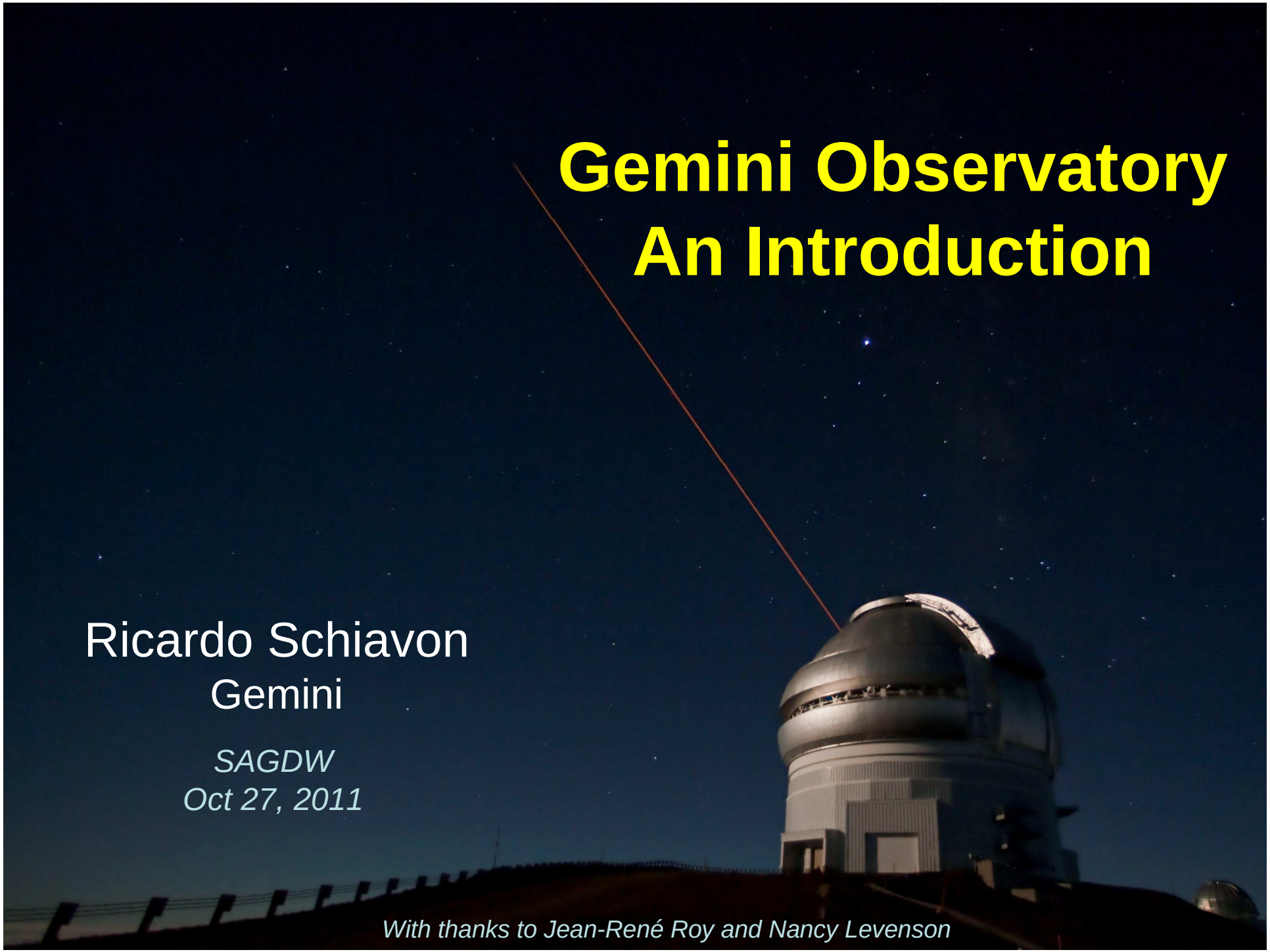


Gemini Observatory
An Introduction

Ricardo Schiavon
Gemini

SAGDW
Oct 27, 2011

With thanks to Jean-René Roy and Nancy Levenson

Contents

- A brief introduction
- Instruments
- Science highlights
- Status of commissioning instruments
- Future instruments

Gemini Observatory

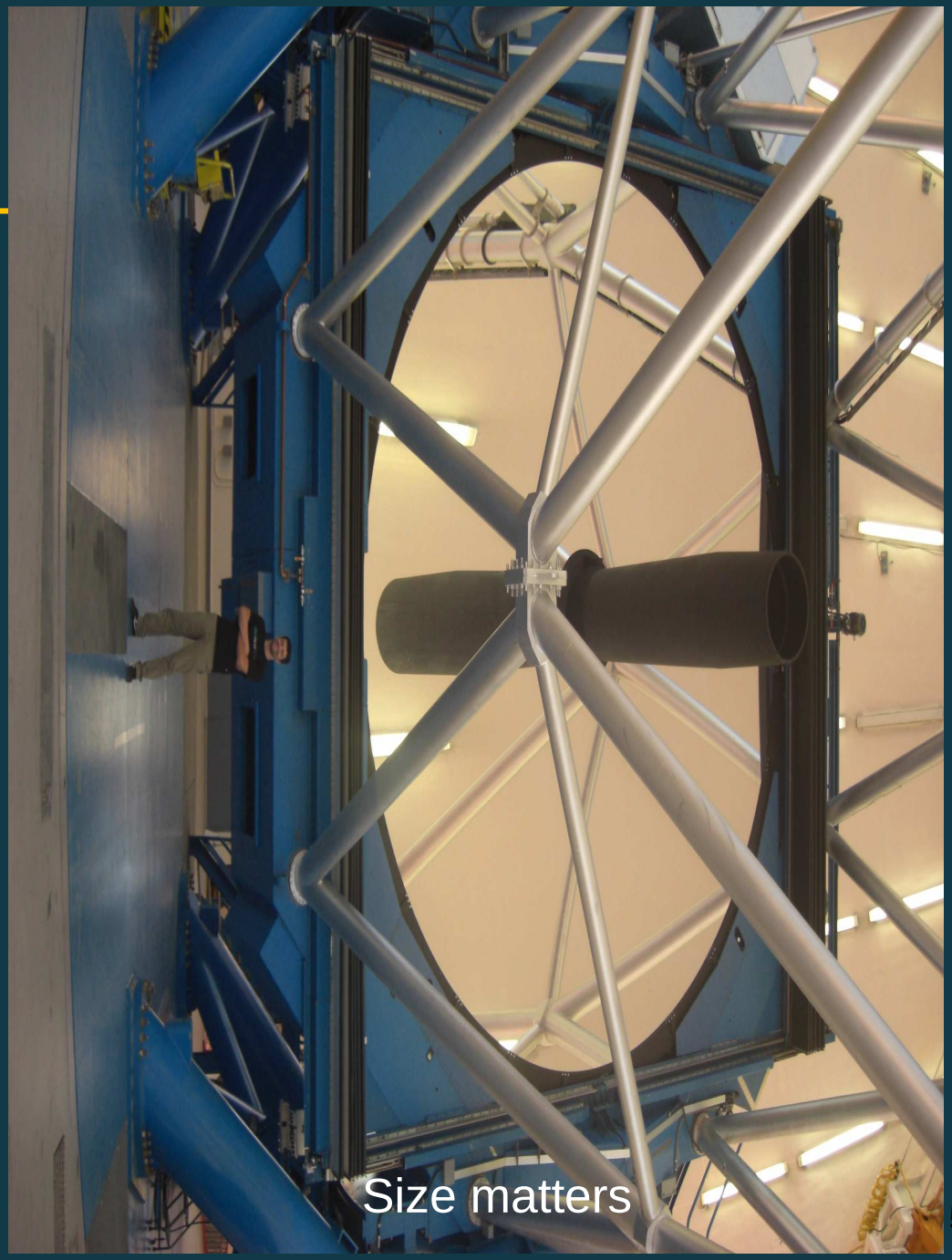
Gemini North, atop Mauna Kea volcano,
Hawaii, USA, alt. 4200m.

Gemini Observatory

Gemini South, atop Cerro Pachón, Chile, alt. 2700m.

Gemini in numbers

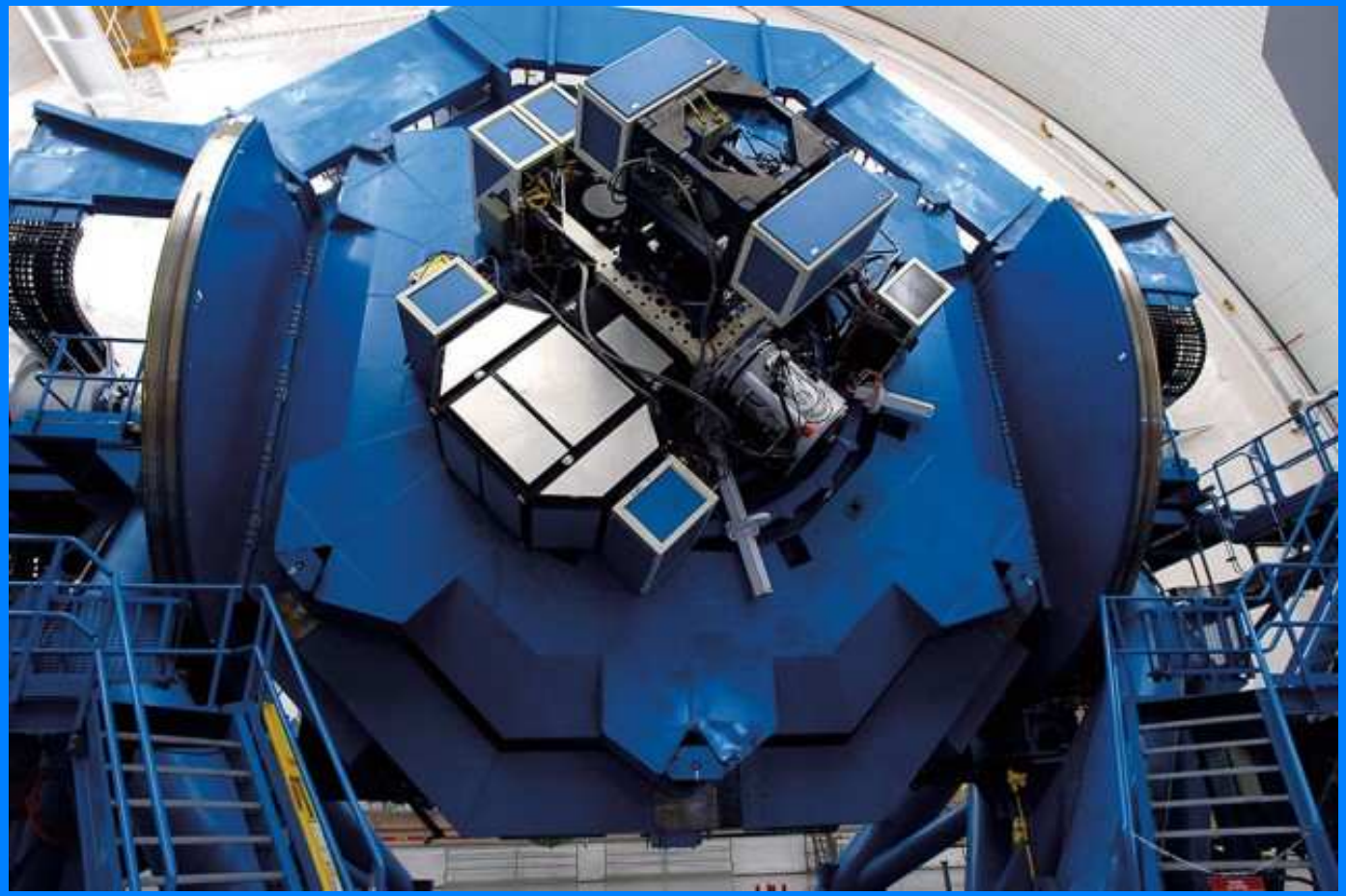
- 2 8m telescopes
- 7 member countries
- Building cost: US$ 184 mi
- Operation cost: ~1 US$/s
- 8 active instruments
- 2 commissioning instruments
- ~200 employees from 15 countries
- 10^2 computers per site
- ~95% queue mode



Instruments

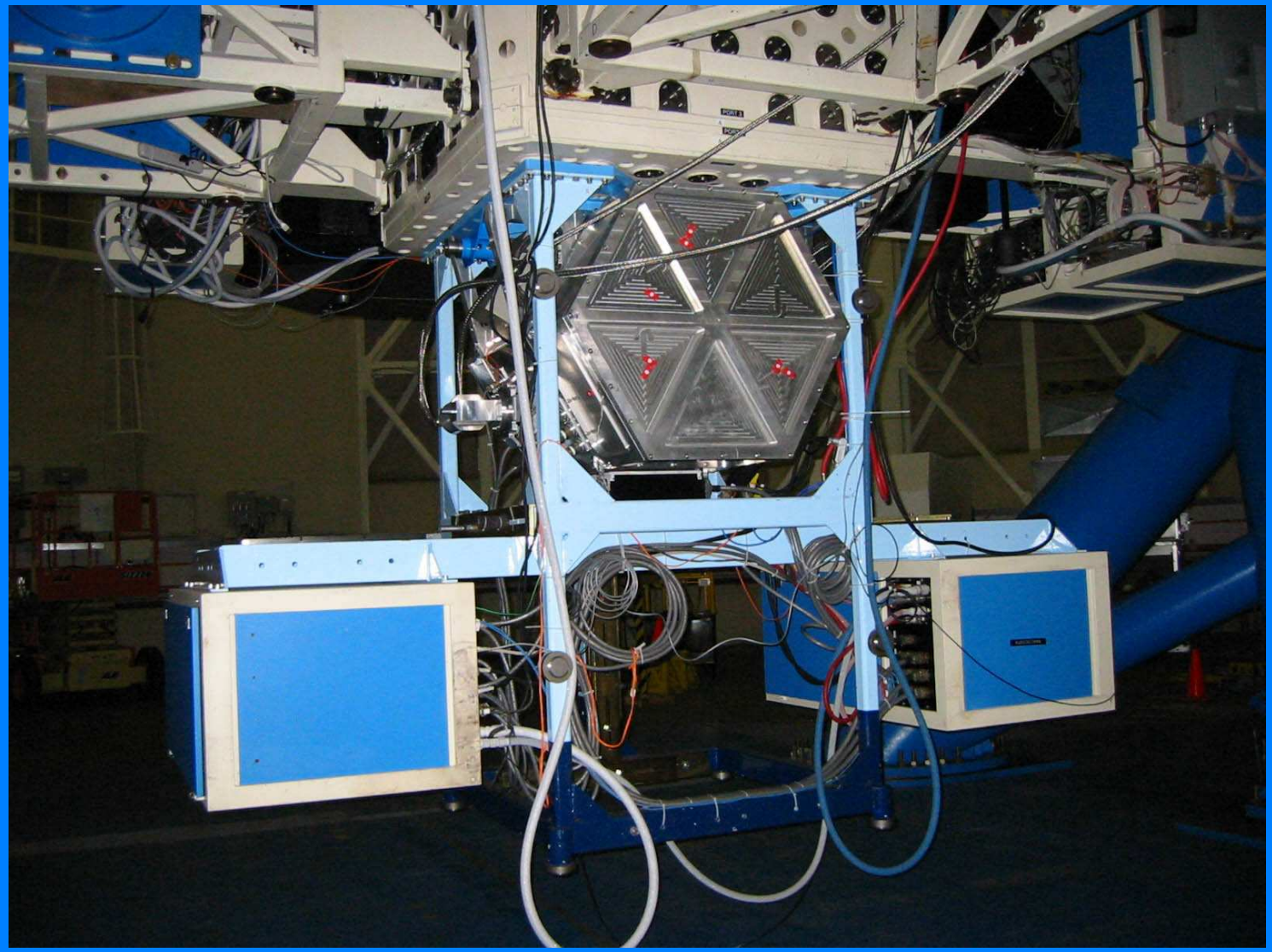
- Gemini North
  - GMOS: Optical, imaging, spectroscopy, longslit, MOS, IFU
  - NIRI: NIR/MIR, imaging, AO
  - NIFS: NIR, IFU spectroscopy, AO
  - GNIRS: NIR, longslit and cross-dispersed spectroscopy, AO
  - Michelle: MIR, imaging, spectroscopy
  - ALTAIR: AO unit
- Gemini Sul
  - GMOS: Optical, imaging, spectroscopy, longslit, MOS, IFU
  - NICI: NIR, imaging coronographer, AO
  - T-ReCS: MIR, imaging, spectrographer
  - FLAMINGOS-2: Imaging, spectroscopy, longslit, MOS, AO
  - GEMS/GSAOI: NIR, imaging, MCAO

