The Giant Magellan Telescope Project

Overview & Status

Patrick McCarthy & Daniel Fabricant

JWST & ELTs - April 13, 2010

The GMT Concept

Giant-Segmented Mirror Telescope

f/0.7 primary

Adaptive Secondary Mirror

Aplanatic Gregorian

f/8 focus

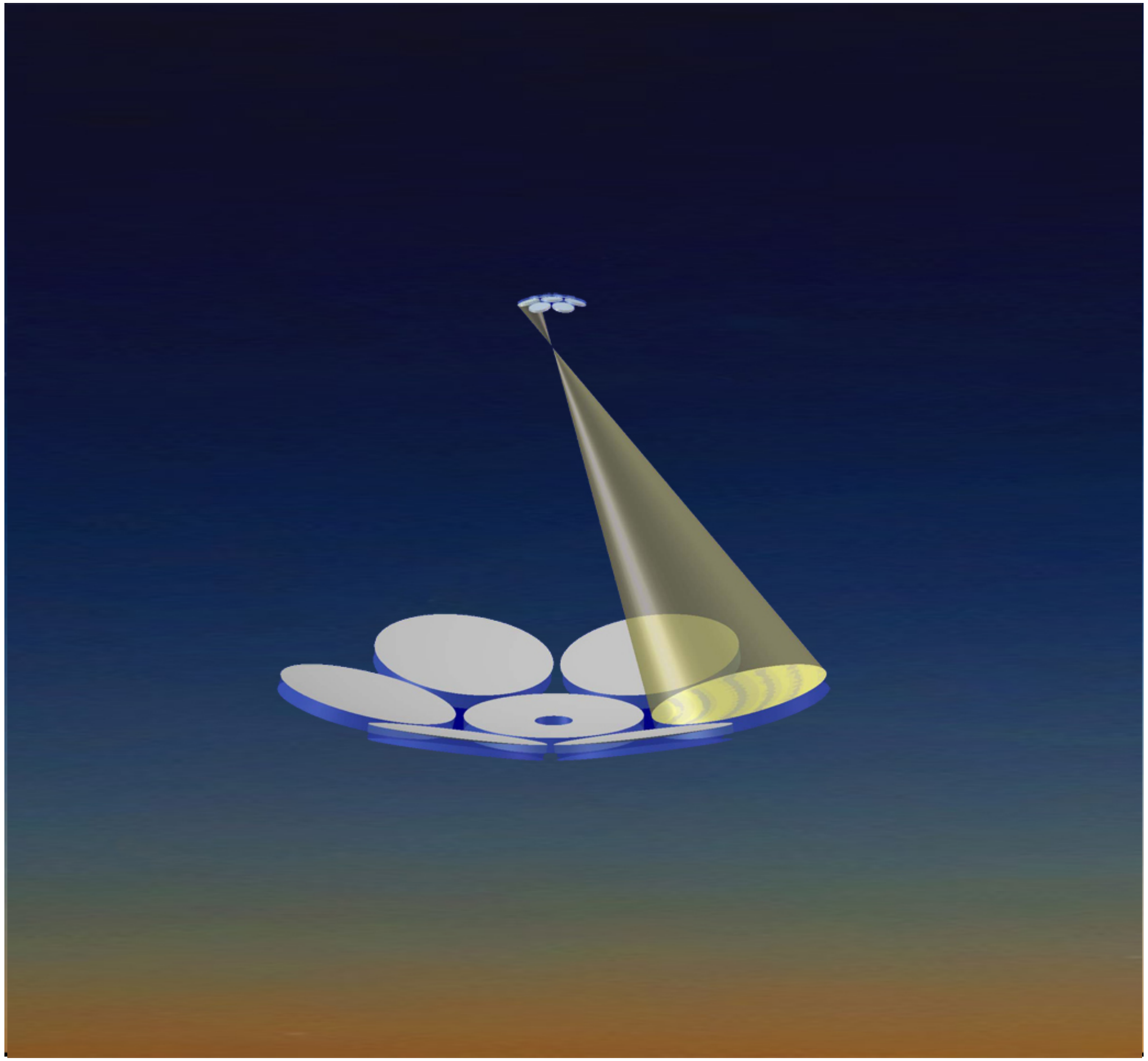
1″/mm at focal plane

10 mas at 1μm

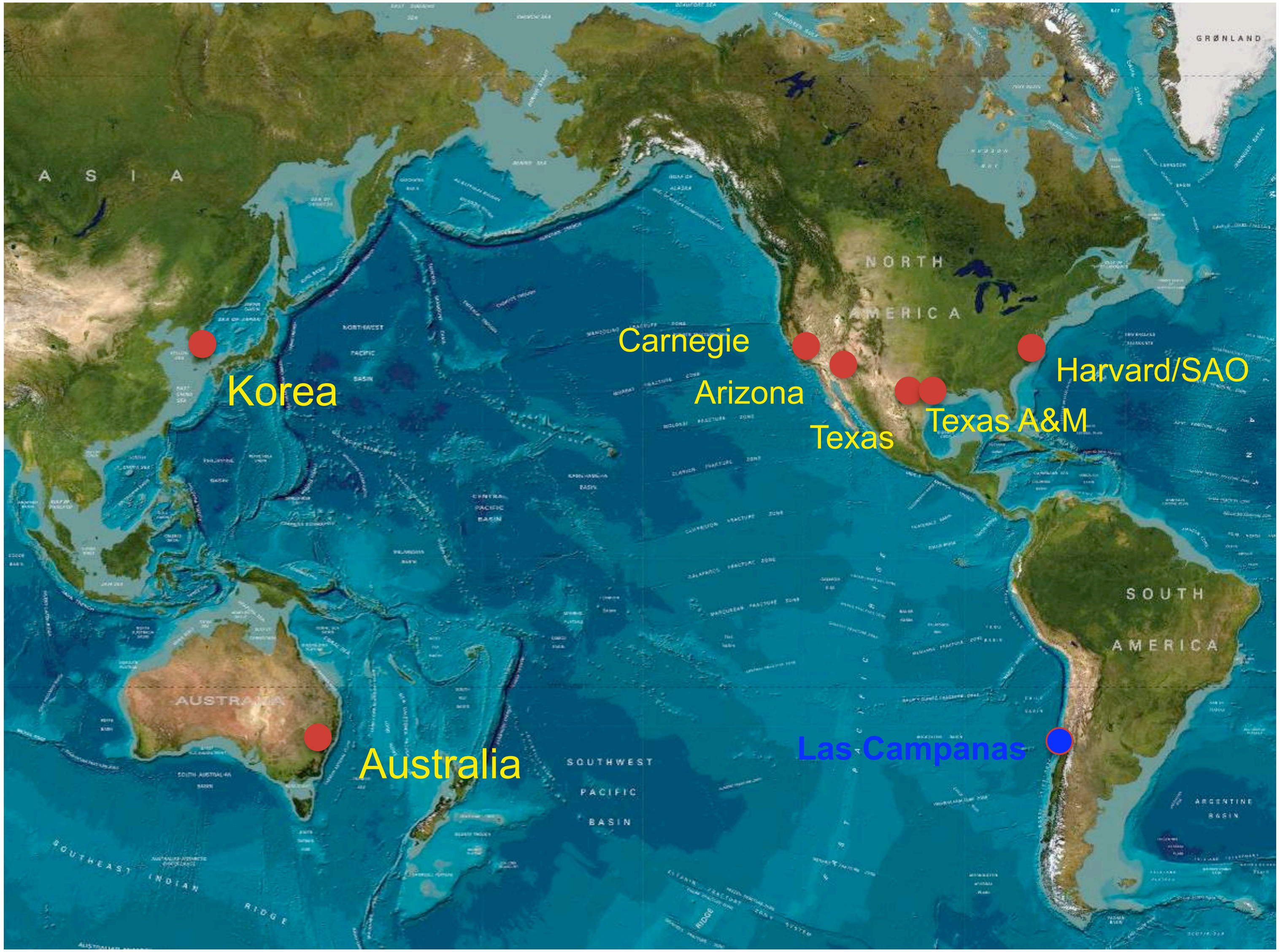
(JWST: ~70mas at < 2μm)

