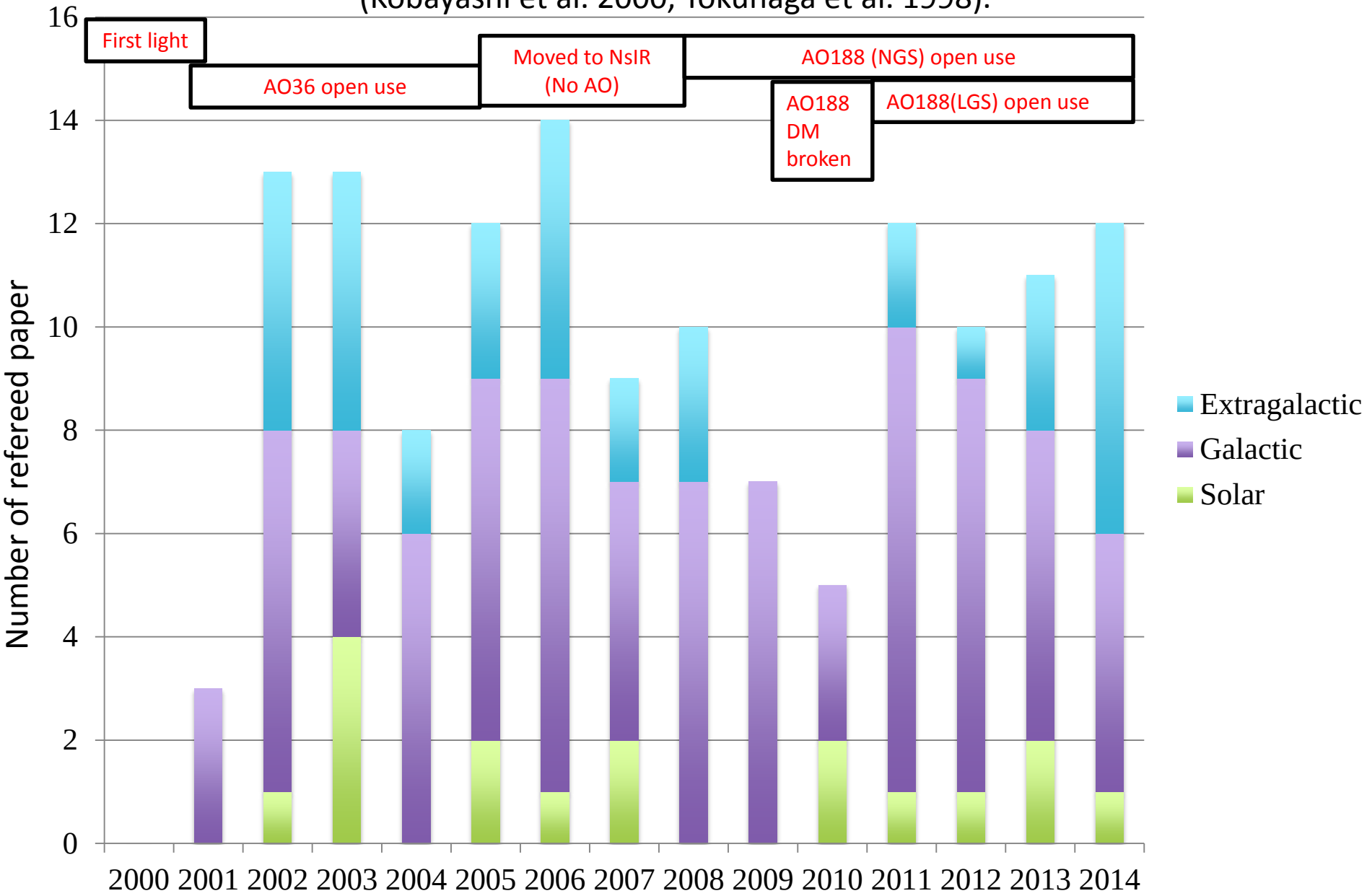
Alternative instruments

- Imaging/low-resolution spectroscopy
  - Keck NIRC2 --- AO performance is slightly better
  - Gemini NIRI+Altair --- AO performance is almost similar
  - VLT NACO --- low thermal background
- High-resolution spectroscopy
  - Keck NIRSPEC – almost similar to IRCS
  - Gemini NIFS (R~5000) – lower spectral resolution than IRCS
  - VLT CRIRES – a bit better spectral resolution than IRCS
- The modes not covered by IRCS
  - mid-resolution spectroscopy (R=2000-5000)
  - IFU (Keck OSIRIS, Gemini NIFS, VLT SINFONI)