Cassegrain focus at GS



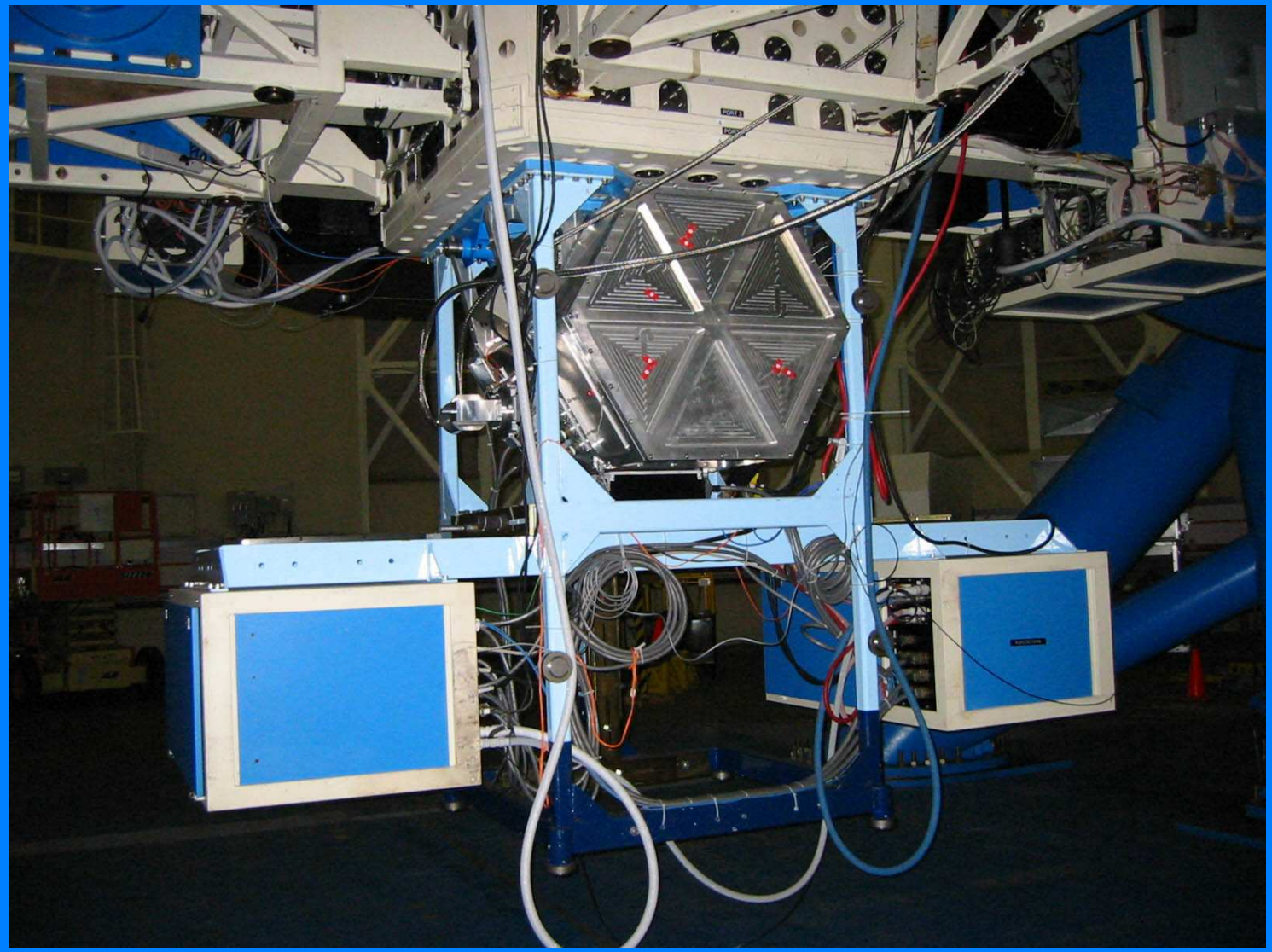
NIRI

Near InfraRed Imager and Spectrometer



NIRI

Near InfraRed Imager



NIRI Features

- Gemini North
- Instrument scientist: Andy Stephens
- Imaging w/out AO
- Long-slit spectroscopy deactivated
- Detetor Aladdin 1024 x 1024 InSb 27 μm

NIRI - Imaging

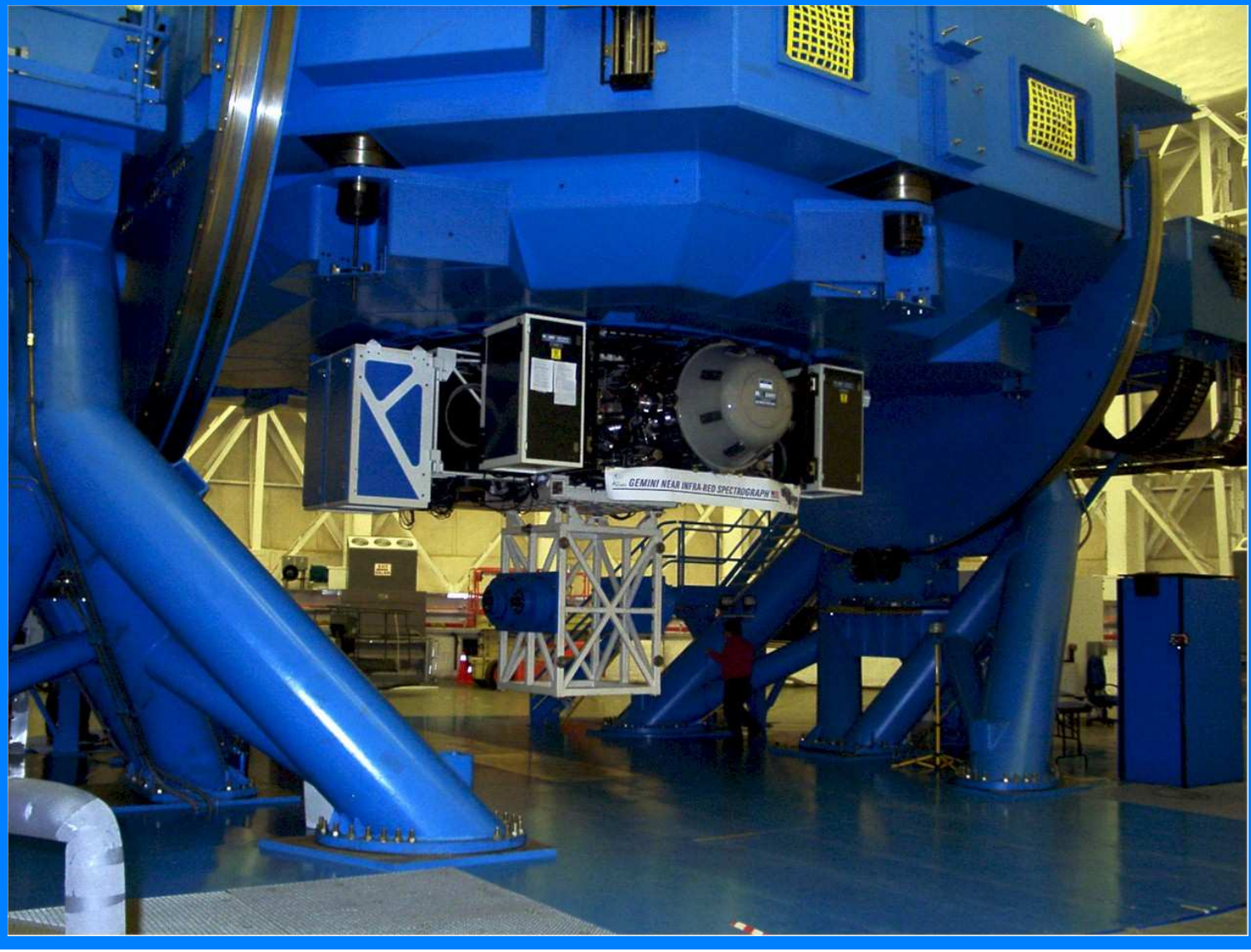
Camera	Pixel dimension (arc sec)	Field of View (arc sec)
f/6	0.1171	119.9 x 119.9
f/14	0.0499	51.1 x 51.1
f/32	0.0219	22.4 x 22.4

NIRI - Filters

Filter Name	Central Wavelength (microns)	Coverage (microns or dl/l)	Gemini ID	Transmission Curve (click for graph)	Numerical Transmission Data	Currently In Dewar?
Broad-band filters						
Y	1.02	0.97-1.07	G0241	yes	warm	yes
J	1.25	1.15-1.33	G0202	yes	warm	yes
H	1.65	1.49-1.78	G0203	yes	warm	yes
H-K notch	-	1.45-1.76;1.93-2.29	G0236	yes	warm	no
K	2.20	2.03-2.36	G0204	yes	warm	yes
K(short)	2.15	1.99-2.30	G0205	yes	warm	no
K(prime)	2.12	1.95-2.30	G0206	yes	warm	yes
L(prime)	3.78	3.43-4.13	G0207	yes	warm	yes
M(prime)	4.68	4.55-4.79	G0208	yes	warm	yes

GNIRS

Gemini Near Infrared Spectrograph



GNIRS Features

- Gemini North (Previously Gemini South)
- Instrument scientist: Rachel Mason
- Spectroscopy (long slit and cross dispersed)
- Aladdin III InSb, 1024x1024 pix

- Coverage:
  - 1 a 5.5 μm long slit, R ~ 1700, 5900 e 18000
  - 0.9 a 2.5 μm cross dispersed, com R ~ 1700

Adaptive optics.

GNIRS - Gratings

Grating	Short camera		Long camera	
	Resolving power	Wavelength coverage	Resolving power	Wavelength coverage
10.44 l/mm	(a)	(a)	1700	0.3 * lambda
31.7 l/mm	1700	0.3 * lambda [b]	5100	0.09 * lambda
110.5 l/mm	5900	0.09 * lambda	17800	0.028 * lambda (~ 17 km/s)

GNIRS - Slits

Slit name	Slit width (pixels) *[nominal values]*		Slit width (measured, arcsec)
	short camera	long camera	
0.10 arcsec	n/a	2	tbd
0.15 arcsec	n/a	3	tbd
0.20 arcsec	n/a	4	tbd
0.30 arcsec	2	6	tbd
0.45 arcsec	3	9	tbd
0.675 arcsec	4.5	12	tbd
1.0 arcsec	6.7	20	tbd

Configuration	Slit length	
	short camera	long camera
Long-slit	99 arcsec	49 arcsec
Cross-dispersion	6.1 arcsec	3.1 arcsec

NIFS

Near Infrared Integral Field Spectrometer

NIFS Features

- Gemini North
- Instrument scientist: Richard McDermid

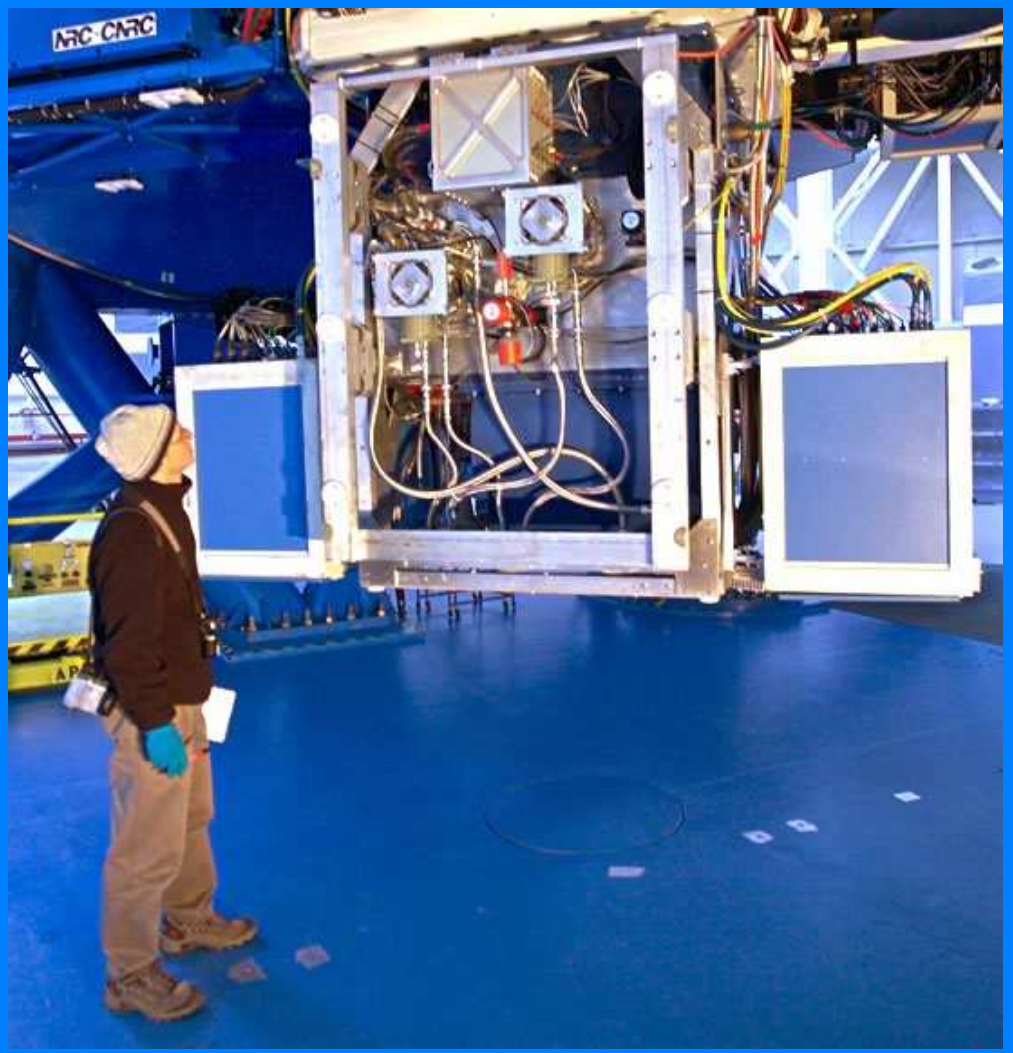
- IFU spectroscopy
- ZJHK bands (0.9 – 2.2 μm)
- Detector Rockwell Hawaii HrCdTe, 2048 x 2048
- Adaptive optics

NIFS - Features

Spatial Properties				
Field of View	3" × 3"			
Pixel Scale	0.103" across slices 0.04" along slices			
Spatial Resolution (FWHM)	0.1" full AO correction (NGS/LGS) Seeing limited without AO			
Spectral Properties				
Grating	Z	J	H	K
Standard Wavelength Range (μm)	0.94 - 1.15	1.15 - 1.33	1.49 - 1.80	1.99 - 2.40
Spectral Resolution	4990	6040	5290	5290

Michelle

Mid Infrared Echelle Spectrometer



Michelle Features

- Gemini North (originally UKIRT)
- Instrument scientist: Marie Lemoine-Busserolle
- Detector Si:As IBC 320x240 pix
- Plate scale: 0.1”/pixel (imaging) or 0.18 (spectroscopy)
- No adaptive optics (diffraction limit reached in MIR without AO).

Michelle - Filters

Filter Name	Name in Headers [a]	Central Wavelength (microns)	Bandwidth (microns)	Approximate 50% power points (microns)	Transmission Data (text)	Transmission Curves (jpeg)	Currently Available
Mediumband and Broadband Filters							
N'	I112B21	11.2	2.4	10.1 - 12.5	✓	✓	Yes
Qa	I185B9	18.1	1.9	17.13 - 19.06	✓	✓	Yes
Q'	I198B27	19.8	5.4	17.1 - 22.5	-	-	Yes [b]
N	I105B53	10.5	5.3	7.7 - 13.0	✓	✓	Yes [b]
Q	I209B42	20.9	8.8	16.5 - 25.3	✓	✓	Yes [b]
Silicate Filters							
Si-1	I79B10	7.7	0.7	7.39 - 8.08	✓	✓	Yes [c]
Si-2	I88B10	8.8	0.9	8.35 - 9.25	✓	✓	Yes
Si-3 [d]	I97B10	9.7	1.0	9.2 - 10.2	✓	✓	Yes
Si-4 [d]	I103B10	10.3	1.0	9.8 - 10.8	✓	✓	Yes
Si-5	I116B9	11.6	1.1	11.15 - 12.25	✓	✓	Yes
Si-6	I125B9	12.5	1.2	11.9 - 13.1	✓	✓	Yes
Longpass Filters for 10um and 20um Spectroscopy							
LP-7	Nblock	-	-	6.8 - >14	-	-	Yes
LP-16	Qblock	-	-	16.1 - >25	-	-	Yes

Michelle - Gratings

Name	Usable wavelengths	Dispersion (microns/pixel)	Resolving power 10um, 2pw slit	Resolving power 20um, 3pw slit	Wavelength coverage for single grating setting (microns)
LowN	7-14um	0.024	200	-	7.7
LowQ	16-26um	0.031	-	110	9.9
Medium (R~1000)	7-26um	0.0047	1000	1300	1.5
High (R~3000)	7-26um	0.0016	3000	4000	0.50
Echelle	7-22.5um *		~ 20,000-40,000	~ 13,500-27,000	1500 km/sec at blaze wavelength

Michelle - Slits

Name	Width (pixels)	Width (arcsec)
Open	-	-
1	1	0.201
2	2	0.402
3	3	0.603
4	4	0.804
5	8	1.61
pinhole mask	-	-