380 square meters

10 x JWST Collecting Area



GMT Institutions



Project Status

Design phase moving to completion

- Preliminary Design Review in late 2011

- Start of construction - 2012

Funding moving ahead rapidly

- Some partners funded through construction, others progressing

Hiring of project staff nearing completion

- AO, Instrumentation, Systems Engineering,... positions filled

Site Selected

- Las Campanas Peak, Chile

- Site preparatory work to begin soon

GMT Project Team

AO and Instrumentation Leads

George Jacoby

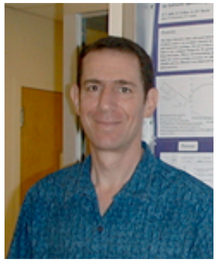
GMT Instrumentation Scientist

Steve Shectman

Project Scientist

Antonin Bouchez

GMT AO Scientist



Dan Jaffe

GMT SAC Chair

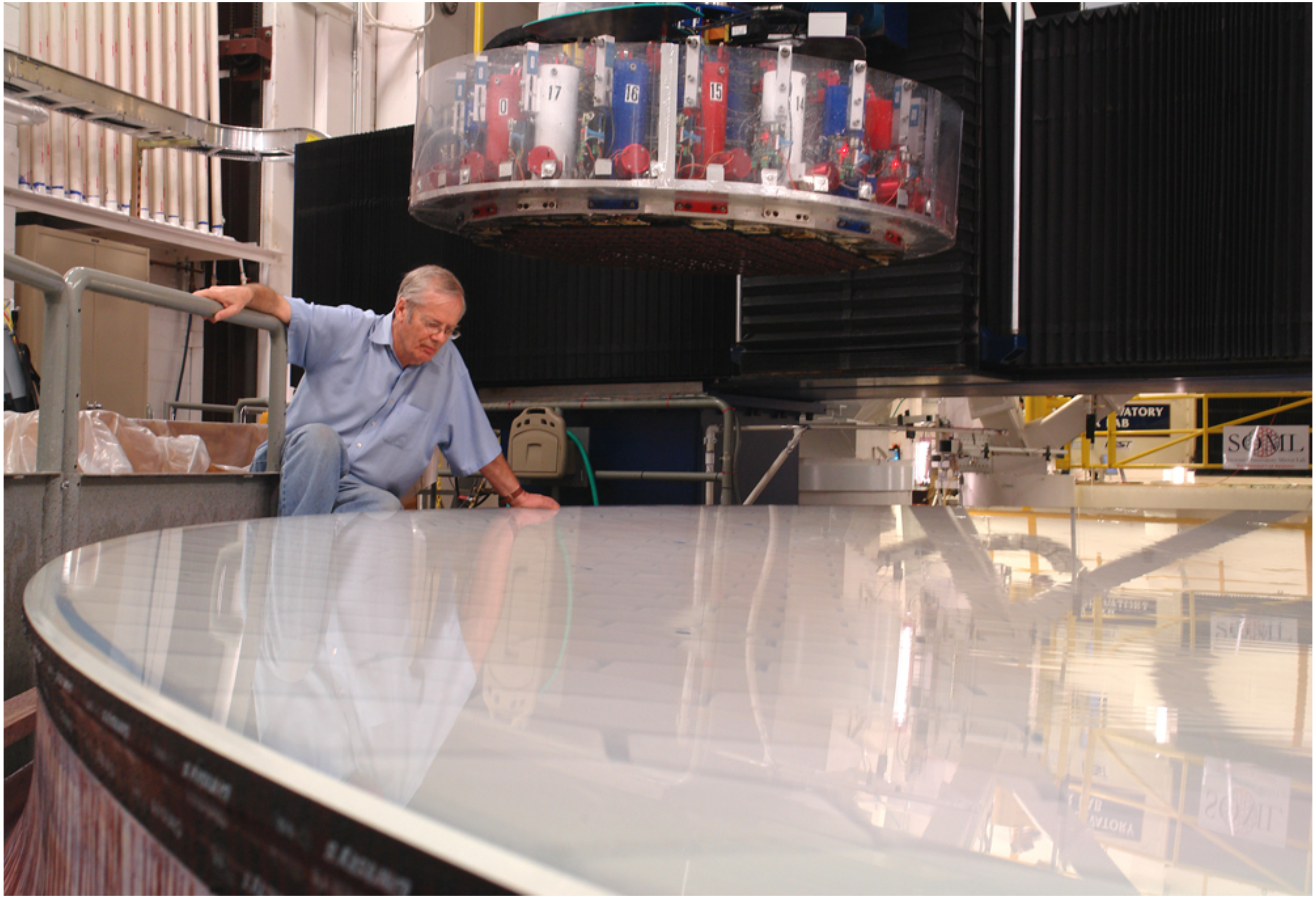
Phil Hinz

AO Consultant

Marcos Van Dam

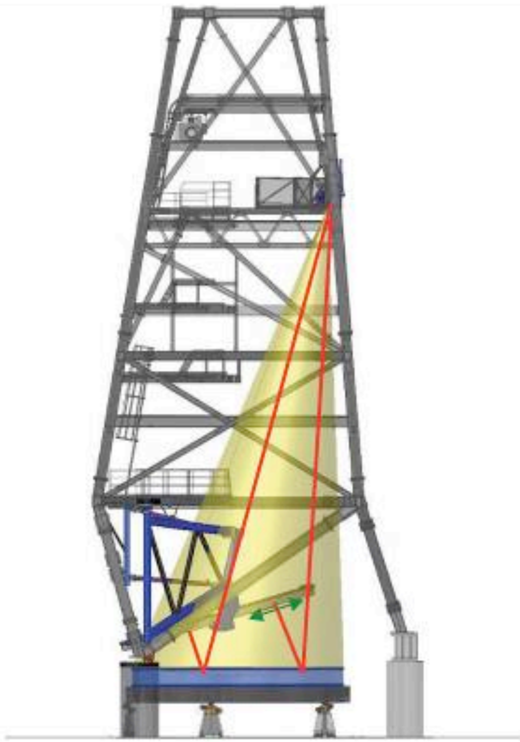
AO Consultant

Polishing First Off-Axis GMT Primary Segment

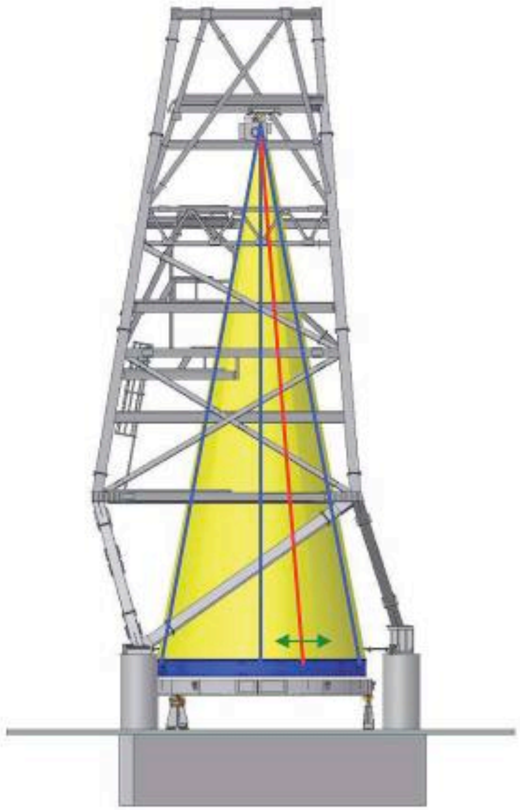


GMT Primary Mirror Metrology

Principal optical test
Full-aperture, interferometric test
Also provides shear test



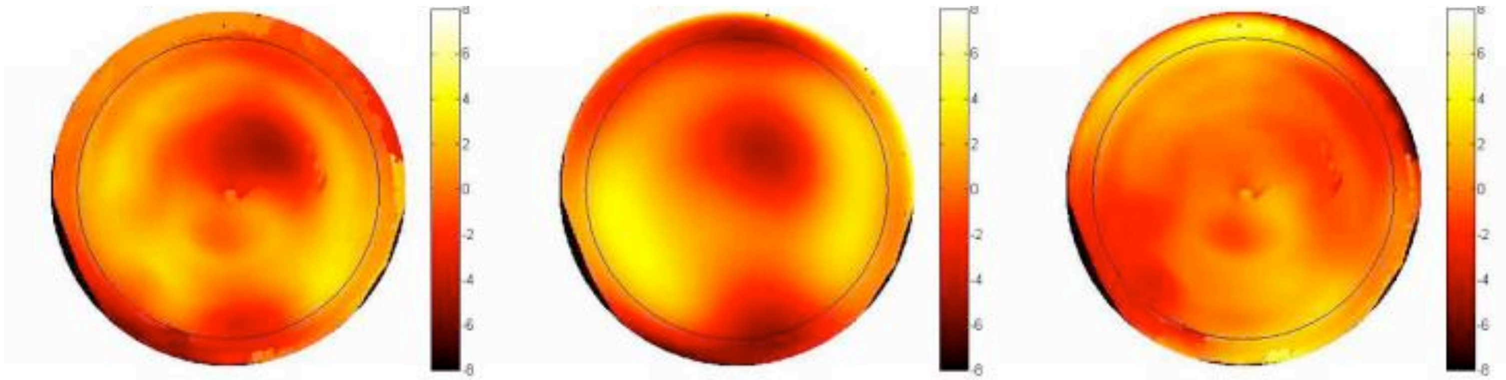
Scanning pentaprism test
Measures low-order aberrations
via slopes