Note: all of the alternative instruments are already more than 10 years old (same age as IRCS).

IRCS science publication history

Number of refereed science papers which cite IRCS instrument papers
(Kobayashi et al. 2000, Tokunaga et al. 1998).



Recent upgrade for IRCS

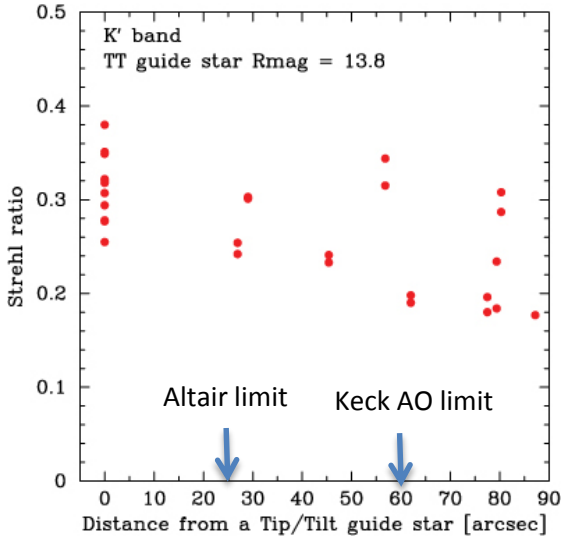
Shri Kulkarni's Subaru Seminar

- *The usable lifetime of instruments, if not upgraded, is 10 years*
- *Upgrades increase the productivity of instruments at very low cost*

- 2008-2011 AO upgrade (AO36→AO188+LGS)
  - Number of extragalactic program is increasing
- 2013: New filters, grism
  - Follow-up emission line galaxies discovered by MOIRCS survey with Subaru's unique NB filter set
- 2013: Spectro-polarization mode in YJHK
  - unique capability, which is not available with the similar instruments at the other telescope
- 2014 or Future: TBD
  - Expand the wavelength coverage of the polarization mode up to L-band

AO188

- 188 elements curvature WFS and bimorph DM
- Used with IRCS, HiCIAO, Kyoto-3DII, SCExAO, CHARIS, IRD
- History
  - 2008 NGS open use
  - DM broken
  - 2011 LGS open use
- Alternative
  - Keck: (NIRC2, NIRSPEC, OSIRIS)
  - Gemini: Altair (NIRI, GNIRS), GEMS (GSAOI, FLAMINGOS, GMOS)
  - VLT: NAOS (NACO), SINFONI, CRIRES



- Uniqueness of AO188
  - AO performance is almost same as the other 8-10m telescope AO system
  - The area for finding TTGS for the LGS mode is the widest among the AO system at Maunakea
- Weakness of AO188
  - No NIR IFU capabilities
  - A bit larger overhead due to immature operation procedure
  - Faint LGS (the laser power is the weakest)