Phoenix

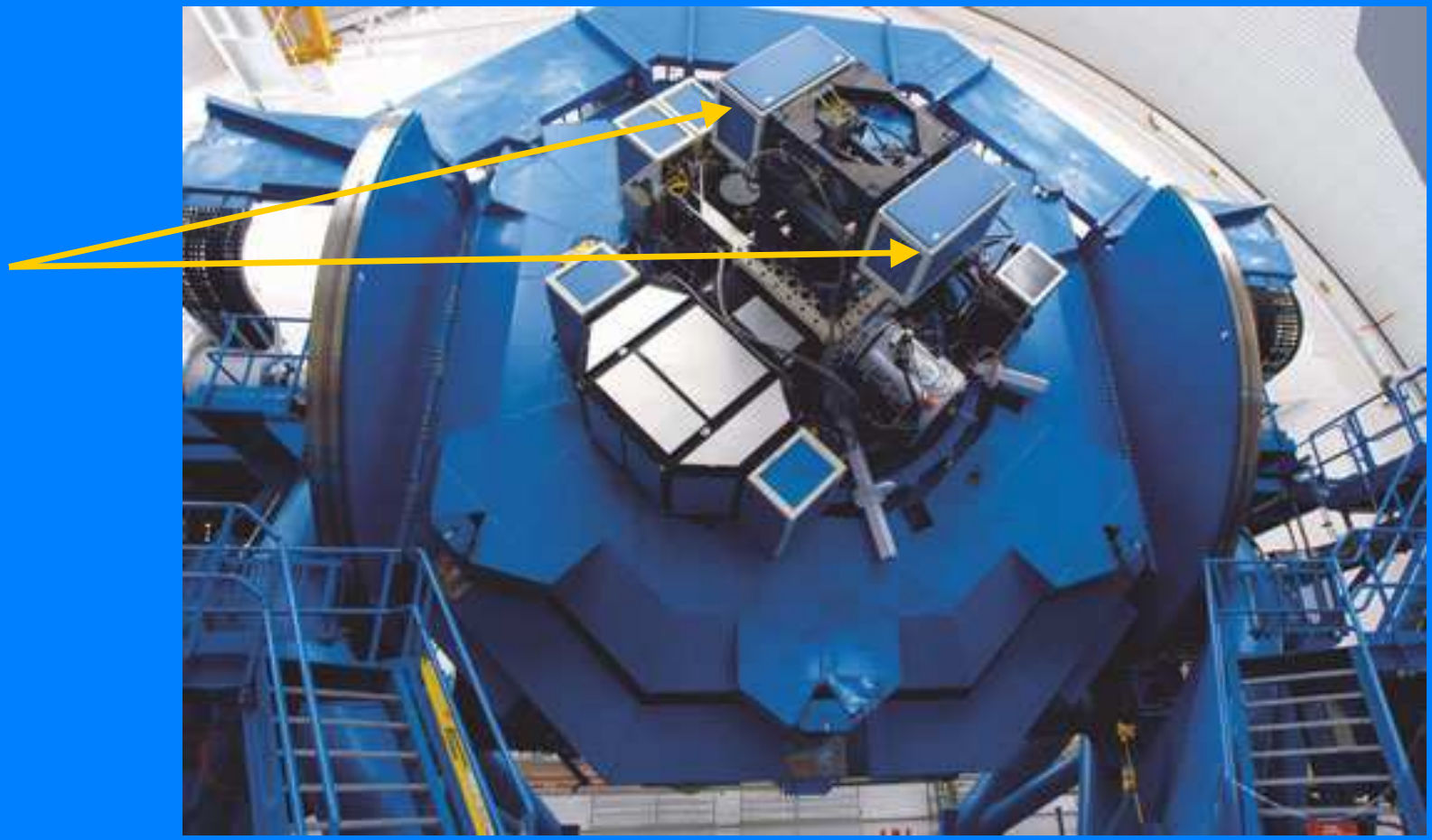
Near Infrared Echelle Spectrometer

Phoenix - Características

- Gemini Sul (originalmente Kitt Peak)
- Instrument scientist: Germán Gimeno
- Espectrógrafo de alta R: 25000 - 80000
- IV próximo: 1 - 5 μm (mas cobertura espectral limitada)
- Detetor InSb Alladin II, 512x1024 pix
- Largura de fenda: 0.17 - 0.34 arcsec
- Comprimento: 14 arcsec

T-ReCS

Thermal Region Camera Spectrograph



T-ReCS - Features

- Gemini South
- Instrument scientist: James Radomski
- Low-resolution spectroscopy and imaging in the MIR
- Detector Raytheon SRBC, 320x240 pix

T-ReCS - Imaging

Mode	Window	Slit	Filter	Grating	Detector
10 µm Imaging	ZnSe	Open or Occulting Bar	N, Si1-Si6, narrow-band	Imaging flat	High-background
20 µm Imaging	KRS-5	Open or Occultingbar	Qa or Qb	Imaging flat	High-background

- Plate scale 0.09 arcsec/pix
- Field of view 29 x 22 arcsec

T-ReCS - Spectroscopy

Mode	Window	Slit Width	Filter	Grating	Detector
10 µm Lo-Res Spectroscopy	ZnSe	10 µm l/D or 2l/D	N	10 µm Lo-Res	Low-background
20 µm Lo-Res Spectroscopy	KRS-5	20 µm l/D or 2l/D	Qbroad	20 µm Lo-Res	Low-background
10 µm Hi-Res Spectroscopy	ZnSe	10 µm l/D or 2l/D	N	10 µm Hi-Res	Low-background

- Resolution: 100 - 1000
- Slit width: 0.21 - 1.32 arcsec
- Slit length: 22 arcsec

NICI

Near Infrared Choronographic Imager

NICI - Características

- Gemini South
- Instrument scientist: Tom Hayward

- Coronographic imaging with AO
- NIR
- Optimized for detection of Jovian planets
- Two stages observe continuum and core of methane band (though other configurations possible)
- Field of view: 18x18 arcsec
- Plate scale: 18 miliarcsec / pixel

Gemini Multiconjugate Adaptive Optics System

- laser guide star facility, first light Jan 22, 2011
  typical 55W, max 65W

GeMS technical commissioning

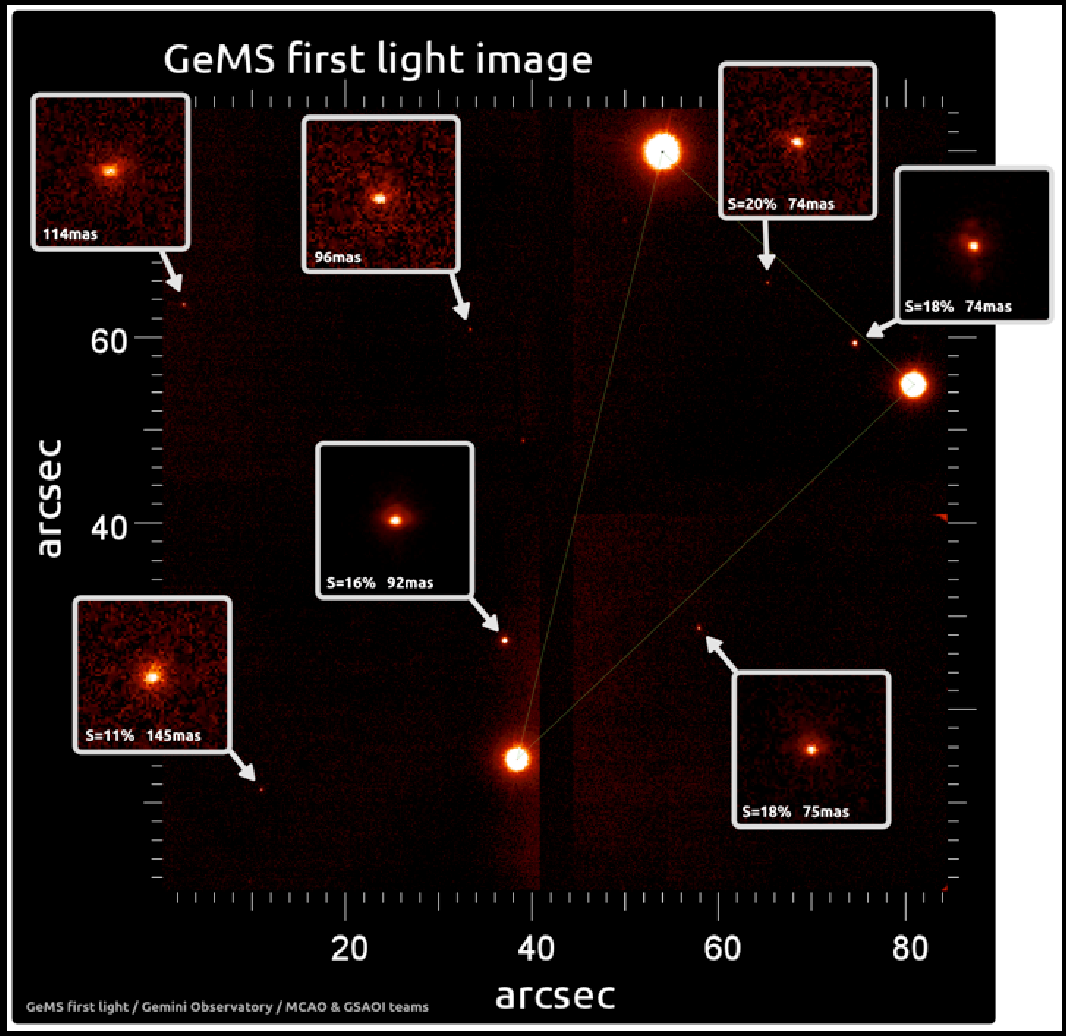
- Canopus AO bench
- All primary loops and offloads comissioned and optimized

GSAOI

- Gemini South Adaptive Optics Imager
- 0.9 – 2.4 μm
- 85” field of view
- Plate scale 0.02”/pix
- Instrument scientist: Rodrigo Carrasco

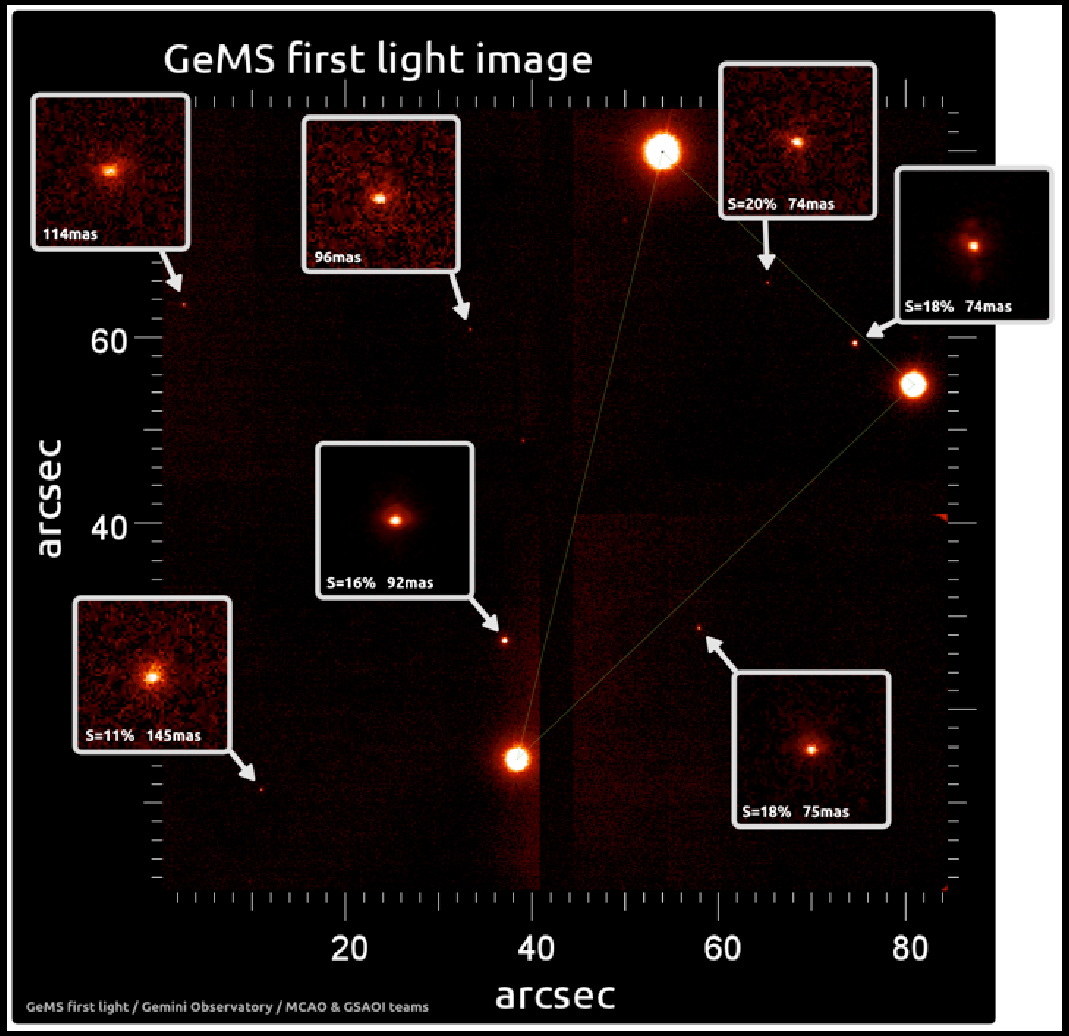
GeMS technical commissioning

- Nearly uniform image quality over 85” field of view
- Strehl up to 20%
- FWHM 0.075”



GeMS Status

- Ongoing 5-month shutdown
- Science commissioning starting in November
- Possible GeMS/GSAOI call for SV proposals in early 2012



FLAMINGOS-2

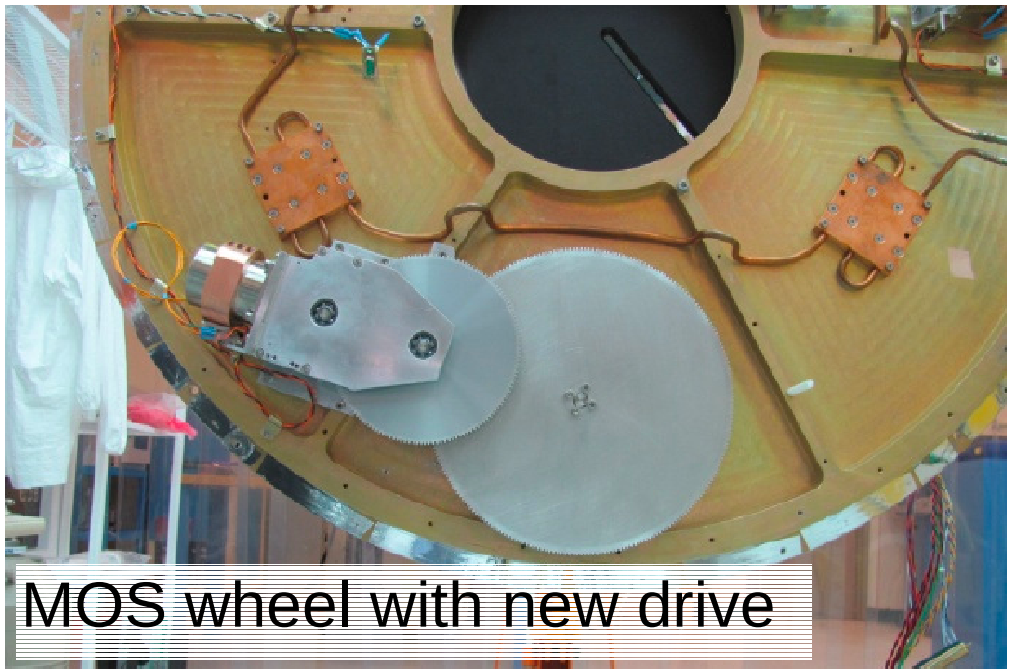
- 0.9-2.4μm imaging, longslit, and multi-object for GS
- work done to

  improve thermal stability

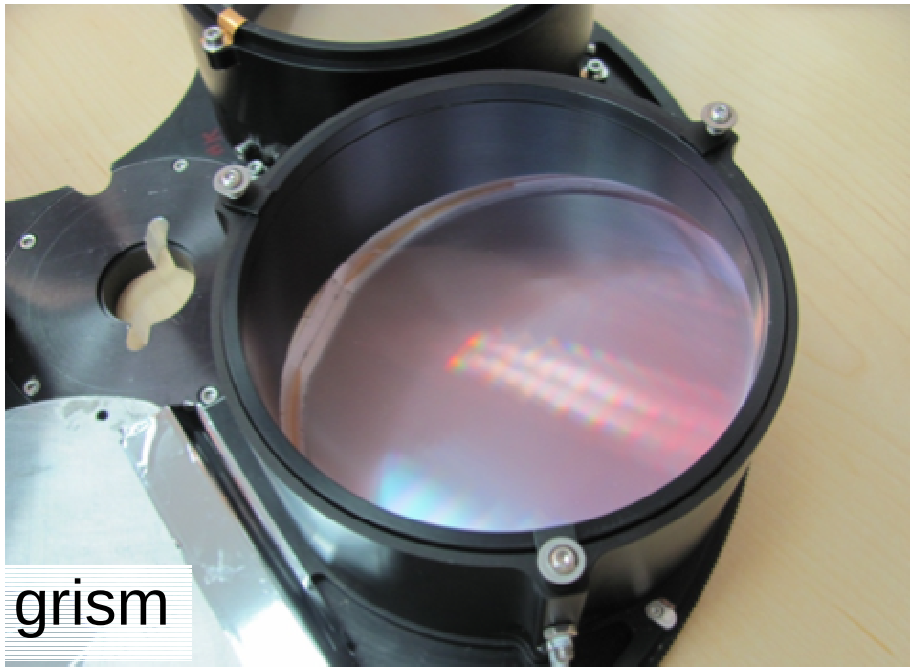
  improve mechanisms and mechanical reliability