Laser Tracker Plus
Scans surface with laser tracker
Works on ground or polished surface

Three technologies provide strong tests of internal consistency of mirror figure

Progress on GMT's Primary Mirrors



Interferometer

Laser Tracker

Difference

(consistent within 1μm tracker errors)

First off-axis segment

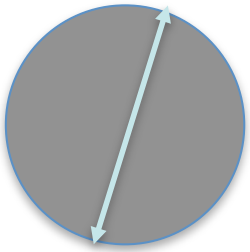
Completion projected for September

GMT's Unique Strengths

• Adaptive secondary mirror allows low background thermal IR observations and wide-field ground layer AO

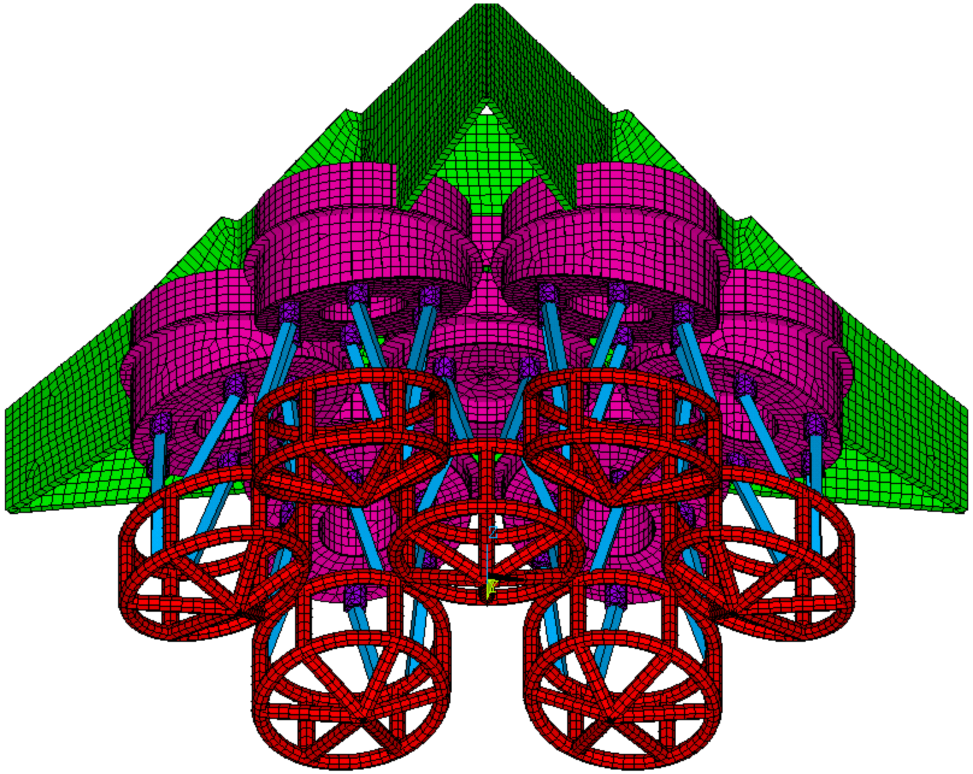
Seven 1.1 m adaptive secondary mirrors

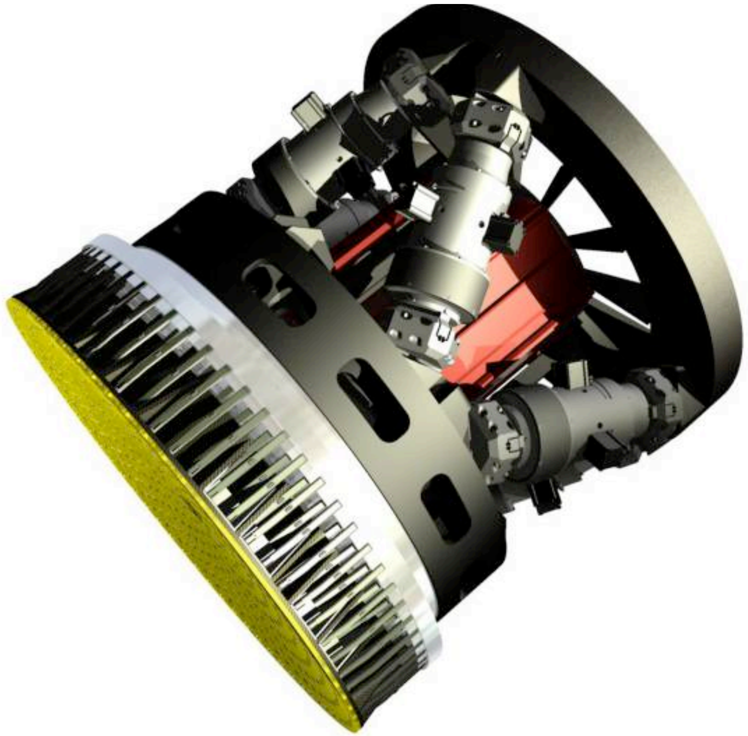
• Fast f/8 final focal ratio allows practical wide-field instruments similar to those on current 8 m class telescopes



Focal plane scale
10′ < 600 mm

Progress on the Adaptive Secondary





ADS/Microgate design and cost study complete
In May

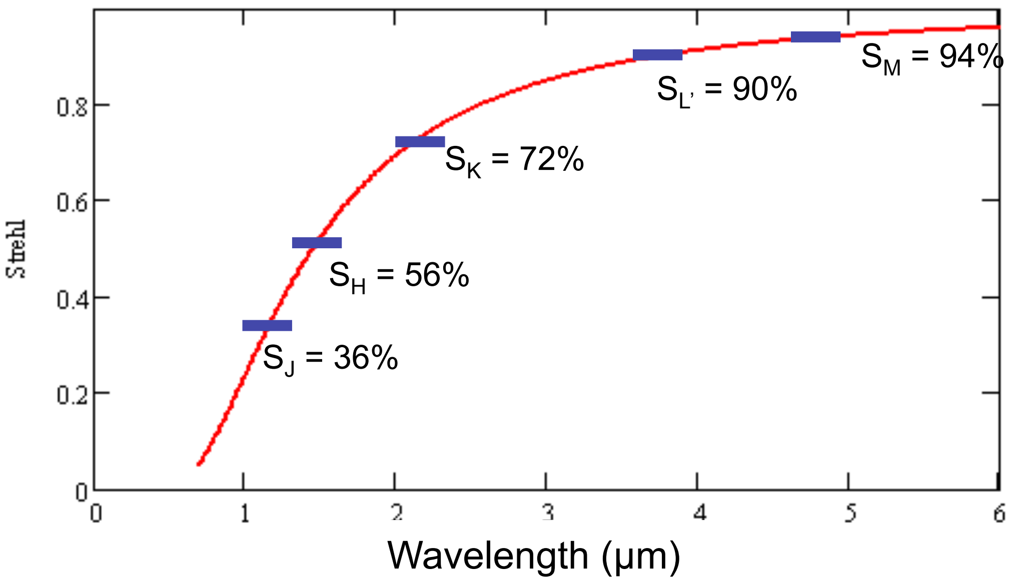
Study supported with funding provided by the NSF and AURA through SP010