Comparison with the other AO system

from Peter Wizinowich's presentation at Keck strategy meeting

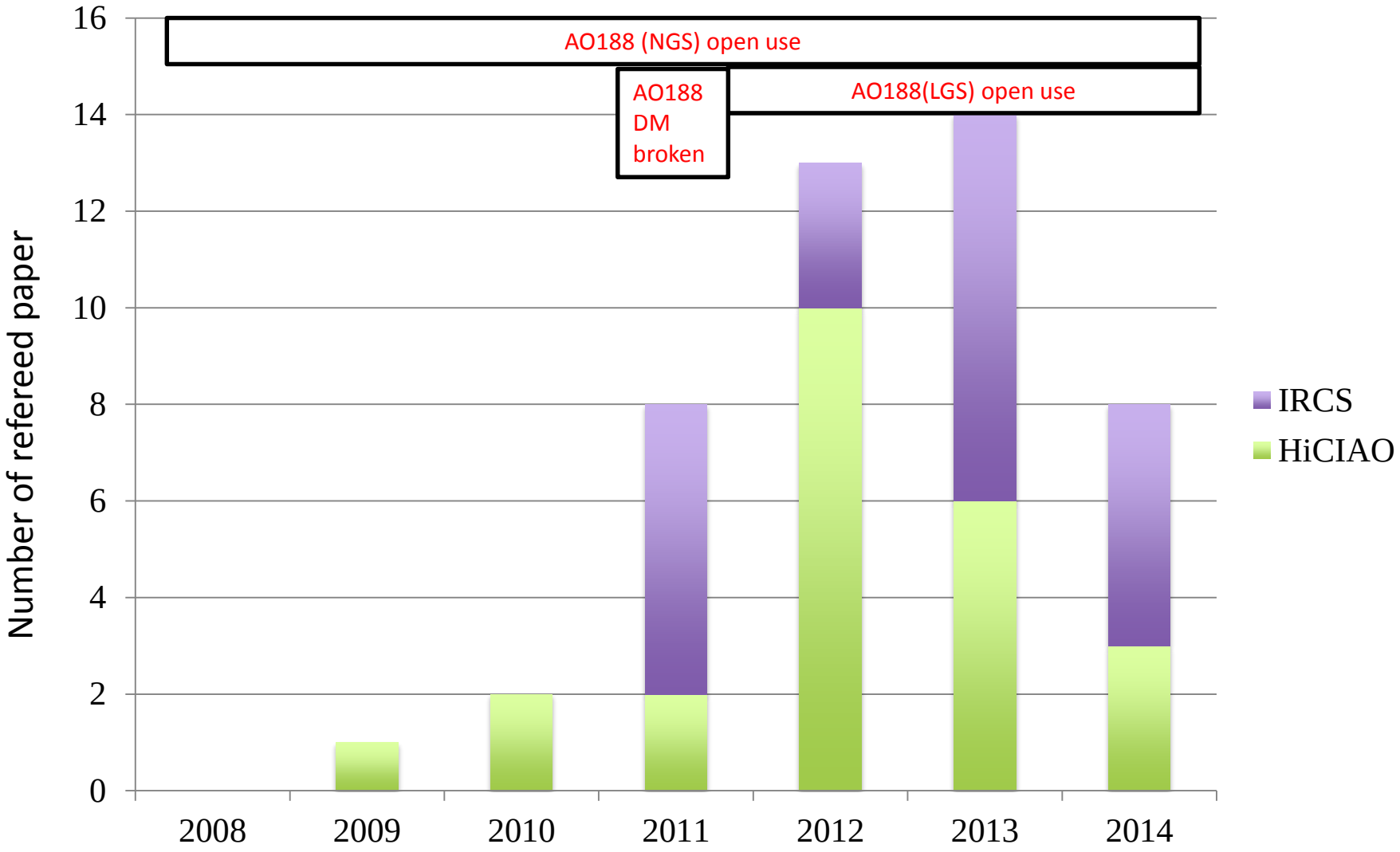
Table 1: Commissioned AO facilities.

GS = Guide Star, SCAO = Single Conjugate AO, MCAO = Multi-Conjugate AO, GLAO = Ground Layer AO.