  install R=3000 grism

  install new science detector



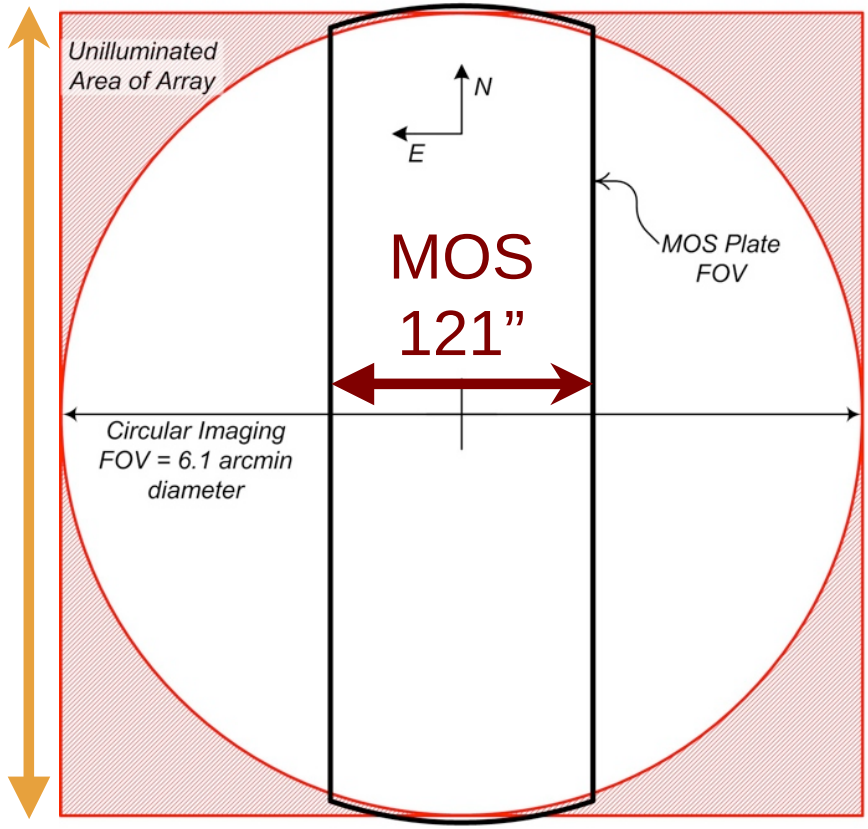
MOS wheel with new drive



grism

FLAMINGOS-2

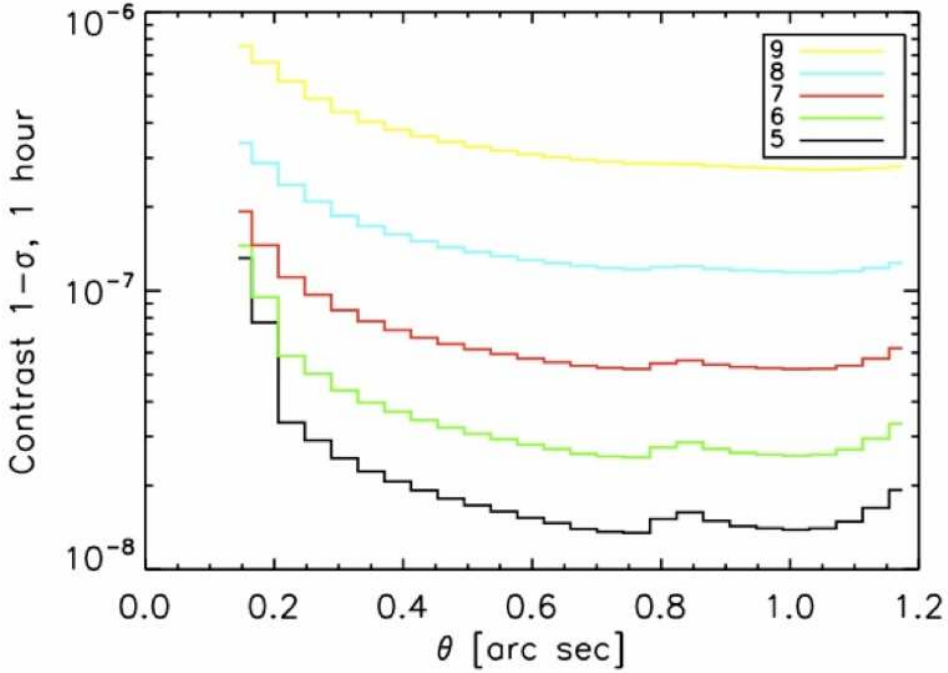
- to Cerro Pachón in October
- on sky in December
- **expect SV call for proposals in 2012, likely January for early 2012 observations**

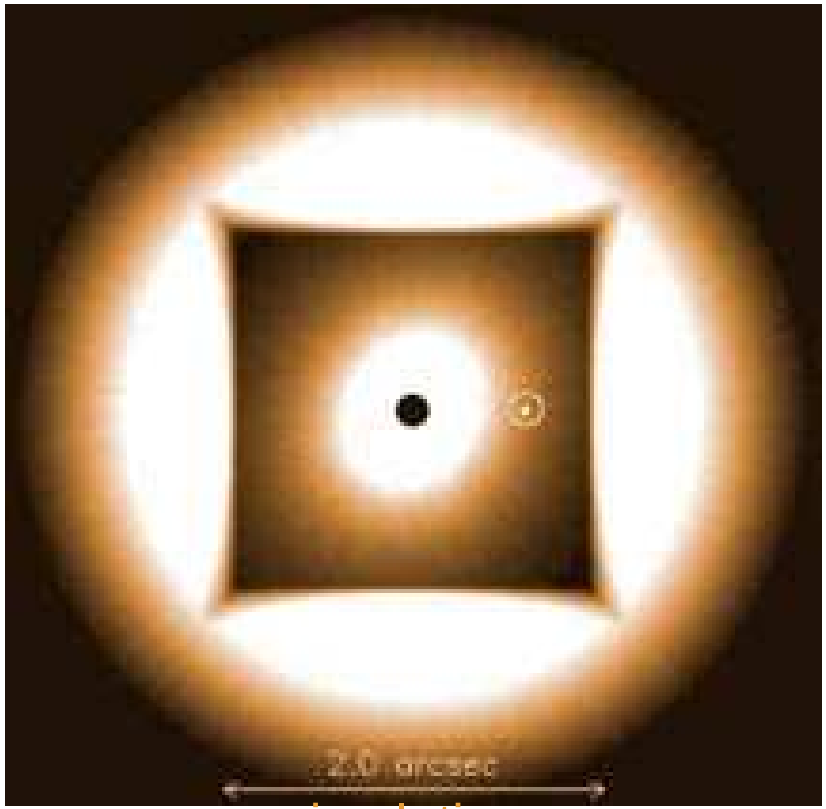


Gemini Planet Imager (GPI)

- extremely high contrast imaging
- integral field spectrograph and polarimeter
- comprehensive survey of giant planets
- astrophysics of brightest ones
- science beyond planets

contrast depends on guide star magnitude

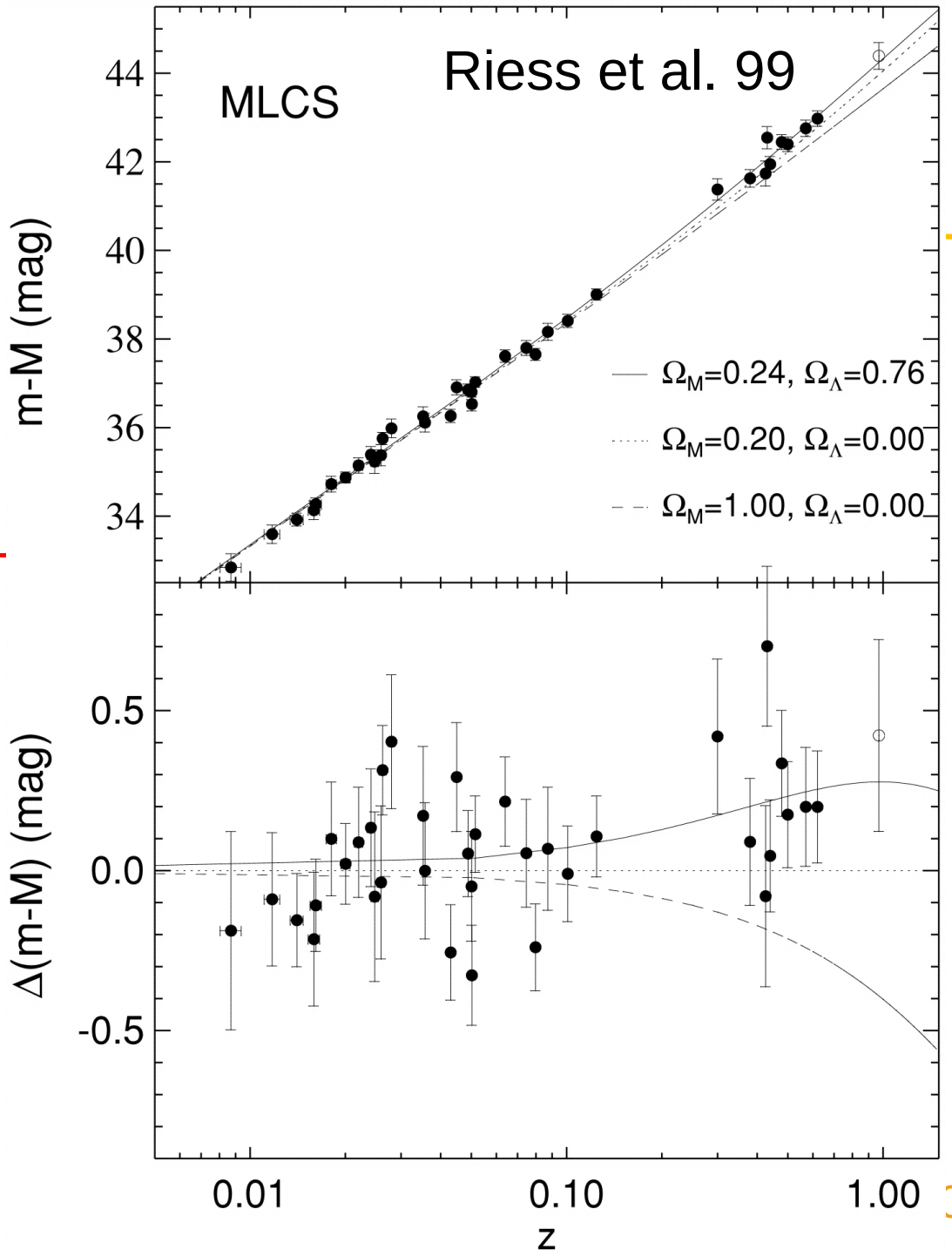




simulation

Gemini and the 2011 Nobel Prize in Physics

Based on data from HST and Keck, Riess et al. and Perlmutter et al. discovered the accelerated expansion of the universe



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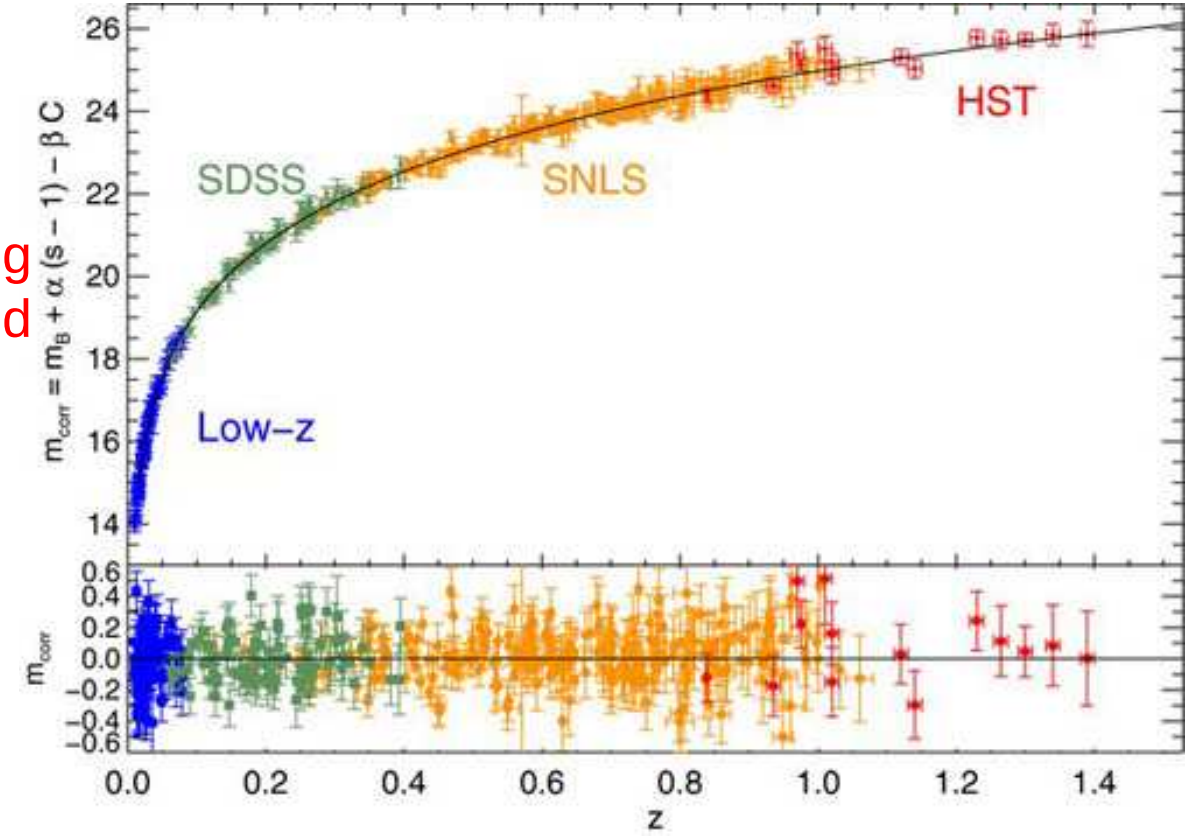
Gemini and the 2011 Nobel Prize in Physics

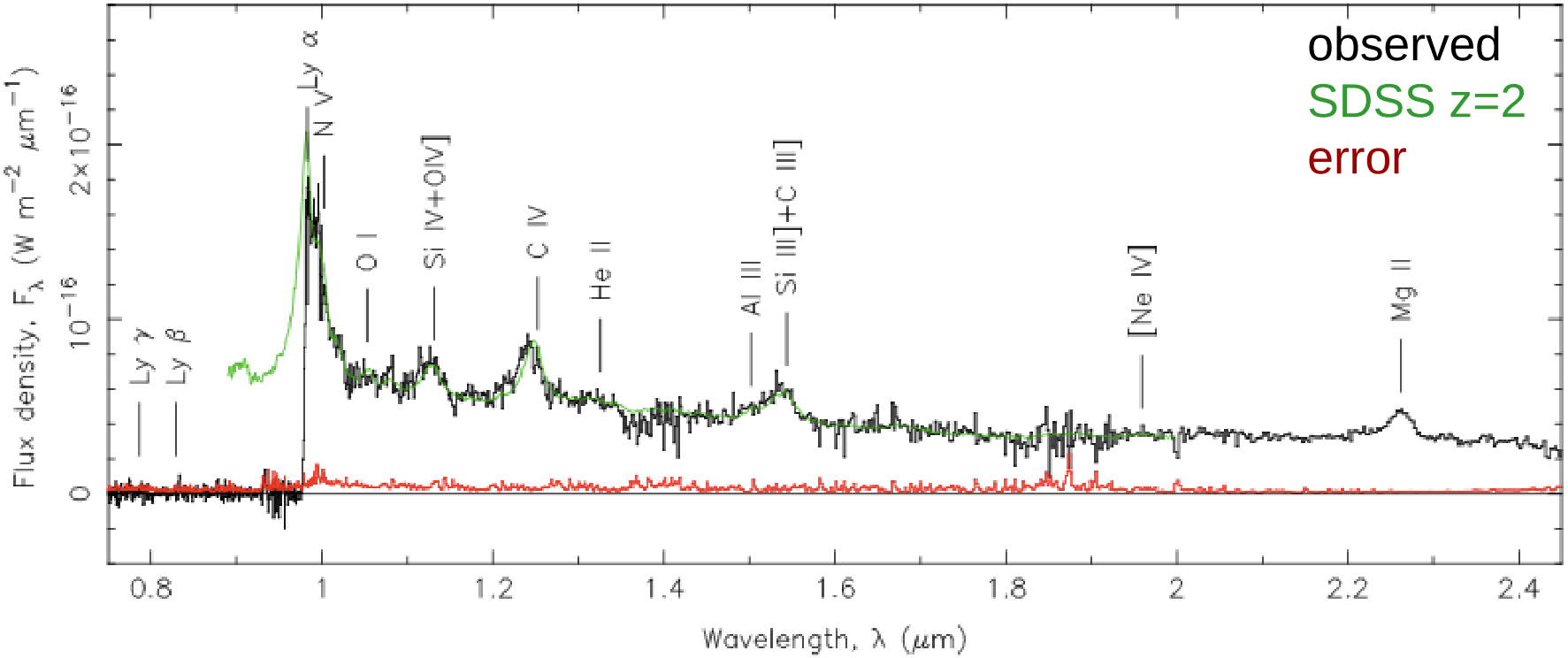
Data collected from 8-10m class telescopes, including Gemini (ToO programs using mostly GMOS), were needed to confirm those results, by extension of SN observations to higher redshift, as well as a better understanding of the systematics.