First Generation GMT AO Modes

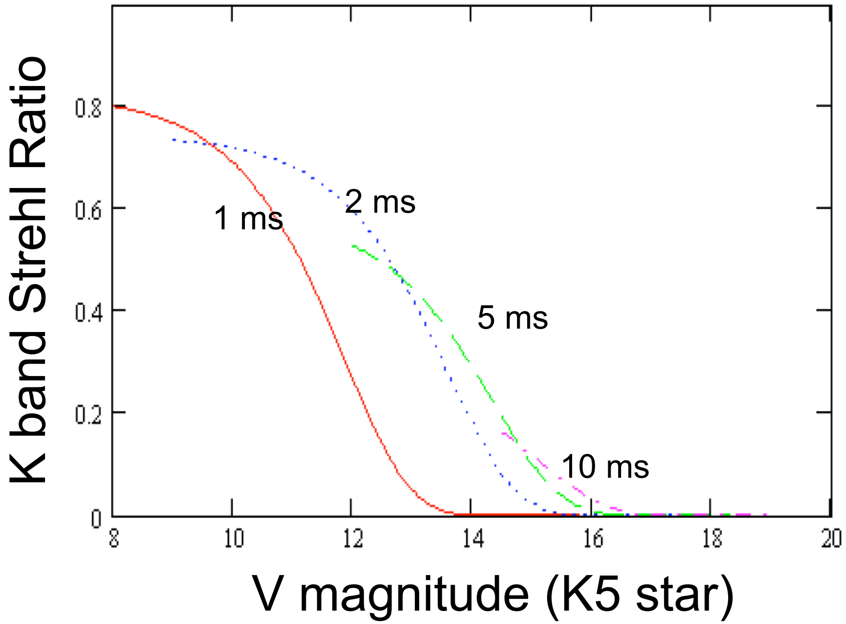
Mode	Description
Natural Guide Star AO (NGSAO)	High Strehl adaptive optics using guide stars within the isoplanatic patch.
Laser tomography AO (LTAO)	All-sky high Strehl adaptive optics using laser beacons in the atmospheric sodium layer.
Ground Layer AO (GLAO)	All sky adaptive optics using laser beacons to correct low-altitude turbulence for factors of 2-4x image size reduction over fields of view up to 9′.

AO System Performance

AO System Performance versus wavelength

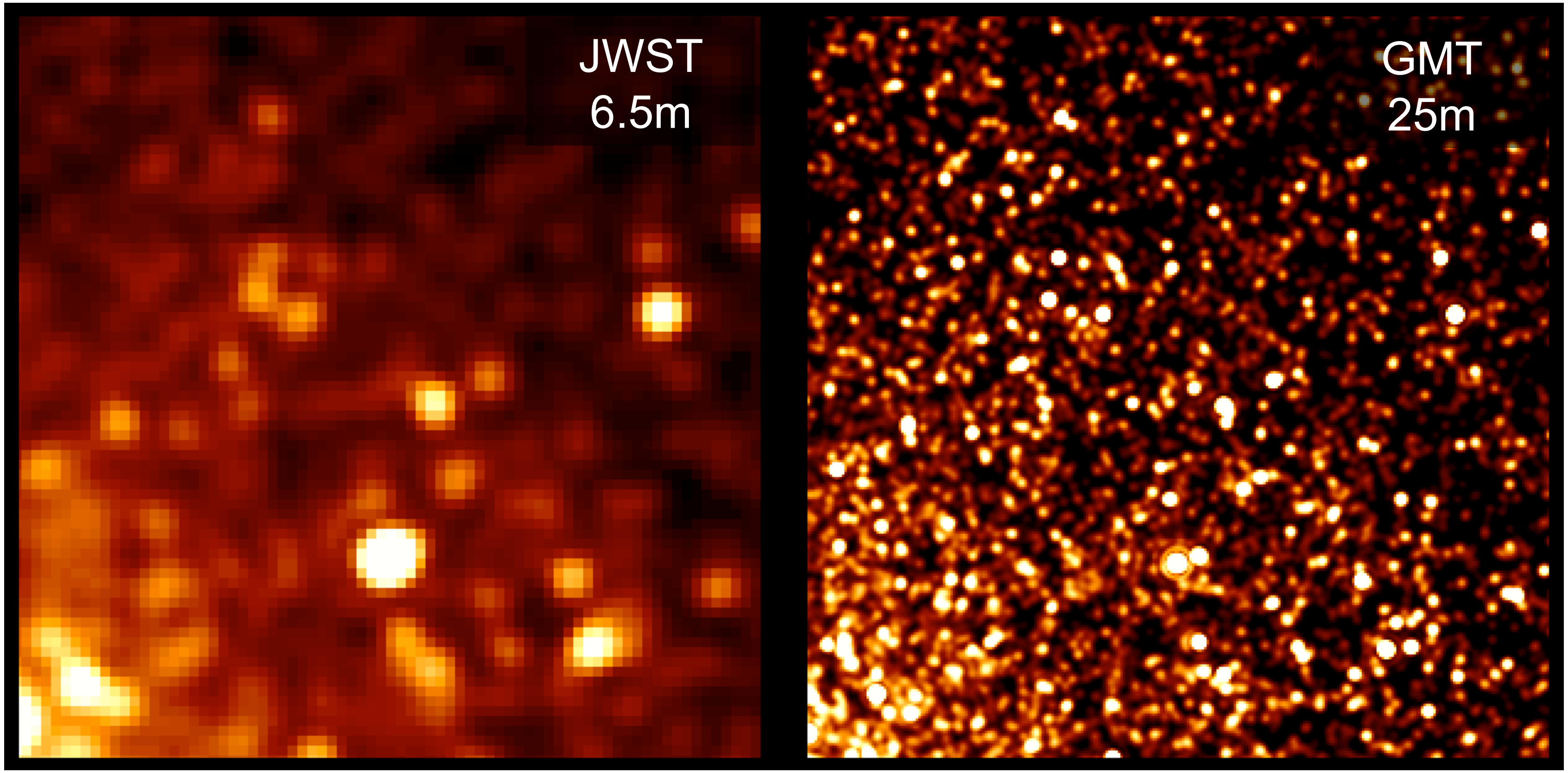


NGS performance versus guide star brightness



Resolving Distant Stellar Systems

Globular Cluster around Cen A   3.8Mpc   3pc core radius   H-band



1.2″ x 1.2″   4mas pixels

Candidate First Light Instruments

Natural Seeing Instruments

- GMACS: wide-field optical imager/spectrograph
- G-CLEF: high-resolution optical spectrograph

Adaptive Optics Instruments

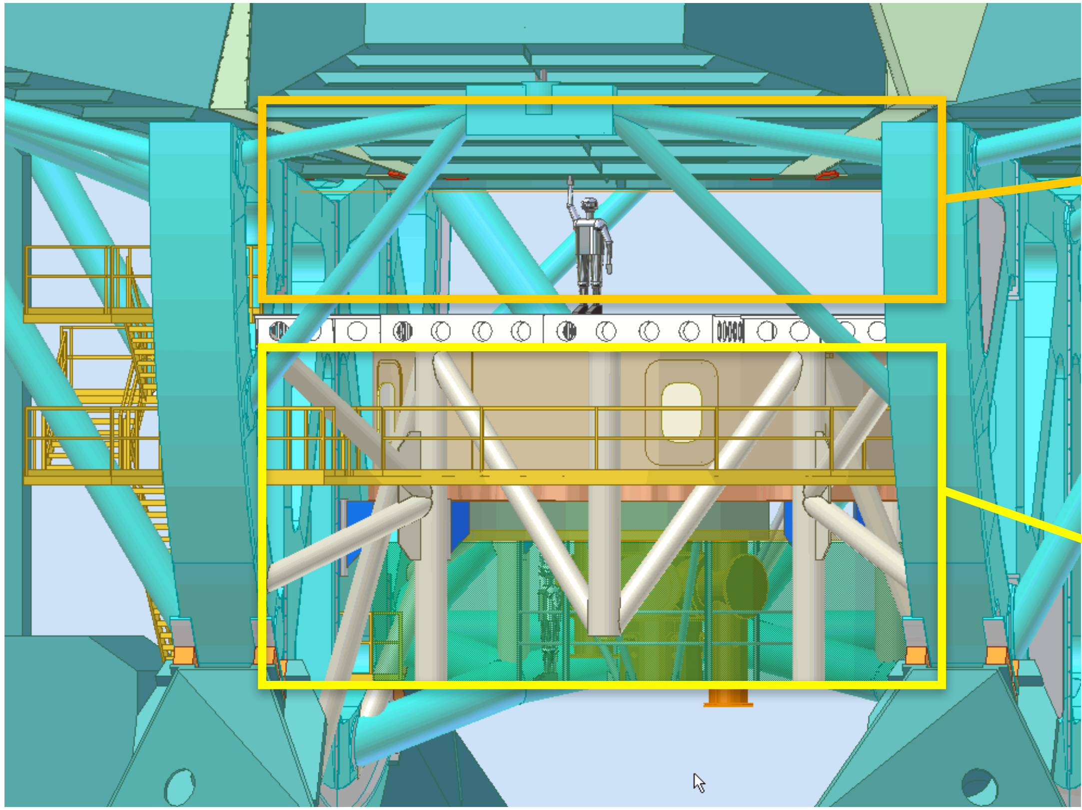
- GMTIFS: near-infrared imager/integral-field spectrograph
- GMTNIRS: high-resolution near-infrared spectrograph
- TIGER: high-contrast thermal-infrared imager/spectrograph