Telescope	System Type	GS Type	Adaptive Secondary	Science Instruments	Science Capabilities
Gemini-N 8m	SCAO	Sodium	No	NIRI, NIFS	NIR Imaging, Spect., IFS
Gemini-S 8m	MCAO	5x Sodium	No	GSAOI	NIR Imaging
Gemini-S 8m	SCAO	NGS	No	NICI	NIR Coronagr. Imager
Keck I 10m	SCAO	Sodium	No	OSIRIS	NIR IFS, Imaging
Keck II 10m	SCAO	Sodium	No	NIRC2, NIRSPEC	NIR Imaging, Spect.
LBT I 8m	SCAO	NGS	Yes	CLIO	NIR imaging
Lick 3m	SCAO	Sodium	No	IRCAL	NIR Imaging
Magellan 6.5m	SCAO	NGS	Yes	CCD, MIRAC	visible/MIR imaging
MMT 6.5m	SCAO	NGS	Yes	ARIES, CLIO	NIR Imaging, Spectrosc.
MMT 6.5m	GLAO	5x Rayleigh	Yes	ARIES	NIR Imaging, Spectrosc.
Palomar 6.5m	SCAO	NGS	No	P1640, SWIFT	Coronagraph, IFS
RoboAO 1.5m	SCAO	Rayleigh	No	CCD	Visible imaging
Subaru 8m	SCAO	Sodium	No	IRCS, HiCIAO (PI-mode)	NIR Imaging, Spectrosc.
VLT 8m	SCAO	Sodium	No	NACO	NIR Imaging
VLT 8m	SCAO	Sodium	No	SINFONI	NIR IFS
VLT 8m	SCAO	NGS	No	CRIRES	Spectrograph
SOAR 4m	GLAO	Rayleigh	No	CCD	Vis Imaging

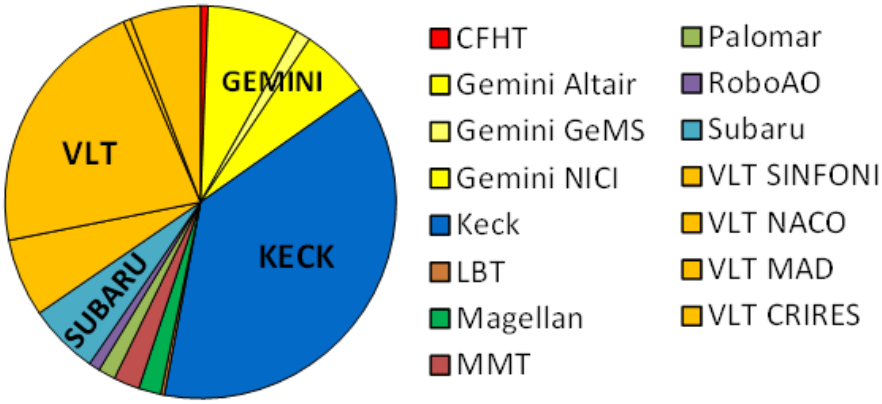
AO188 science publication history

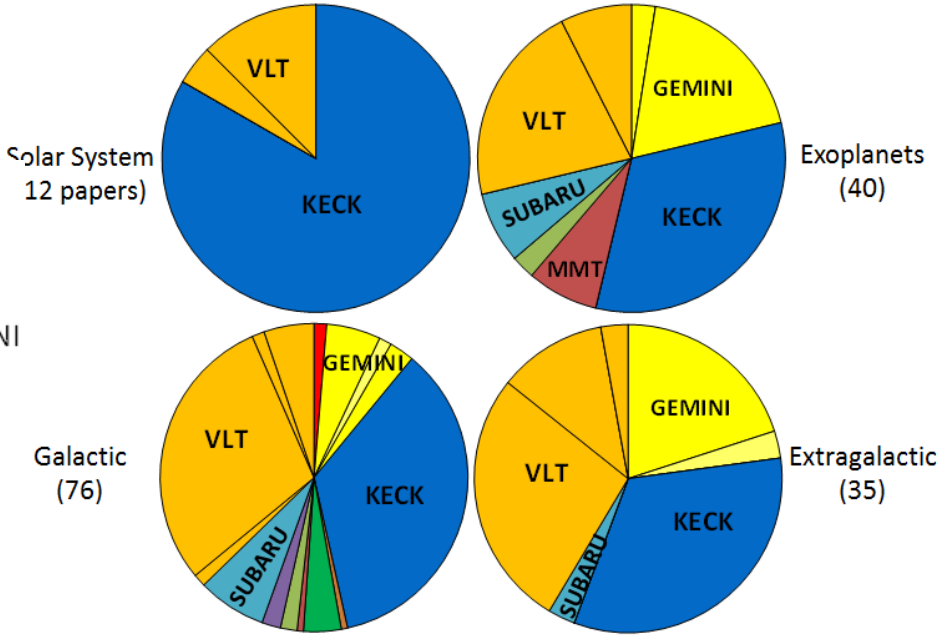
Number of refereed science papers which cite AO188 instrument papers (Hayano et al. 2008, 2010, Minowa et al. 2010).