Conley et al. 2011

42

z = 7.085 quasar



GMOS slow ToO from UKIDSS: suggested broad Lyα

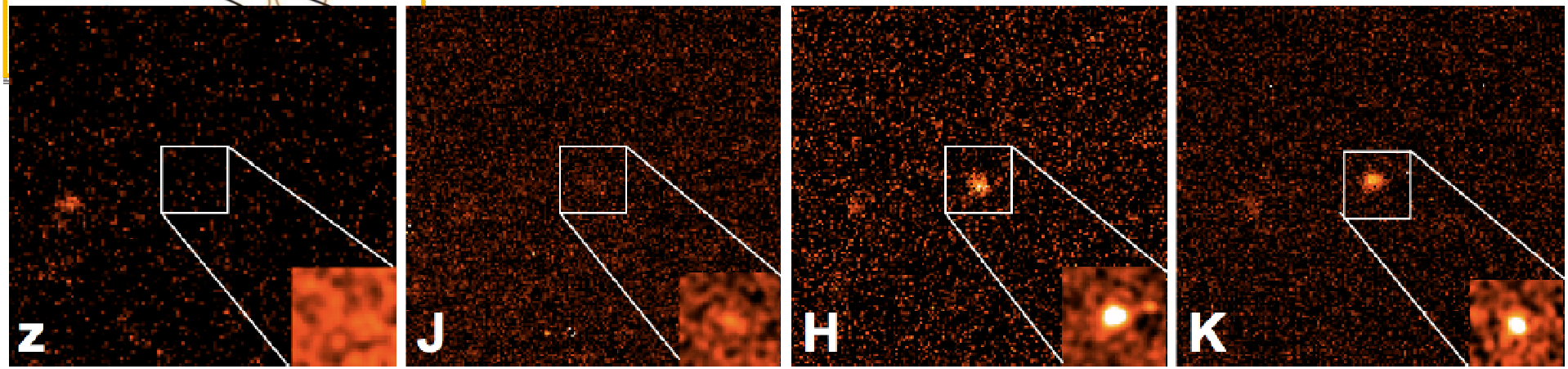
GNIRS days later: obvious quasar spectrum; first z>7

no Lyα emission z>6 except within locally-ionized region

→ neutral density of IGM at z=7 much higher than at z=6

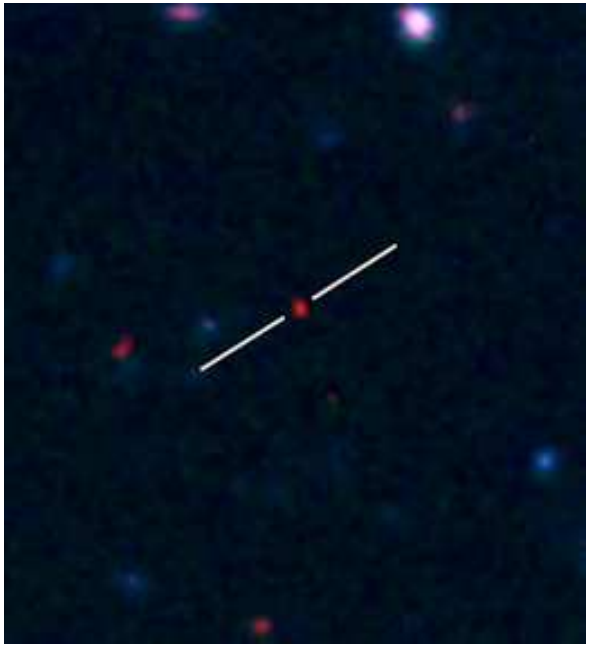
Mortlock et al. 2011

z~9.4 GRB 090429B



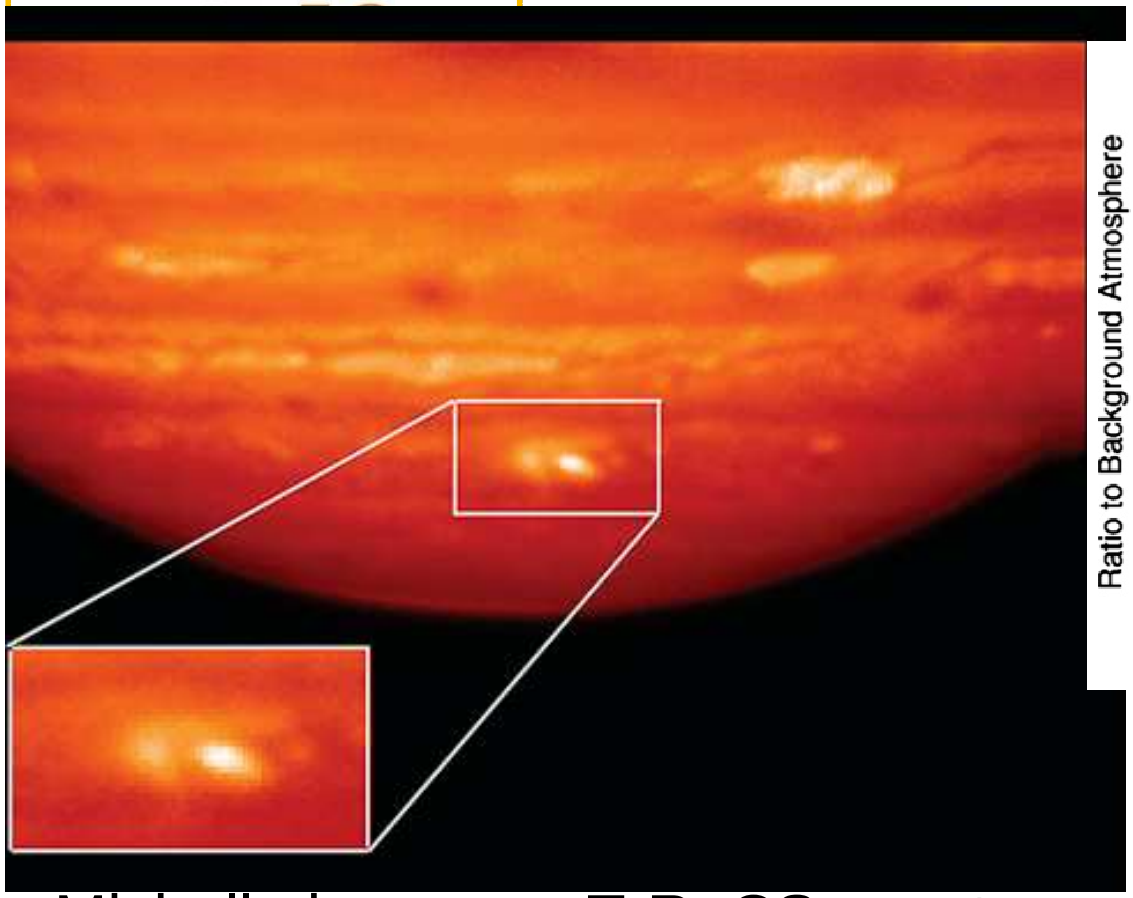
- Swift detection, GMOS + NIRI images.
  Spectroscopy prevented by bad weather.

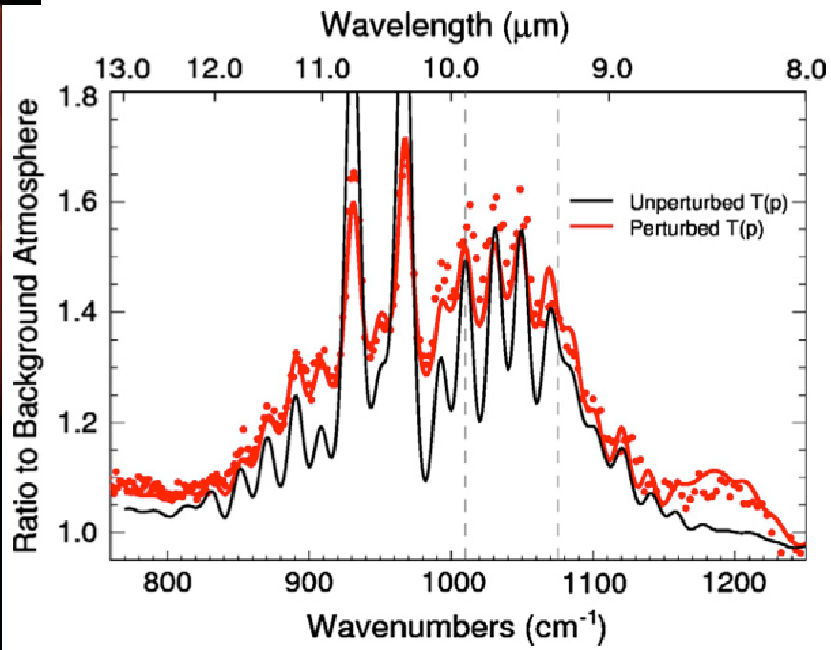
- “normal” GRB
  likely not due to first generation of stars
  significant star formation in first few 100Myr



Cucchiara et al. 2011

2009 Jupiter impact





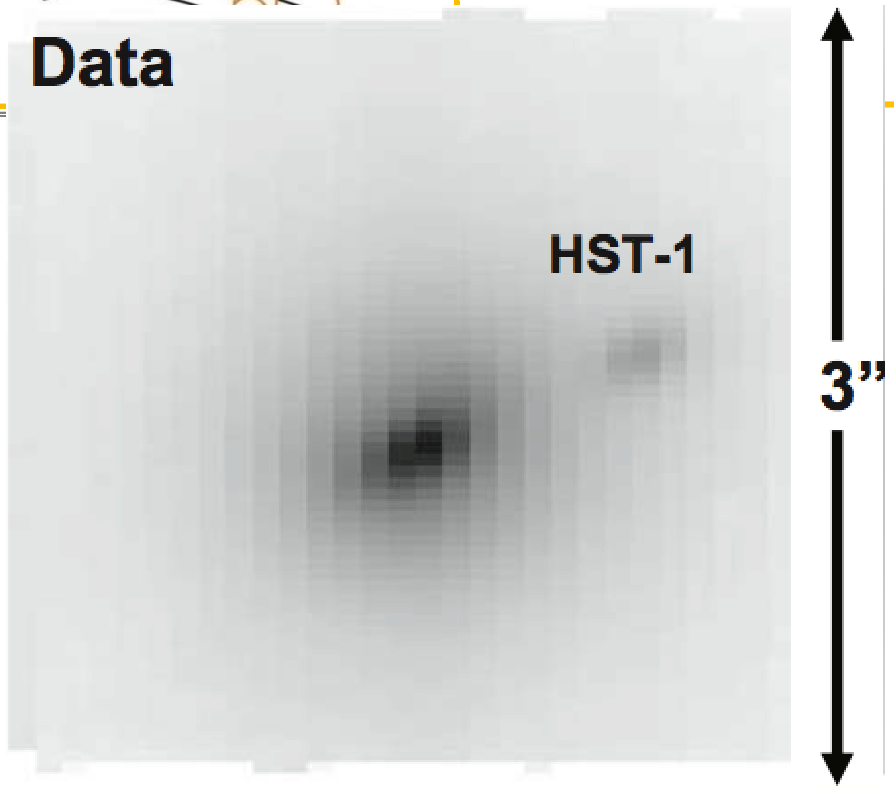
Michelle images + T-ReCS spectra

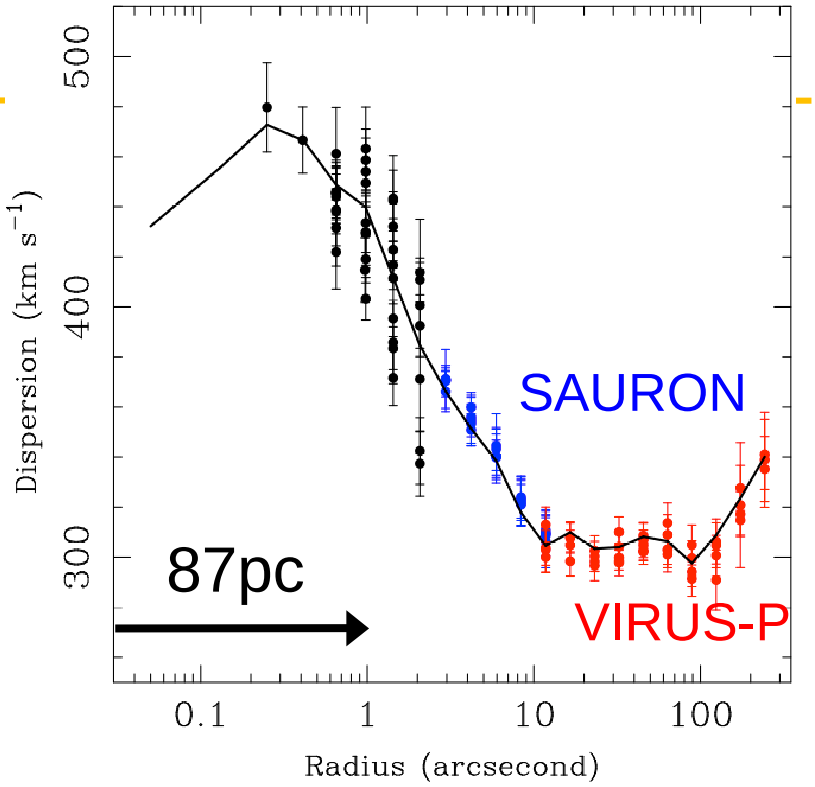
impact results: heating, ammonia dredge-up, and aerosols

silicate signature in spectra → rocky impactor (asteroid, not comet)

Orton et al. 2011
Fletcher et al. 2011

M87 black hole mass





NIFS/LGS observations + modeling

M_{BH} = 6.6 (± 0.4) x 10^9 M_{Sun}

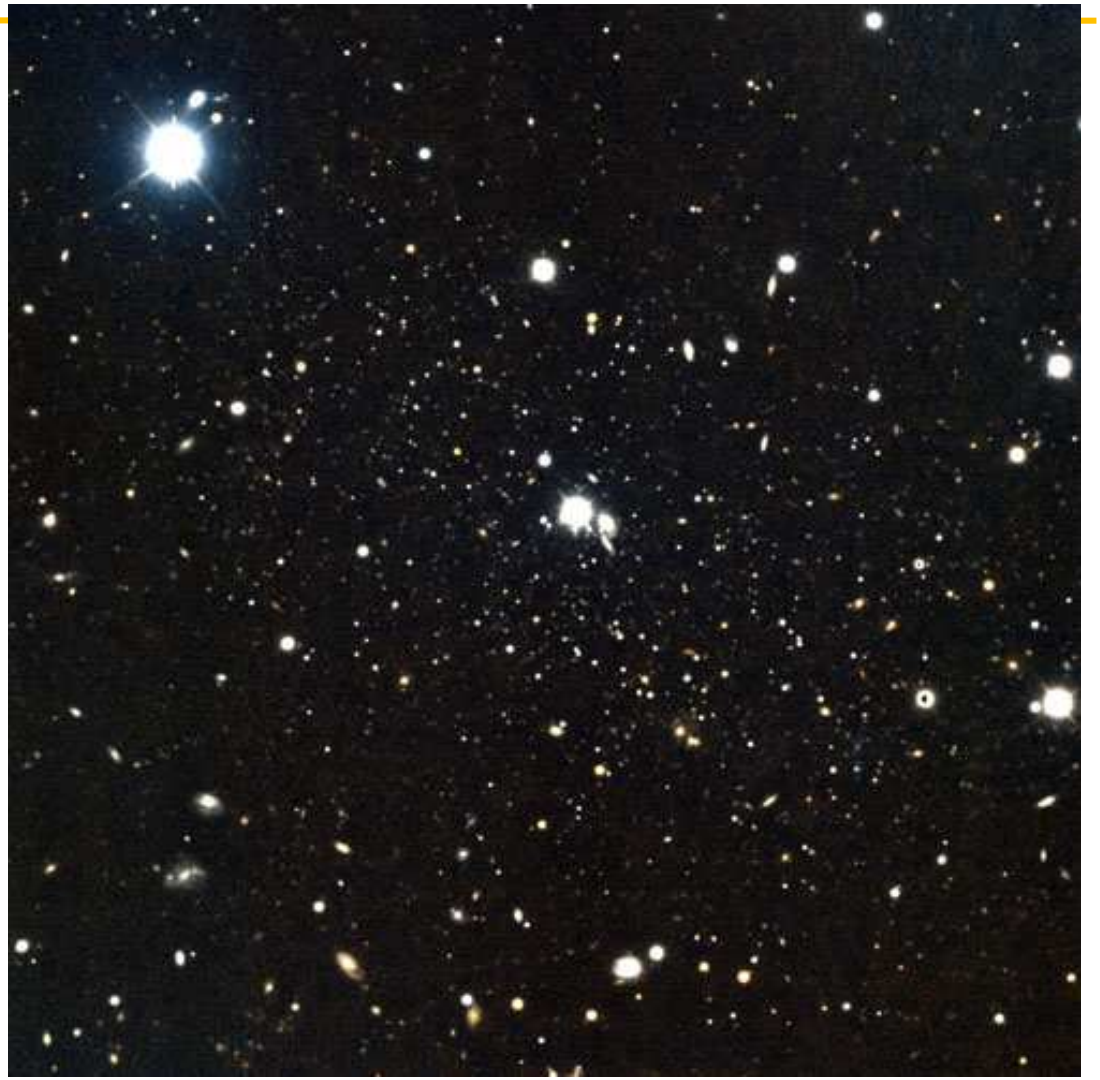
insensitive to dark halo contribution on this scale

M87 is useful to measure high-mass end of M-σ relation

Gebhardt et al. 2011

Andromeda XXIX – a newly discovered M31 satellite

- Fewer dwarf galaxies exist than predicted by cold-dark matter theory (by an order of magnitude)
- Not known whether due to incompleteness in the samples or a flaw in Λ-CDM
- Surveys of the Local Group in search of these extremely faint satellites of the Milky Way and Andromeda are important to better constrain the observational side of the problem
- Eric Bell and team identified a candidate dwarf galaxy from an enhancement in stellar density in SDSS images



Bell et al. ApJL 2011

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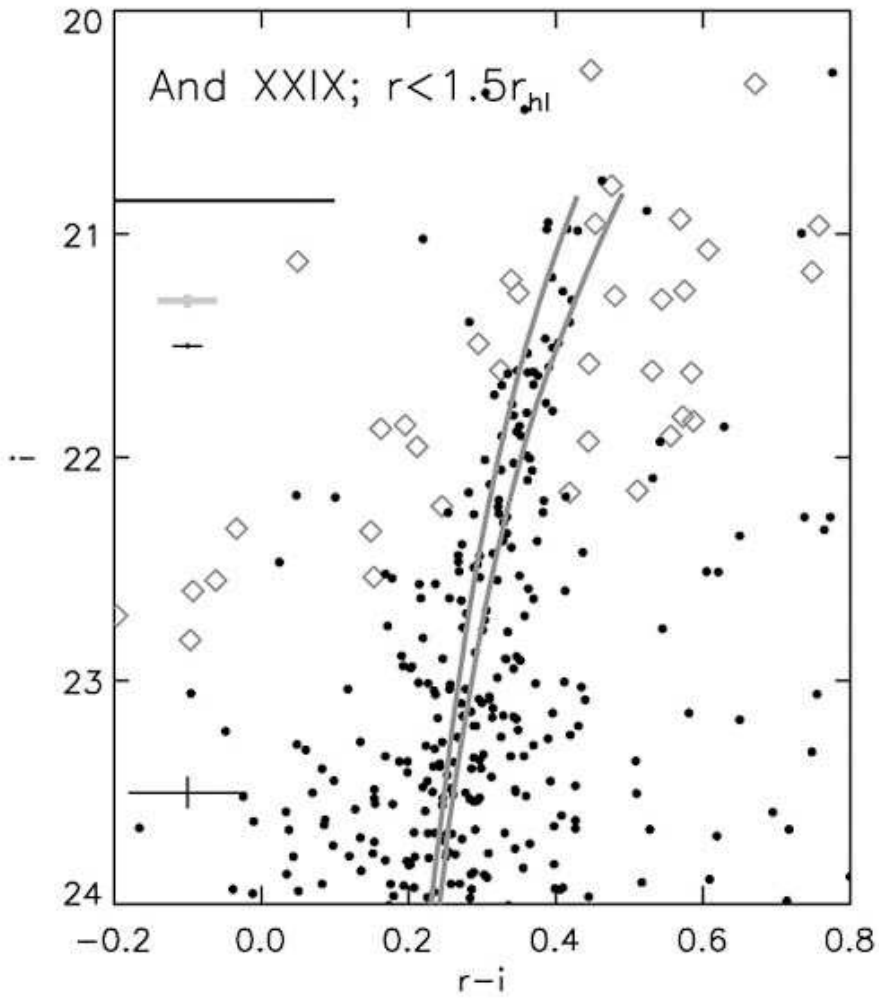
- Surveys of the Local Group in search of these extremely faint satellites of the Milky Way and Andromeda are important to better constrain the observational side of the problem
- Eric Bell and team identified a candidate dwarf galaxy from an enhancement in stellar density in SDSS images
- Deep follow up imaging with GMOS (only a few hours) revealed a clear giant branch, indicative of the presence of a metal-poor stellar system
- New dwarf galaxy located 200 kpc of the center of M31, where properties of satellites are poorly understood