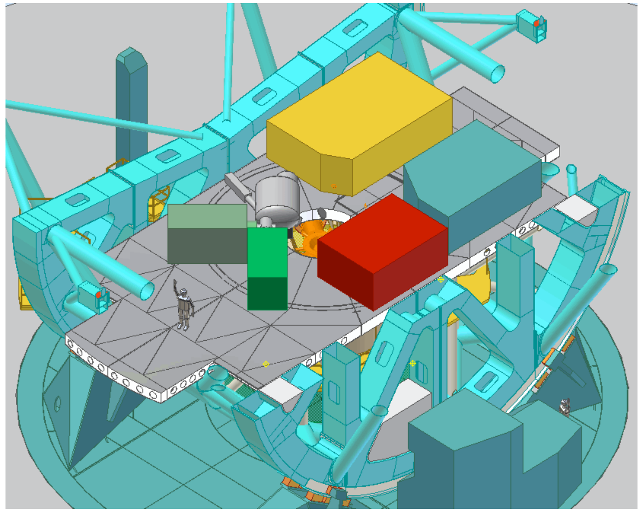
Natural Seeing/Ground Layer AO Instrument

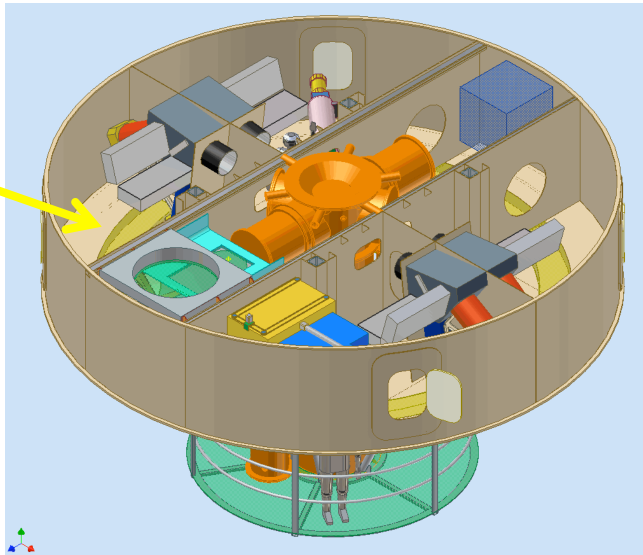
- NIRMOS: wide-field near-infrared imager/spectrograph

Down Select to 2 – 4 instruments Occurs in Fall 2011

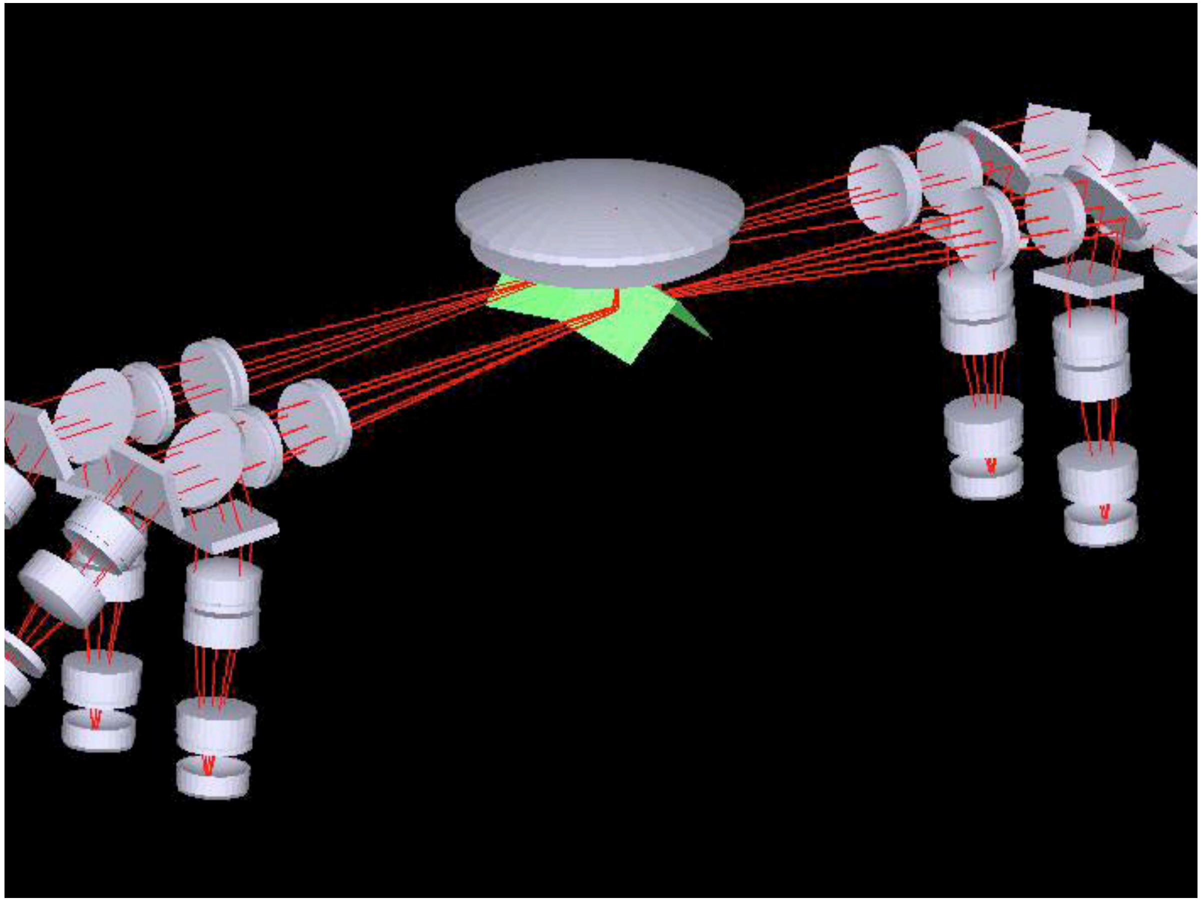
Mounting GMT Instruments







Giant Magellan Areal Camera and Spectrograph



GMT's 20′ corrected FOV addressed by 4 dual-beam optical spectrographs

- Total slit length 36′
- Total field area 144 sq arcmin
- R=1400-2700 with 0.7” slit
- spectral range 0.36 – 1.0 μm