AO science paper publications

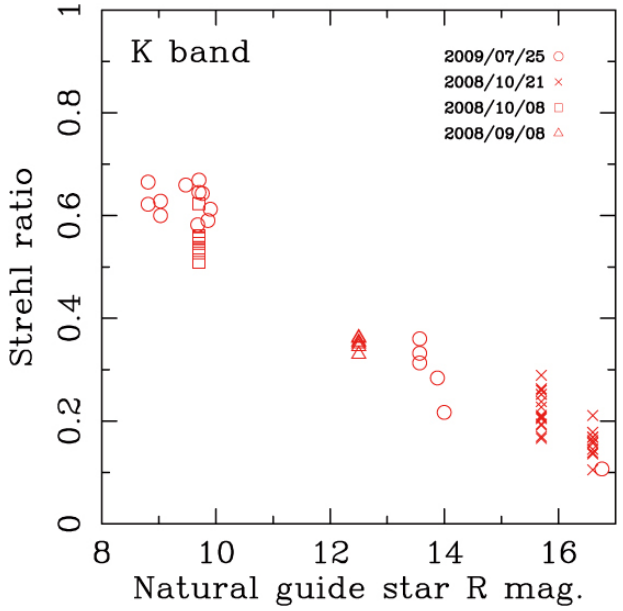
Refereed science paper using AO published in 2013
(from Peter Wizinowich's presentation at Keck strategy meeting)

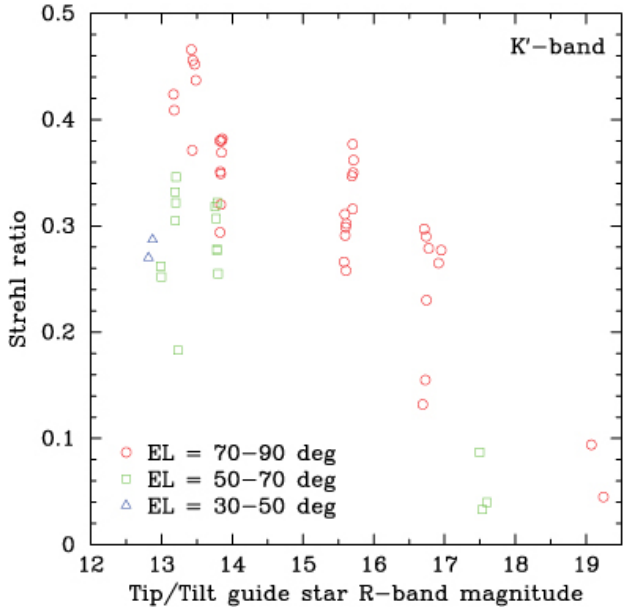




Future upgrade for AO188

- New High power laser to make brighter (R~9-10mag) LGS
  - TOPTICA fiber laser, which will provide 20W instead of current 4W, is a candidate
  - Increase maximum achievable Strehl ratio from current 0.3 (FWHM~0".1-0".2) at K to 0.5 (FWHM<0".1)





- Performance optimization
  - Make operation easier
  - Reduce overhead
    - M. Liu (IfA) who have used all AO system at Maunakea told me at the Keck strategy meeting that performance of AO188 is almost same as Keck-AO, but overhead is much larger for AO188 than Keck AO.