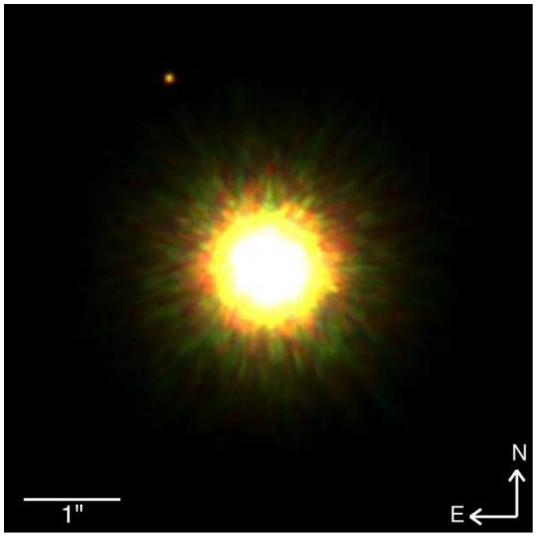


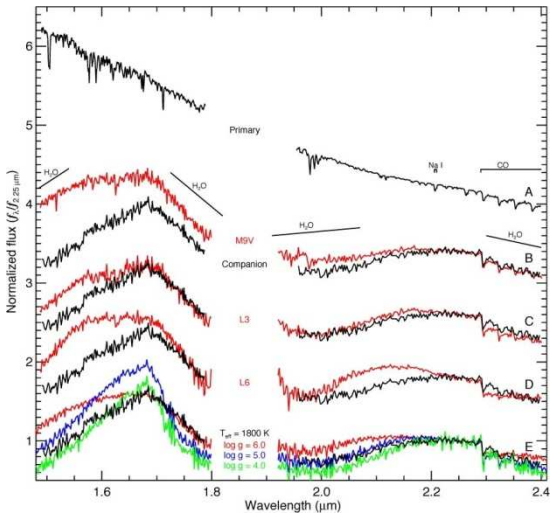
Bell et al. ApJL 2011


Obrigado
Gracias

AO Imaging of large Jovian "companion" of IRXS J…

- Gemini North ALTAIR NIRI discovery of 8 M_{Jup} "companion" to K7-type solar mass star (d ~ 150 pc)
  - In ~5 Myr-old Upper Scorpio association
  - At r = 2.22" or 330 AU orbit?
- Spectroscopy of Jovian planet
  - L4-type with T_{eff} ~ 1800 K
- "Wide" planetary companion poses a challenge to theories
- Needs proper motion measurements over next 2-3 yrs to establish whether planet is bound to star of chance superposition.



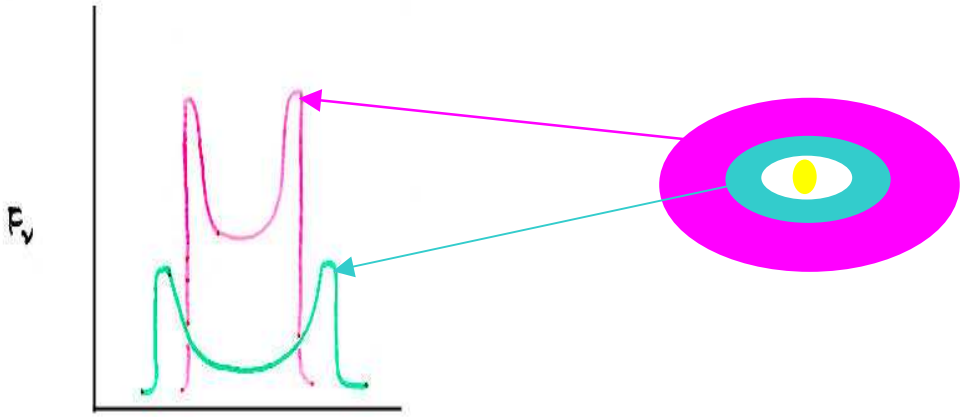


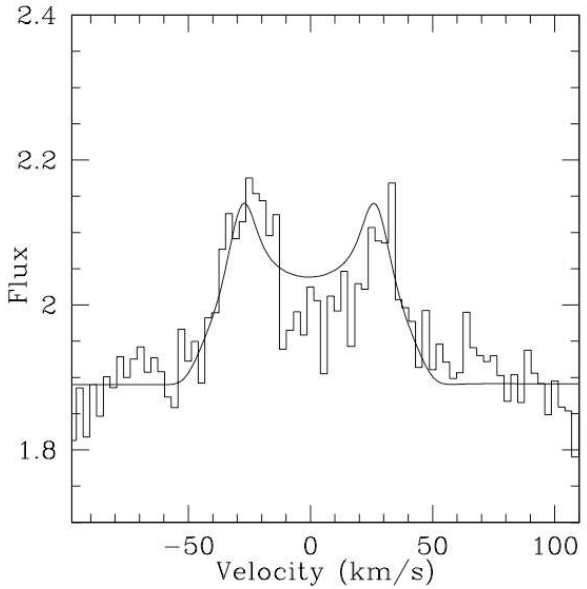
Lafrenière et al. 2008, ApJ in press

After 10 years of trials, first imaging of a self-luminous Jovian planet 'around' a normal star, I.e. lowest mass companion Imaged around normal star so far.

Proto-planetary Disk Kinematics with TEXES

- Kinematics of warm gas in proto-planetary disk with TEXES
  - R = 100,000
- H_2O rotational emission line resolved
  - 90 km/s FWHM
    - From r ~ 0.3 to 1 AU
  - "Double-horn shape profile consistent with ring of gas emission
    - Could be planetary "gap" in planet forming disk or cleared out inner disk by massive proto-planets

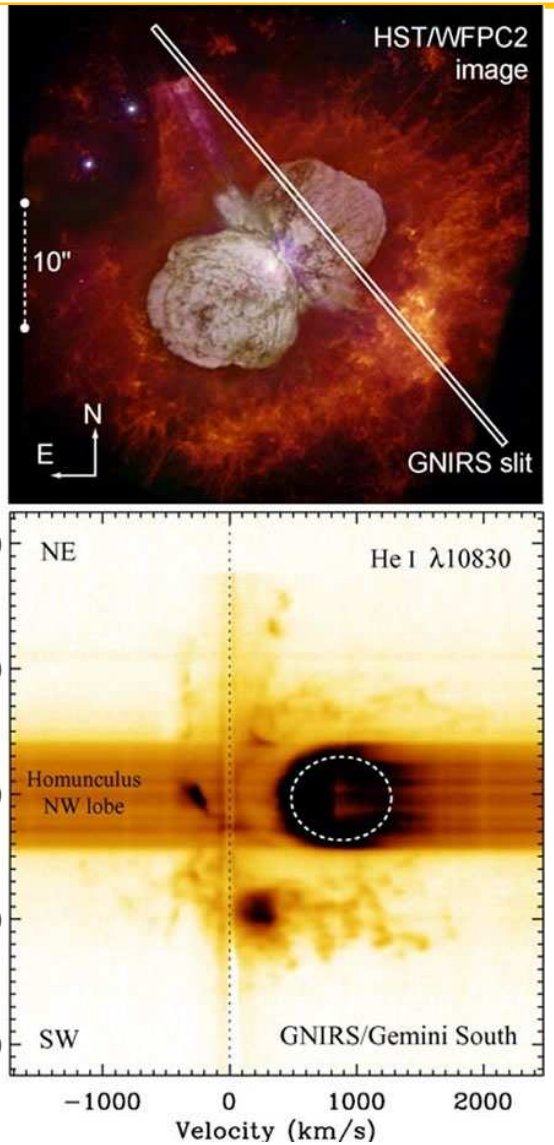




Carr, Najita, Richter, Lacy, Knez, et al. 2008, in prep

Hypersonic gas in ε Car

- Massive ε Car is a Luminous Blue Variable with violent eruptions
  - Precursor to supernova
- GNIRS finds 3,500-6000 km/s gas from 1843 eruption blast wave
  - This fast material doubles kinetic energy of 19th century event
  - Explosion rivalled that of a supernova --> hence more evidence for the class of "***supernova impostors***"



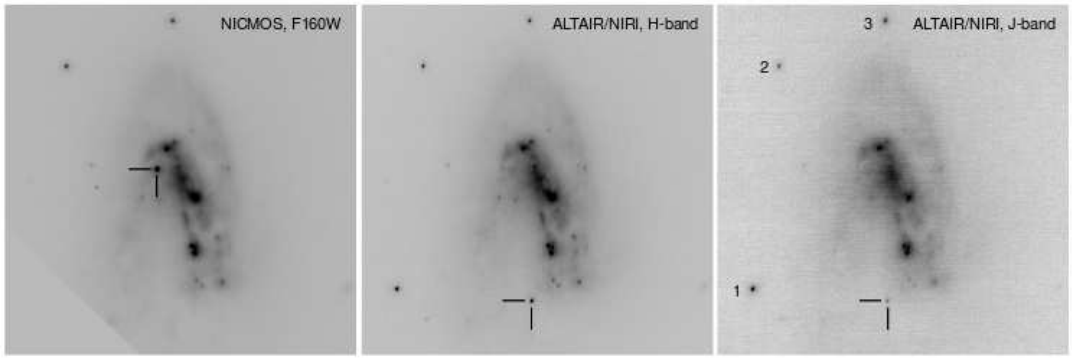
N. Smith 2008, Nature

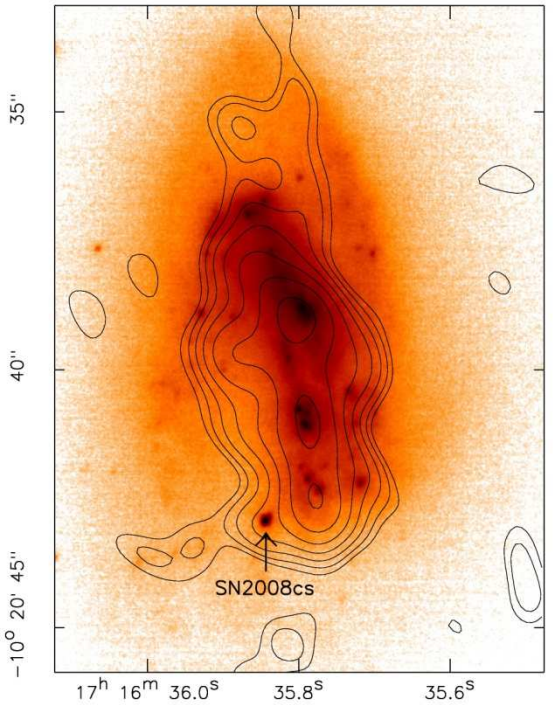
Supernova forensic with GN LGS AO imaging

- SN 2008cs is first SN discovered with GN NIRI ALTAIR LGS AO
  - Located 1.5 kpc from nucleus of LIRG IRAS 17138-1017
- By its radio detection by VLA, SN 2008cs is confirmed as core-collapse event
- JHK colors indicate extinction of ~17 mag in V band!

High extinction events can have impact for SN statistics and implications for high z dusty galaxy SFR

Kankare et al. 2008, ApJL



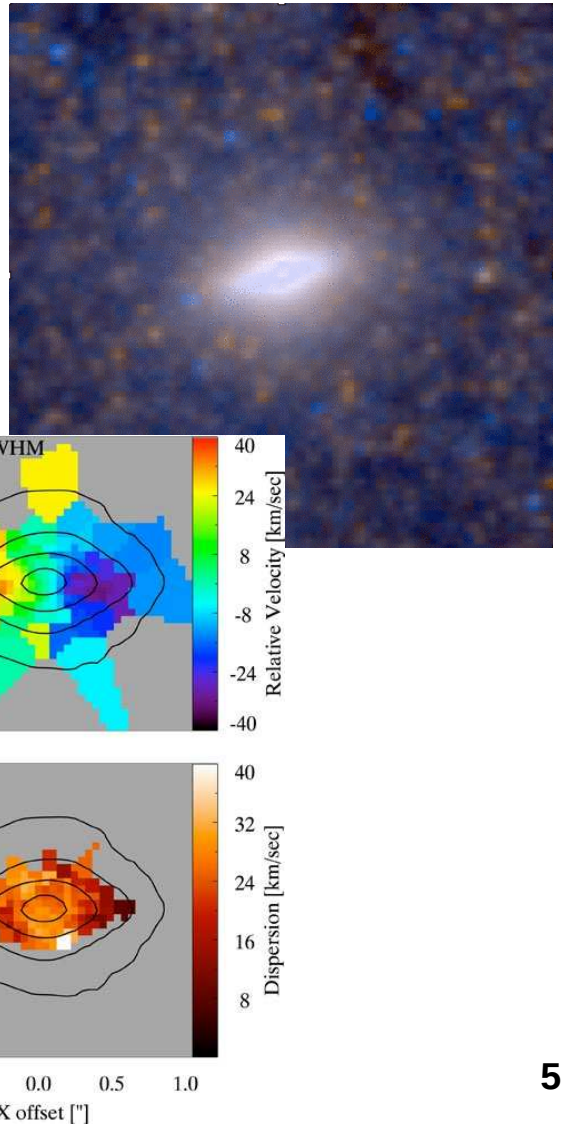


VLA-C 22.4 GHz Contours on 19 May 2008

A Rotating Nuclear Stellar Cluster

- ALTAIR/NIFS LGS AO spectroscopy of flattened nuclear star cluster in edge-on spiral NGC 4244
  - Multiple components
  - Strong rotation +/-30 km/s within the central 10 pc
    - Both young disk and spheroidal components rotate
    - Rotation is in same direction as normal disk
    - 1.7 x 10^6 solar mass located < 8 pc from core

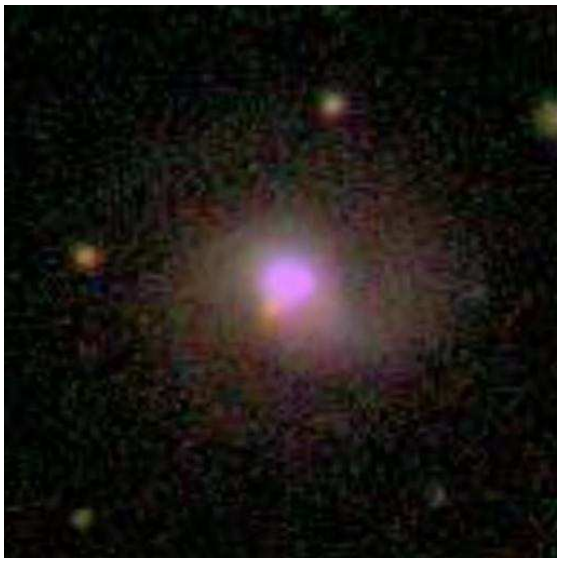
Primary formation of NSC through episodic accretion of material from the disk, gas or young star clusters.