Visible Spectra of $z \sim 3$ Galaxies

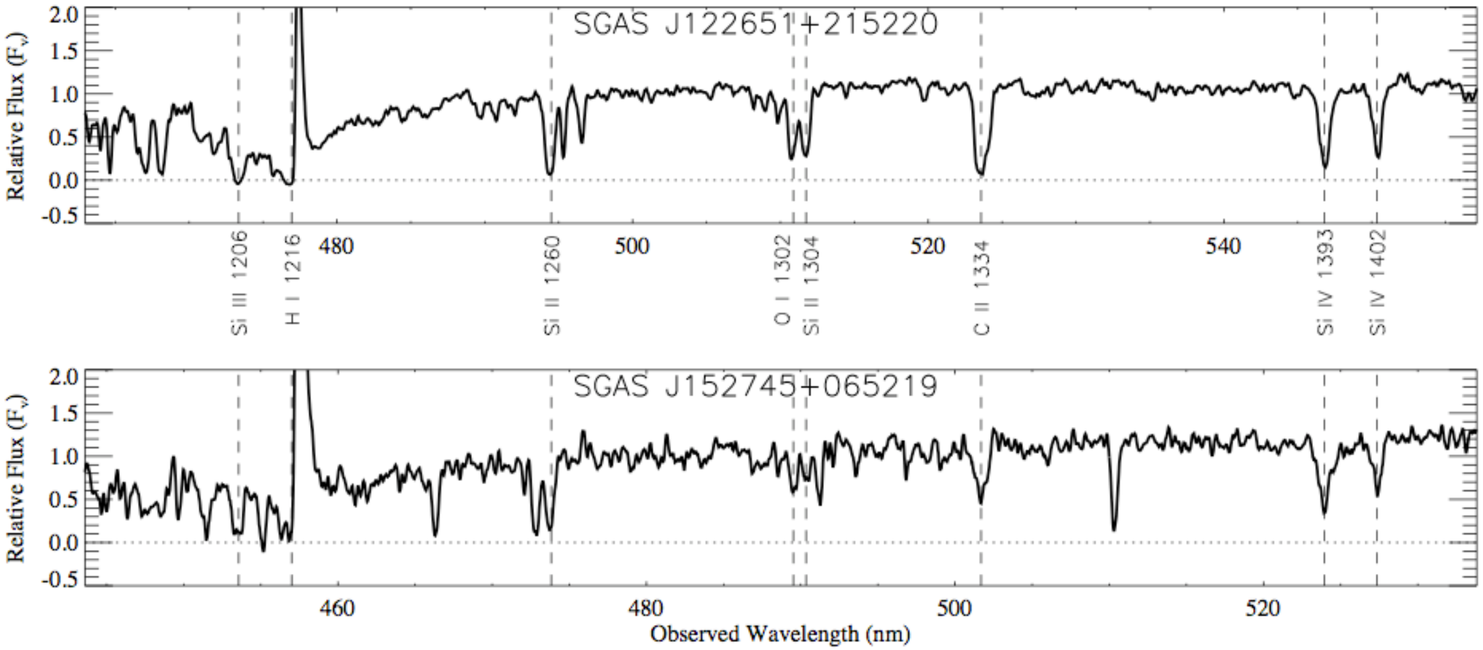


FIG. 2.— $R = 3000$ MagE spectra of 2 new lensed-LBGs. The spectra are smoothed for presentation. *Top panel*: SGAS J122651.3+215220 at $z = 2.9233$. *Bottom Panel*: SGAS J152745.1+065219 at $z = 2.7593$.

Gravitationally lensed galaxies with magnifications of ~ 10

Short wavelengths will remain important in the JWST Era

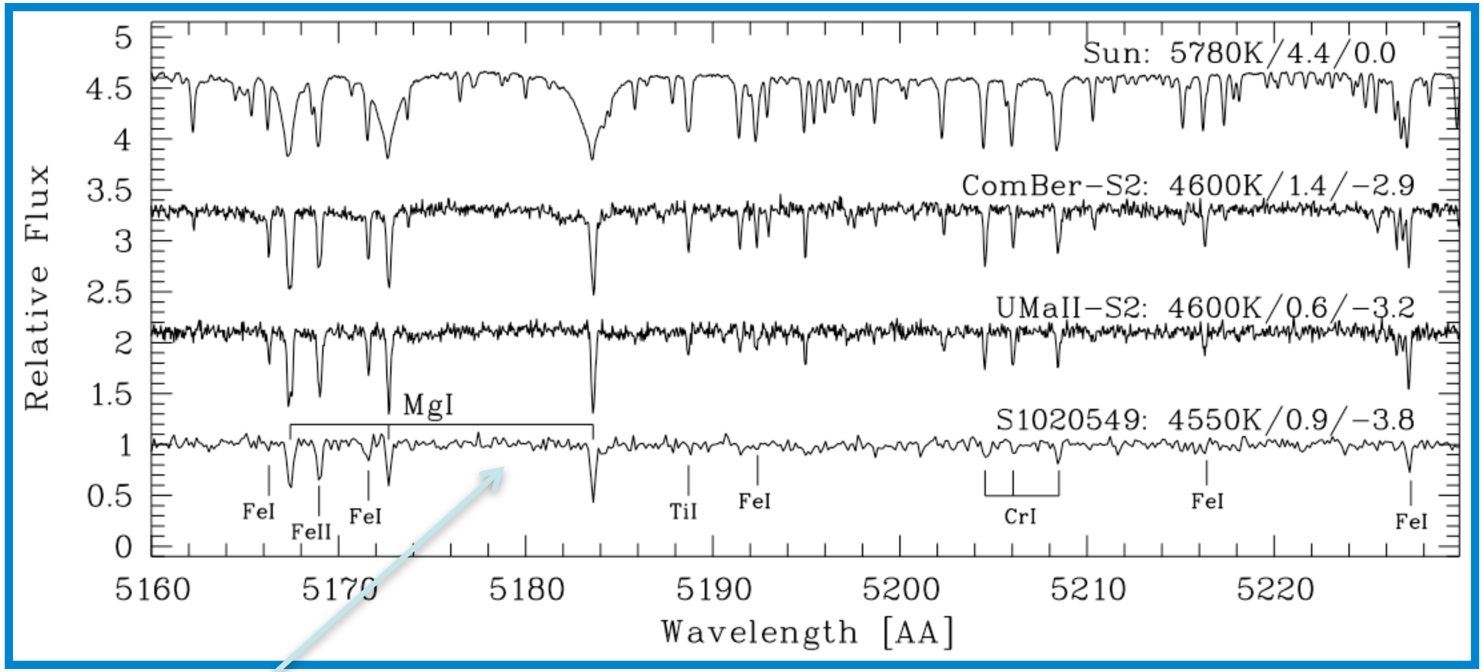
The GMT-CfA Large Earth Finder (G-CLEF)

High-dispersion and precision radial velocity optical spectrograph

- Bench mounted, fiber-fed
- Precison thermal control
- R=20,000-150,000
- 0.35-0.95 μm

Builds on the success of HARPS

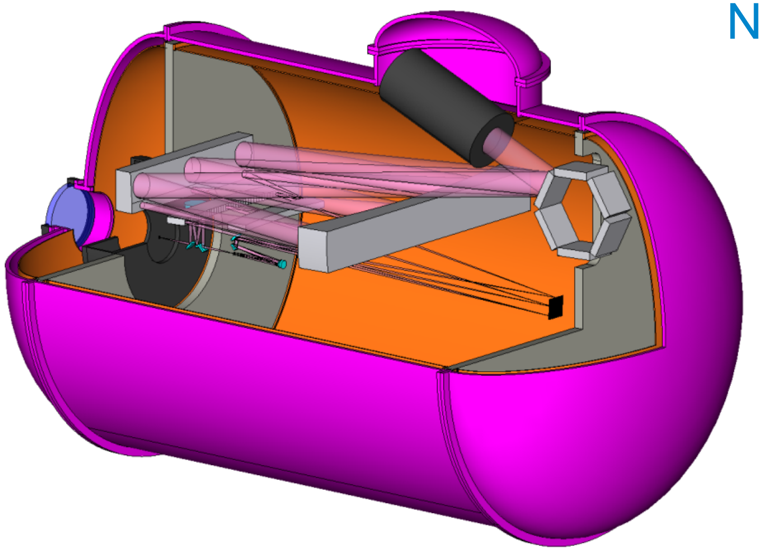
Formation of the MW Halo from Mergers



V=18.2 metal-poor star in Sculptor dwarf

8 hr exposure at Magellan

GMT Integral Field Spectrograph



Near-infrared AO imager and IFU spectrograph

Single-object integral-field spectrograph
• R=5000
• 6, 12, 25, or 50 milliarcsec sampling
• Up to 4.5" by 2.3" field of view