Extreme AO

from Peter Wizinowich's presentation at Keck strategy meeting

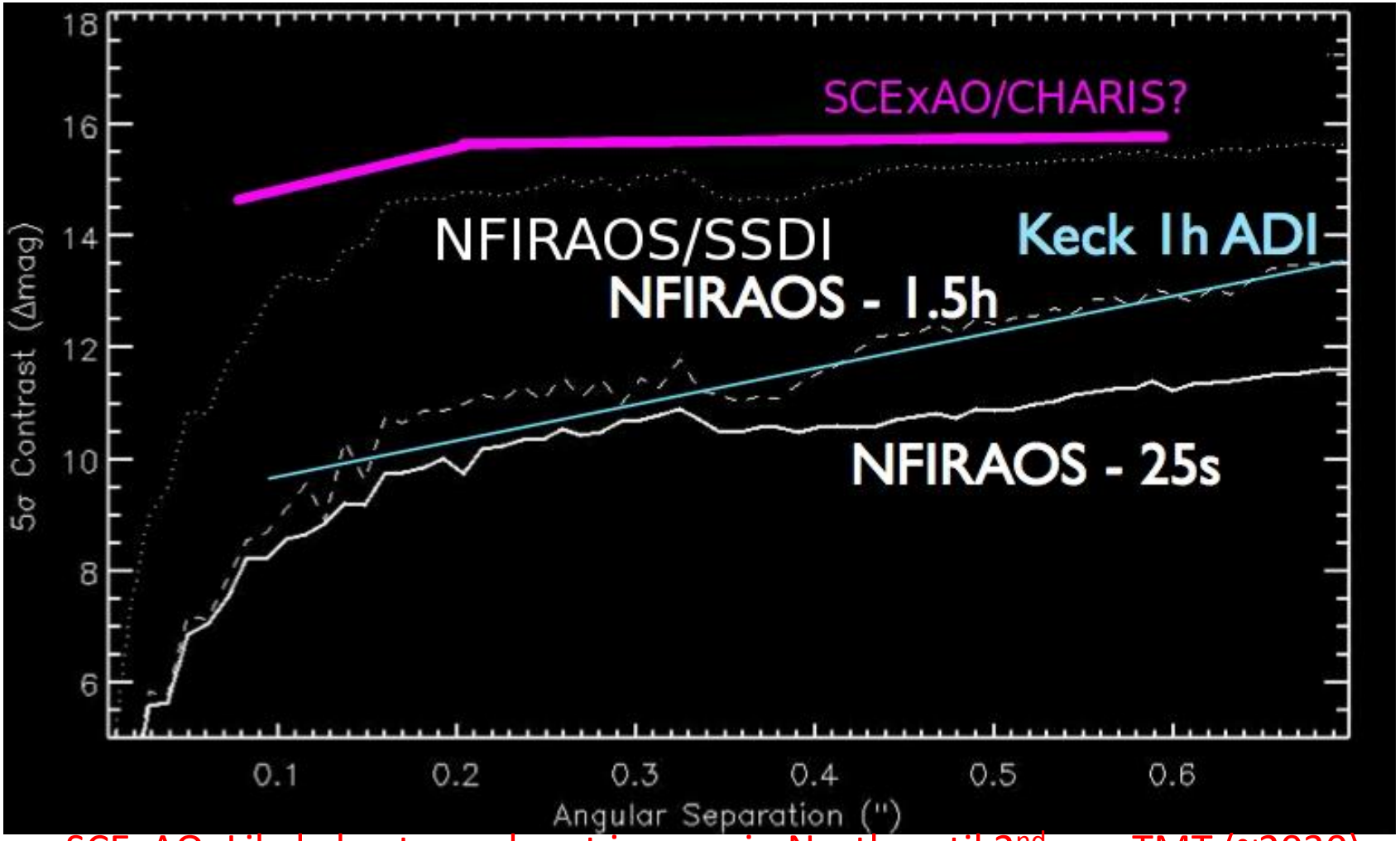
Table 3: AO facilities currently undergoing on-sky commissioning (XAO = eXtreme AO).