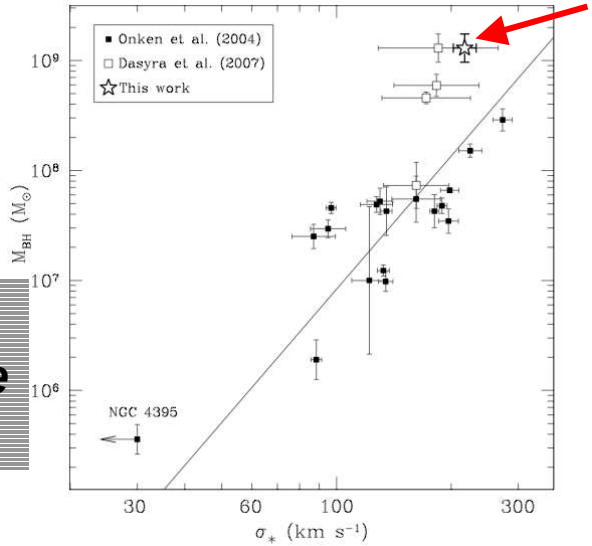


Seth et al. 2008, ApJ

Weighing A Super-massive Black Hole with NIFS LGS

- ALTAIR NIFS LGS velocity mapping of heart of PG 1436+015 quasar
- Stellar velocity dispersion from near IR Si and Mg lines and CO bandheads
  - M_{BH} lies significantly above M_{BH} - σ* relation
  - σ* = 217 +/- 15 km/s from 0.1” to 1.0” (0.16 to 1.6 kpc)
- Matching K5III template indicates surprising young population



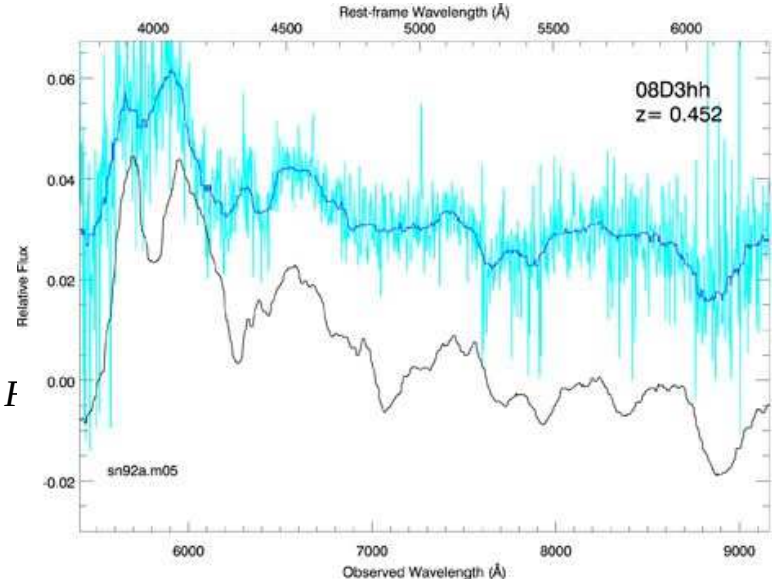


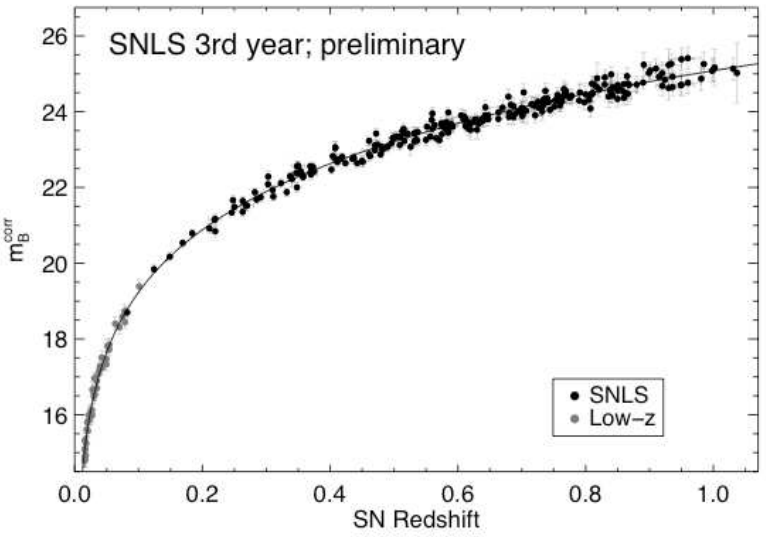
Another ALTAIR/NIFS LGS study indicates also much higher mass for central supermassive black hole than derived from RM

Watson et al. 2008, ApJ

SNLS 2003-2008

- Goal: produce a definitive sample of distant SN Ia for cosmology for distinguishing DE theories
- 400 spectroscopically confirmed SN from GN&GS, VLT, Keck and Magellan
  - 230 objects from Gemini (~500 hours of observing time)
- 15 refereed publications; team of ~40 from 7 countries





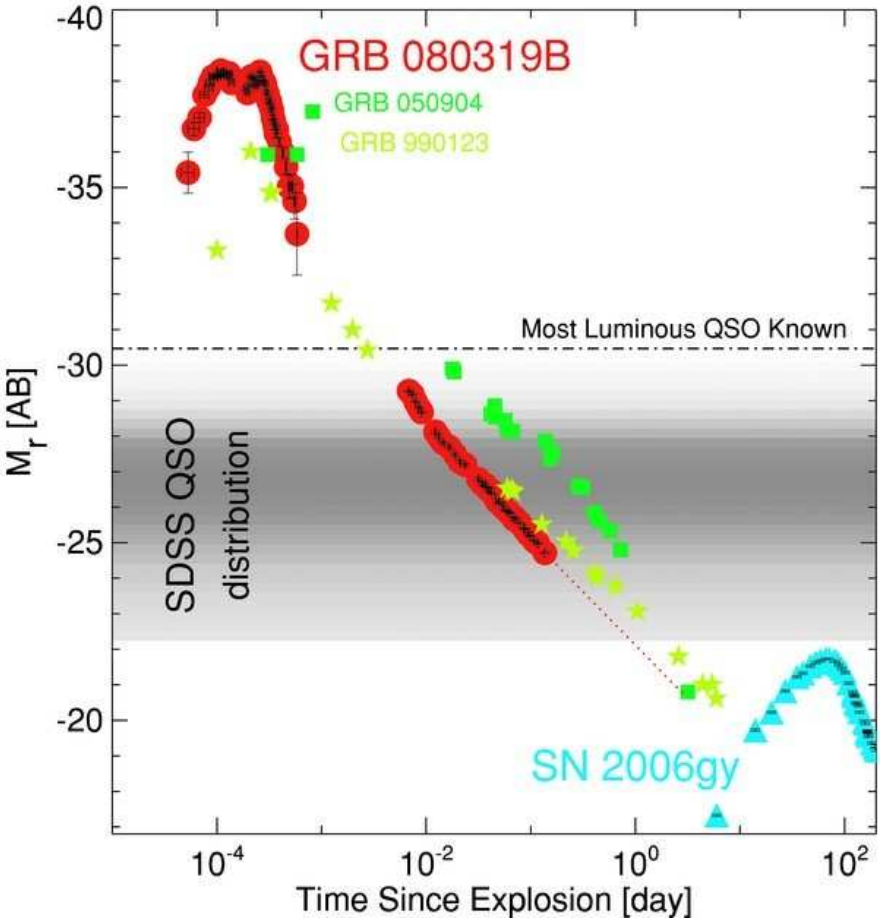
"Gemini's key role was to provide spectroscopic redshifts and classification of the SN types for the most distant (hence faintest) supernovae candidates. The N&S mode on GMOS made this possible by greatly reducing systematic effects associated with sky subtraction."

Isobel Hook

SNLS team, 2008

GRB 080319b:A naked-eye event !

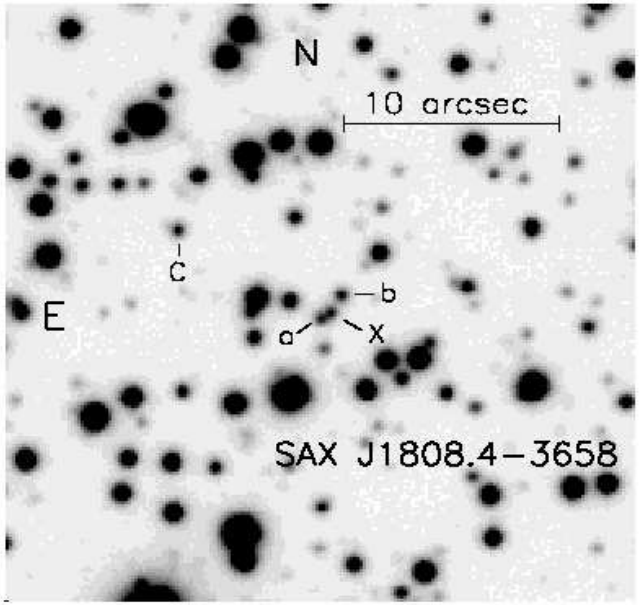
- Gemini rapid ToO programs at GN&GS
  - GRBs are tracked/monitored by a battery of space and ground-based telescopes
- GRB 080319b at z = 0.97
  - J ~4.5with PAIRTEL
  - afterglow imagery with GMOS North & South
    - Deepest late-time observations
    - Evidence for an optical jet break and luminous supernova
- For 30 min (rest frame), GRB 080319b was brightest than the most luminous QSOs
  - If it had occurred in the Milky Way, would have had M_{GRB} ~ -28.5, several times Sun's brightness

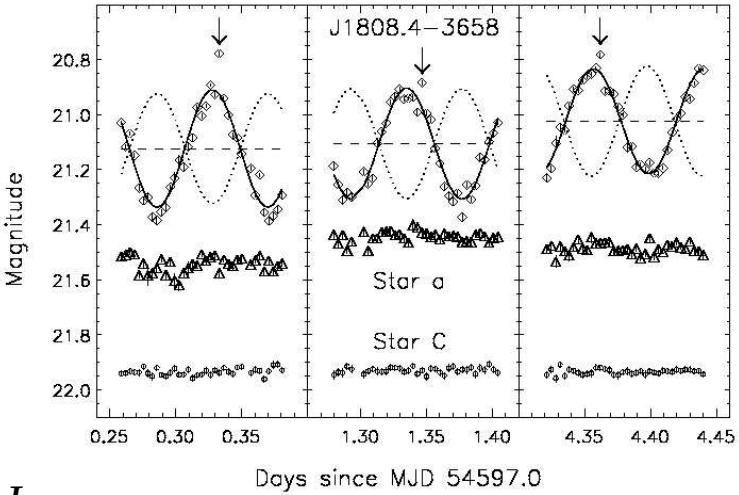


Bloom et al. 2009, ApJ

A freaky cosmic dwarf pair

- X-ray binary msec pulsar SAX J1808.4-3658 (d~3.5 kpc)
  - Strange pair: 1.4 M_{Sun} neutron star with 0.05 M_{Sun} brown dwarf on a 630,000 km orbit
  - BD dumps matter onto NS accretion disk
- GMOS-South orbit determination from light curve → P~2.01 hour
  - ***Modulated light comes from irradiated companion (locked phase)***
  - ***Persistent light comes from accretion disk***
- Companion will be ablated by pulsar wind → "*black widow*" system



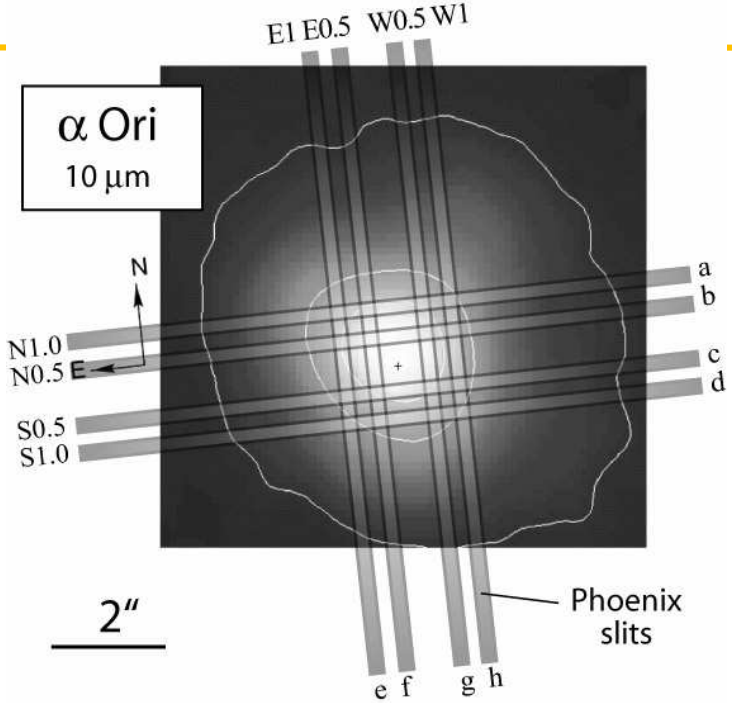


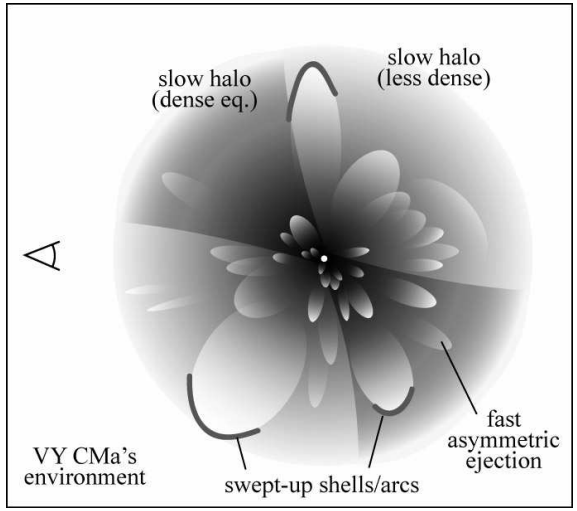
Wang et al. 2009, ApJ

Betelgeuse and VY CMa as future supernovae

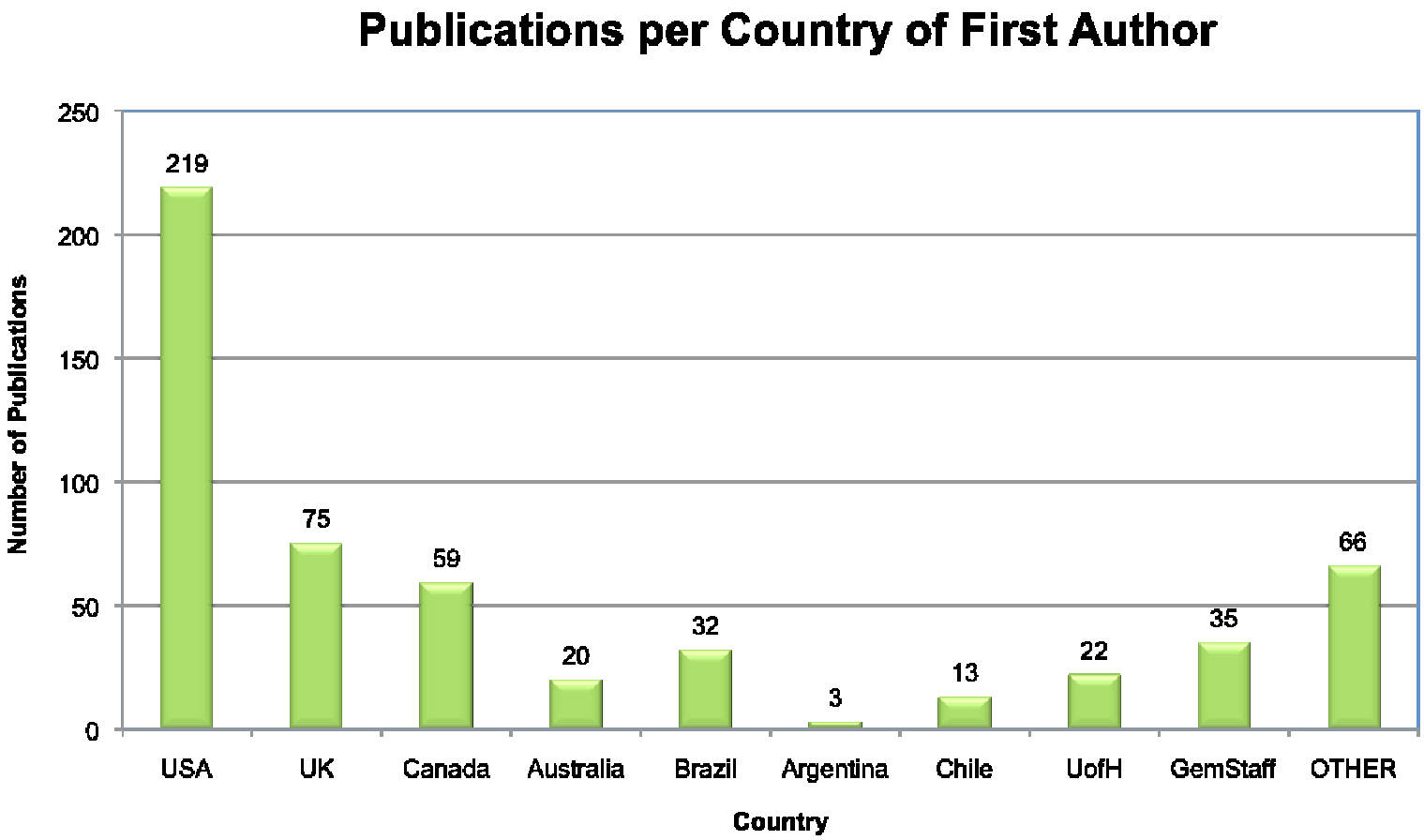
- PHOENIX spectroscopy of red supergiant circumstellar envelopes: geometry and kinematics
- Betelgeuse: from CO emission to 1000 AU
  - Velocity structures up to 35 km/s
  - Clumpy spherical shell shaped by steady stellar wind with 2 x 10^{-6} Msun/yr for last 300 years
  - ***Will be luminous SN II with blast wave ~15,000 km/s***
- VY Cma: CO emission coincident with KI shell
  - Clumpy asymmetric shell shaged by prodigious mass loss (100 x of Betelgeuse and multiple ejections since 1000 years
  - ***Will be moderately luminous, long lasting, SN II with balst wave of a few 1,000 km/s***