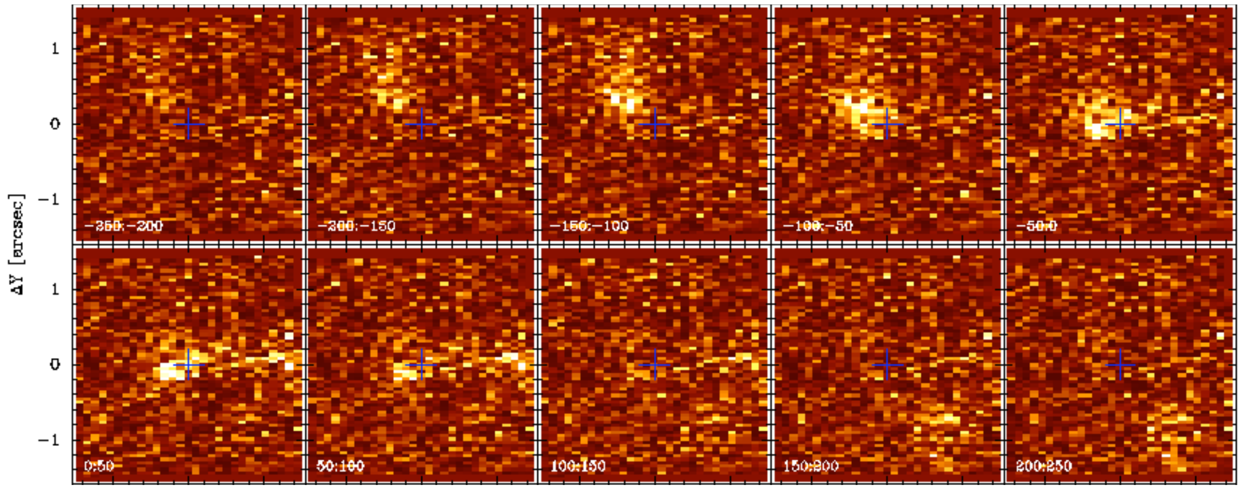
AO Imager
• 5 milliarcsec sampling
• 20.5" by 20.5" field of view

Builds on NIFS and GSAOI Heritage

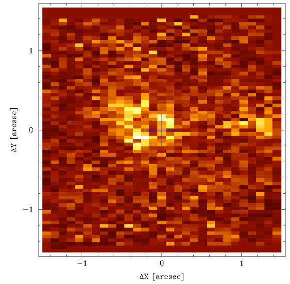
Galaxy Dynamics at z = 2

z = 1.57, M_B = -21.0, 5 hr object, 5 hr sky

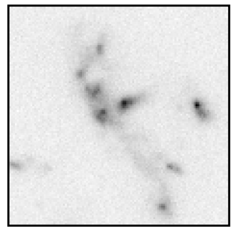
Bournaud et al. 2008, arXiv:0803.3831

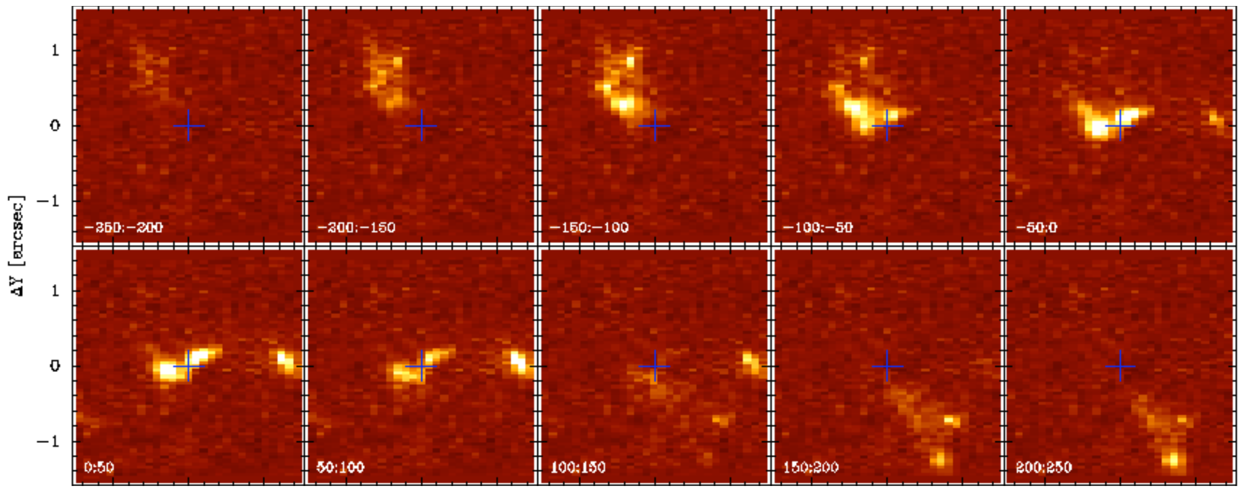


NIFS - Sum

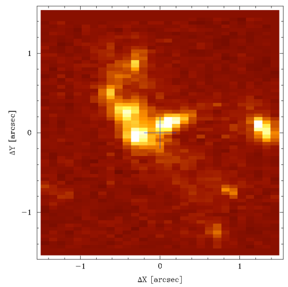


HUDF - i

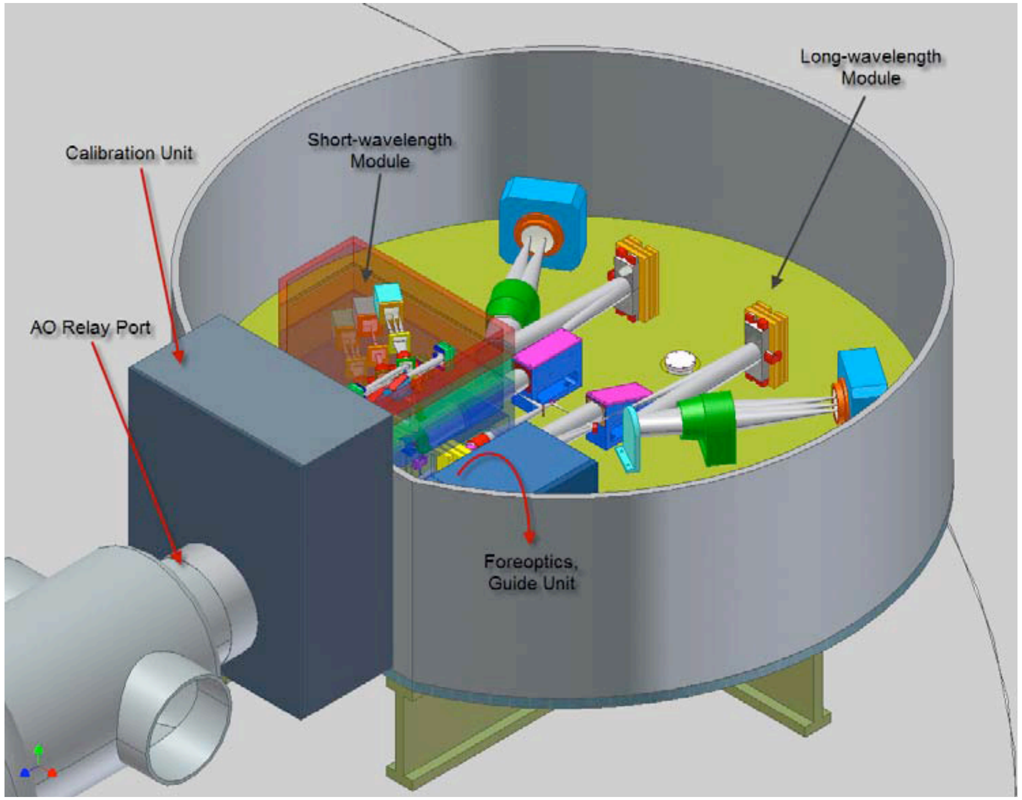




GMT - Sum



GMT High-Resolution Near-Infrared Spectrograph



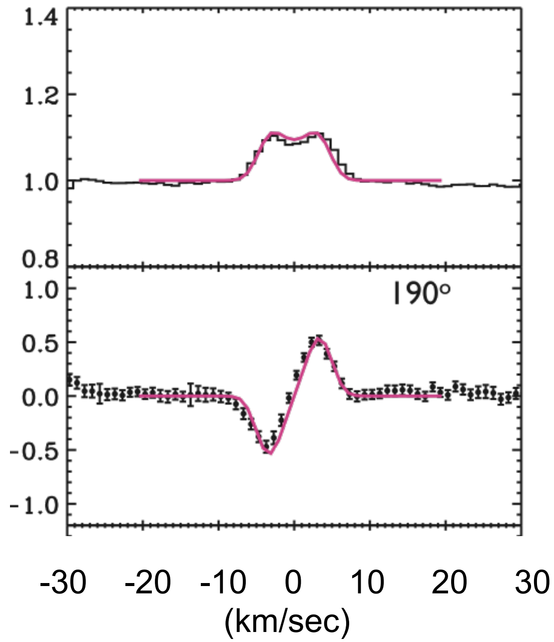
- AO fed
- 30-80 milliarcsec slits
- 1.1-5.5 μm in one shot
- R=60,000-100,000