Telescope	System Type	GS Type	Adaptive Secondary	Science Instruments	Science Capabilities
Gemini-S GPI	xAO	bright NGS	No	GPI	hi-con NIR Imaging, IFS
Keck I upgrade	SCAO	Sodium	No	Upgraded OSIRIS	+ NIR tip-tilt sensor
Keck II upgrade	SCAO	Sodium	No	NIRC2, NIRSPEC	+ new center launch laser
Lick upgrade	SCAO	Sodium	No	ShARCS	Imaging, Spectrosc.
Subaru SCexAO	xAO	bright NGS	No	CCD,HiCIAO	hi-con NIR Imaging
VLT SPHERE	xAO	bright NGS	No	IRDIS, IFS, ZIMPOL	hi-con NIR IFS,Polarimetry

- SCExAO with Phase-II capabilities will be available from 2015
  - >90% Strehl ratio at H-band is expected
- CHARIS will be delivered to Subaru at the end of 2015, which will provide NIR IFU capability for characterizing the atmosphere of exoplanets.
- High contrast imaging is not planned for TMT 1st gen. instruments
  - SCExAO could beat early TMT (mid 2020) in this area (Thayne Currie's Subaru Seminar)
- AO188 (or new AO with adaptive M2) is necessary for Subaru's ExAO

SCExAO vs. First-Light TMT

From Thayne Currie's presentation at Subaru Seminar (06/12/2014)



SCExAO: Likely best exoplanet imager in North until 2nd gen TMT (~2030)

NFIRAOS estimates from Marois et al. 2012

Future AO system

from Peter Wizinowich's presentation at Keck strategy meeting

Table 4: AO facilities currently in fabrication or design (LTAO = Laser Tomography AO).

Telescope	System Type	GS Type	Adaptive Secondary	Science Instruments	Science Capabilities
LBT ARGOS	GLAO	6x Rayleigh	Yes	LUCIFER 1 & 2	NIR Imaging, Spect., MOS
VLT GRAAL	GLAO	4x Sodium	Yes	HAWK-I	NIR Imaging
	SCAO				NIR Imaging
VLT GALACSI	GLAO			MUSE	24 Vis IFS
	LTAO				1 Vis IFS
Keck NGAO	LTAO	7x Sodium	No	Upgraded OSIRIS	NIR imaging, IFS
VLT ERIS	SCAO	Sodium	Yes	new NACO, SINFONI	NIR imaging, IFS
ULTIMATE-Subaru	GLAO	4 x Sodium	YES	Fiber IFU?, Imager?	NIR imaging , IFS

Summary (IRCS)

- IRCS provides basic functions of 8m class telescope, which are useful for all types of astronomy (solar system, exoplanets, galacitc objects, extragalactic).
- Although IRCS is 1st gen. instrument at the Subaru, the demand for using IRCS is increasing after AO188
  - Number of the submitted proposals is always at the highest or the second highest after HSC.
  - Keeping the number of the publication at the same level since 2001
- There are similar instruments at Keck/Gemini which can be used through time exchange program, but those are almost same age as IRCS (i.e., there is a risk of the failure or decommission).
- It is not good idea to actively decommission IRCS without making coordinated instrument development/decommission plan with Keck/Gemini.
- Even after AO188 is decommissioned, IRCS can be a unique instrument at Maunakea with thermal infrared imaging/spectroscopy capabilities if the Subaru have a deformable secondary mirror, which realizes low-background and high Strehl ratio of ~ 1.0 (same concept as VLT/ERIS).
- Without deformable secondary, IRCS is not a competitive instrument at all within several years.

Summary (AO188)

- AO188 provides the similar performance as the other AO system at Maunakea, slightly wider FOV for finding TTGS, although the publication record is poor compared with the other AO at the 8m class telescopes.
- Number of the extragalactic publications has been increasing since LGS mode was opened on 2011 (but still low).
- Future laser upgrade will make the LGSAO performance of AO188 highest level among the SCAO system in the world.
- Science capabilities with AO188 itself will not be unique at all after future AO system becomes available.
- AO188 (or newAO with ASM) +SCExAO is still a unique ExAO at the northern hemisphere even in the era of TMT
- It is not good idea to decommission AO188 without having the other facility AO system