Smith et al. 2009, ApJ



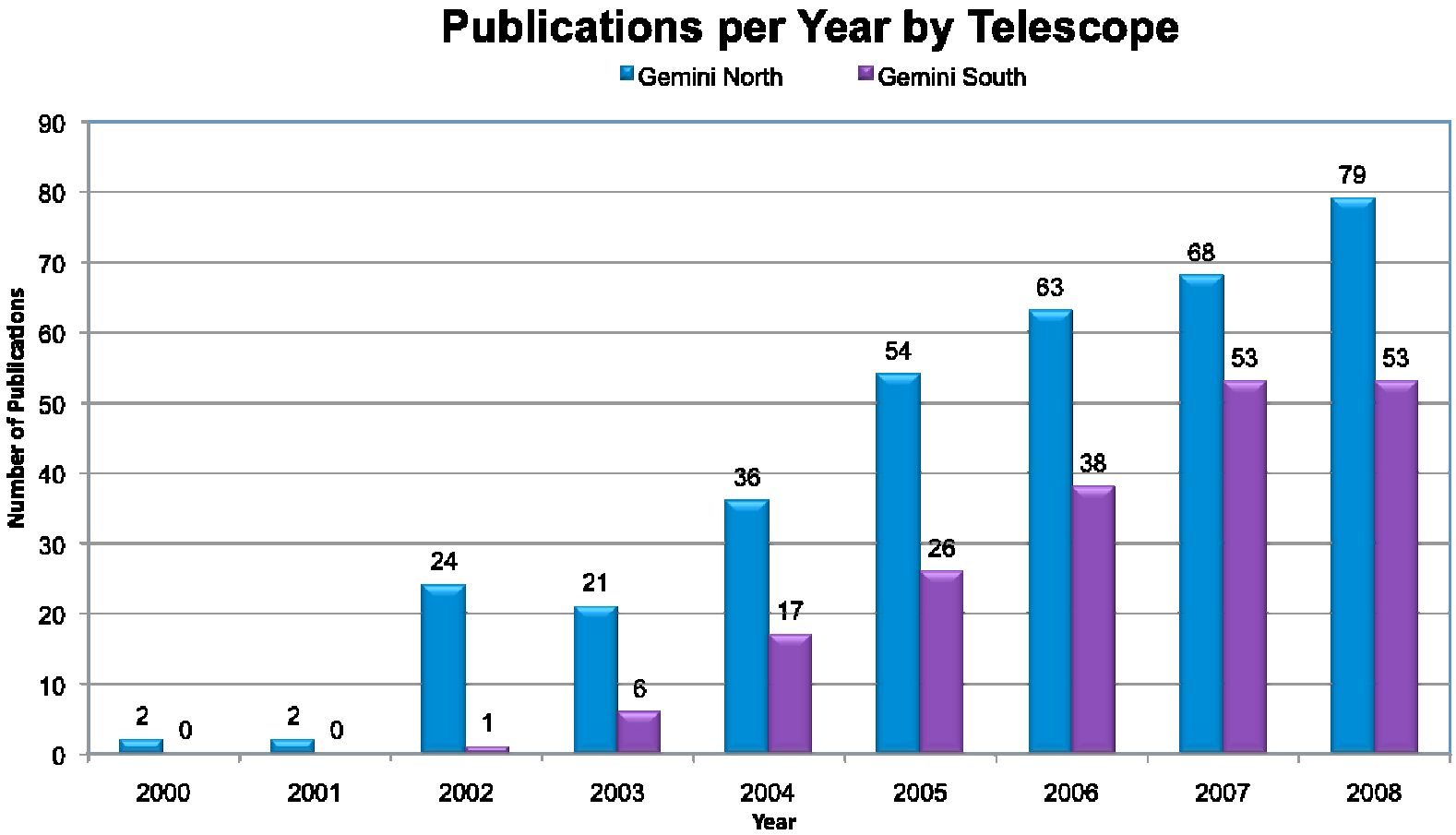


Publications



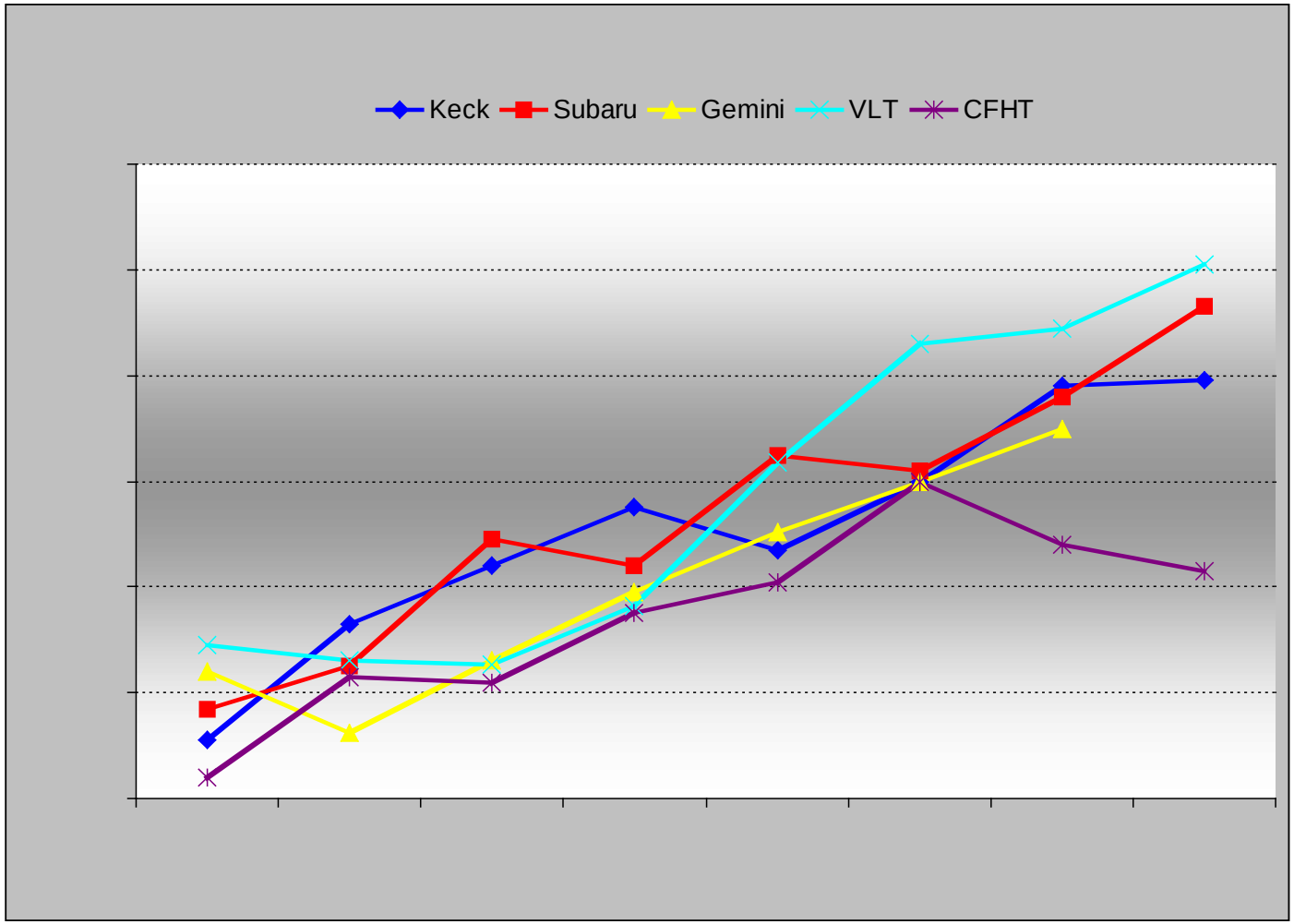
Equilíbrio na "produtividade" dos países-membro. Exeções são o Brasil (altamente produtivo), Argentina (baixa produtividade)

Publications



Growth of refereed papers for GN and GS. "Gap" started to close in 2007 - but seems to continue in 2008… +/- Impact of GNIRS at GS?

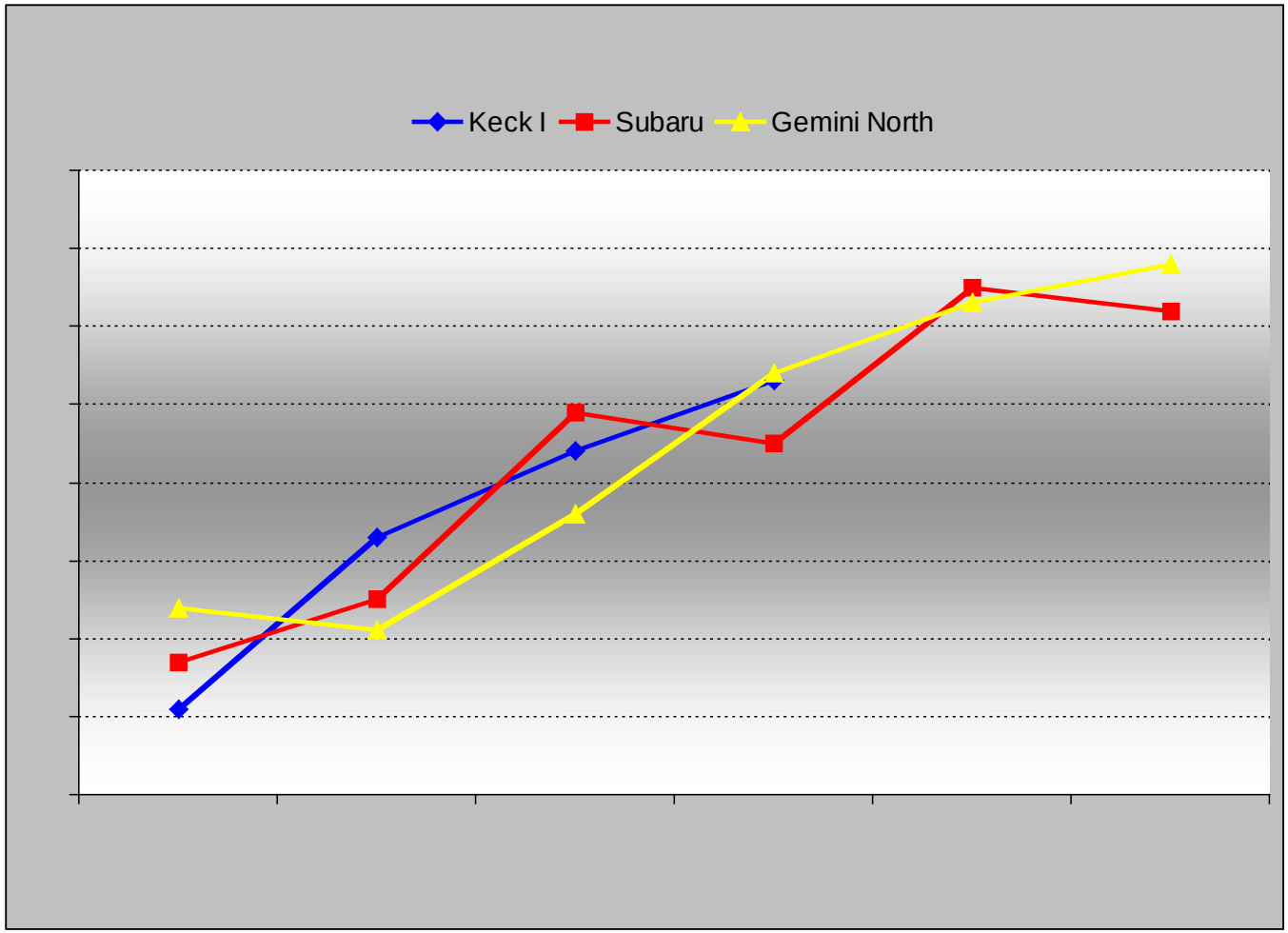
Publications



At Gemini's age (~7) observatories typically produce ~70-80 papers per telescope

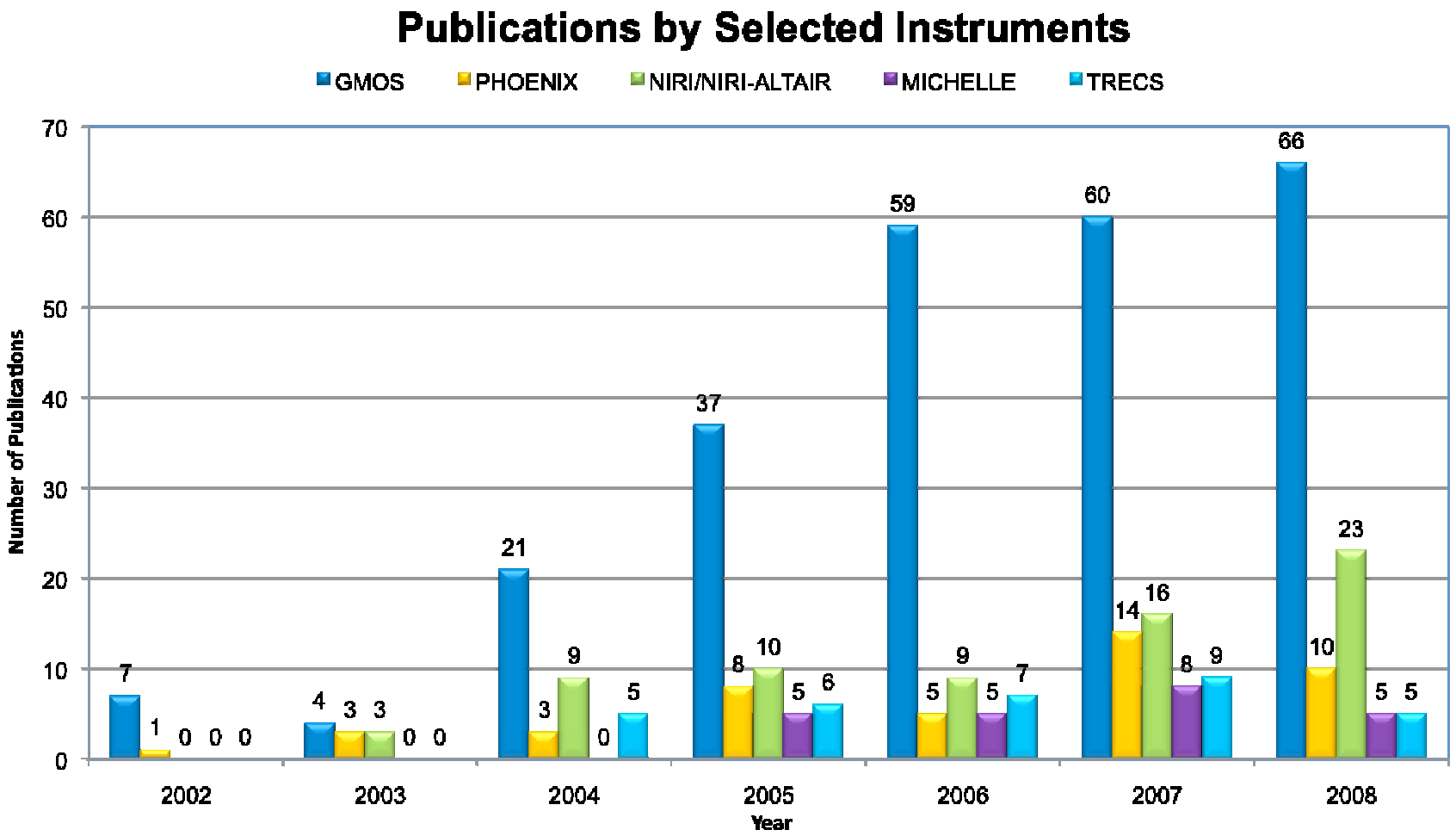
Publications

 # papers per yr

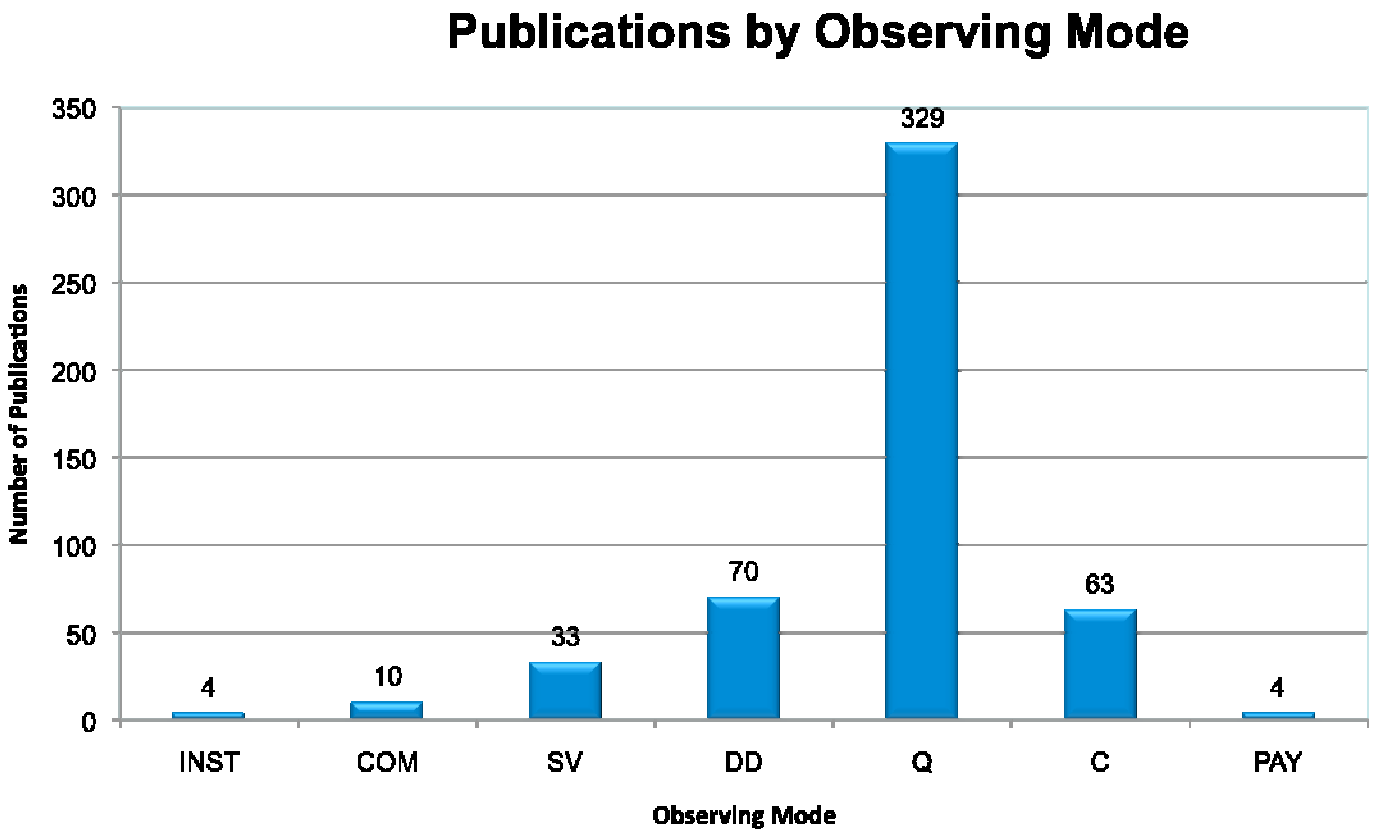


Papers growth of MK single 8-10 m telescopes

Publications



Publications



INST = instrument , COM = commissioning, SV = system verification, C = classical, DD = Director's time, Q = regular Queue program, PAY = visitor instrument payback