Structure and Chemistry of Protoplanetary Disks

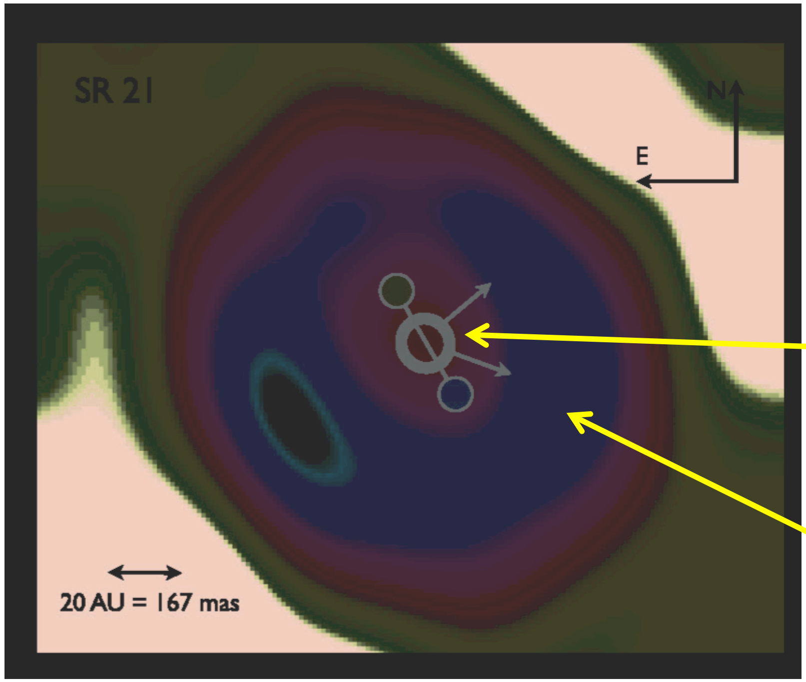
Spectroastrometry: use high resolution IR spectroscopy to measure spatial distribution of molecular gas at finer scales than the spatial resolution.

CO flux
4.7 µm

CO Line
Centroid
Shift (AU)



Pontoppidan et al. 2008 CRIRES VLT



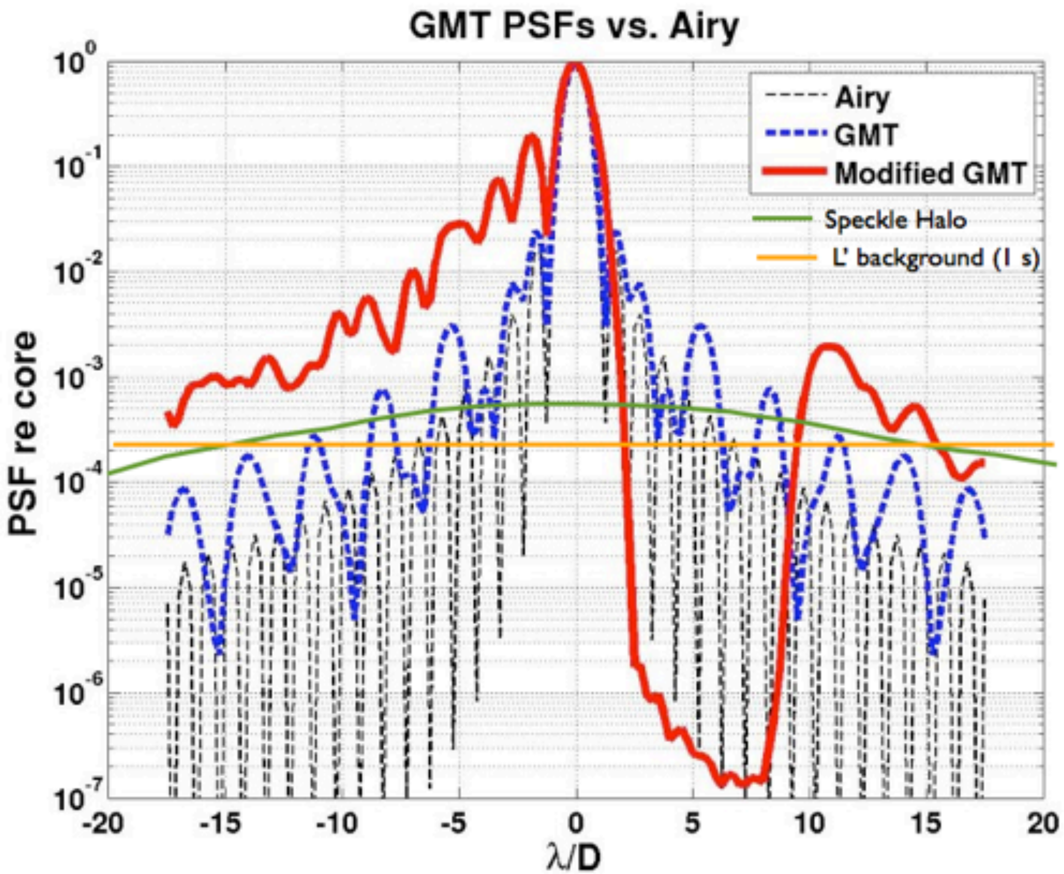
CO disk
~7 AU radius

Dust disk
~50 AU radius

Disk not cleared by companion at r > 4 AU

TIGER: AO High-Contrast Thermal IR Imager

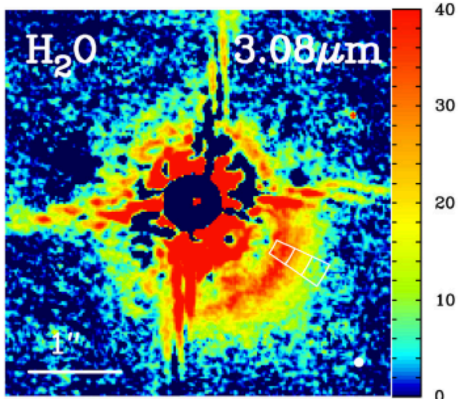
Coronagraphic techniques optimized for the GMT pupil reduce PSF well below speckle and sky backgrounds

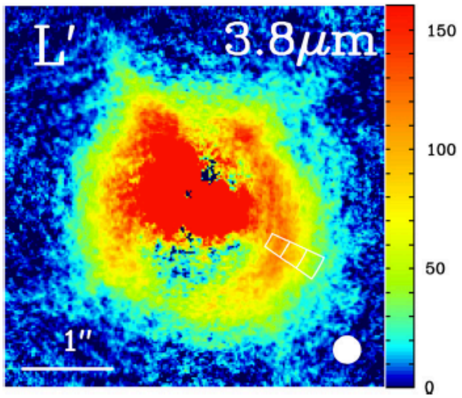


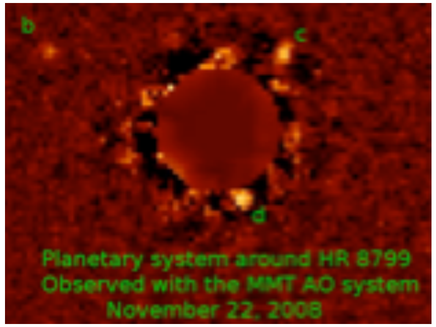
- Mounted at direct Gregorian focus
- 3-14 µm coverage
- 10 milliarcsec pixels
- 15-30" field of view

7th mag in L

Circumstellar Disks and Exoplanet Imaging





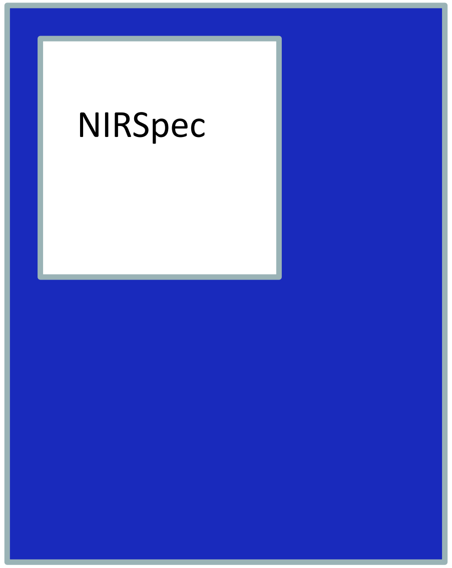


3-5 μm observations detect the existence of icy grains and probe composition variations within a disk (Honda et al. 2009)

L band detection of the three planet system around HR 8799. (Hinz et al. 2010)

- Determine structure of disks from protoplanetary to debris phase.
- Detect <1 M_J planets at r > 3 AU.
- Detect rocky planets around a small sample of stars via thermal emission

Near IR Multiple Object Spectrograph



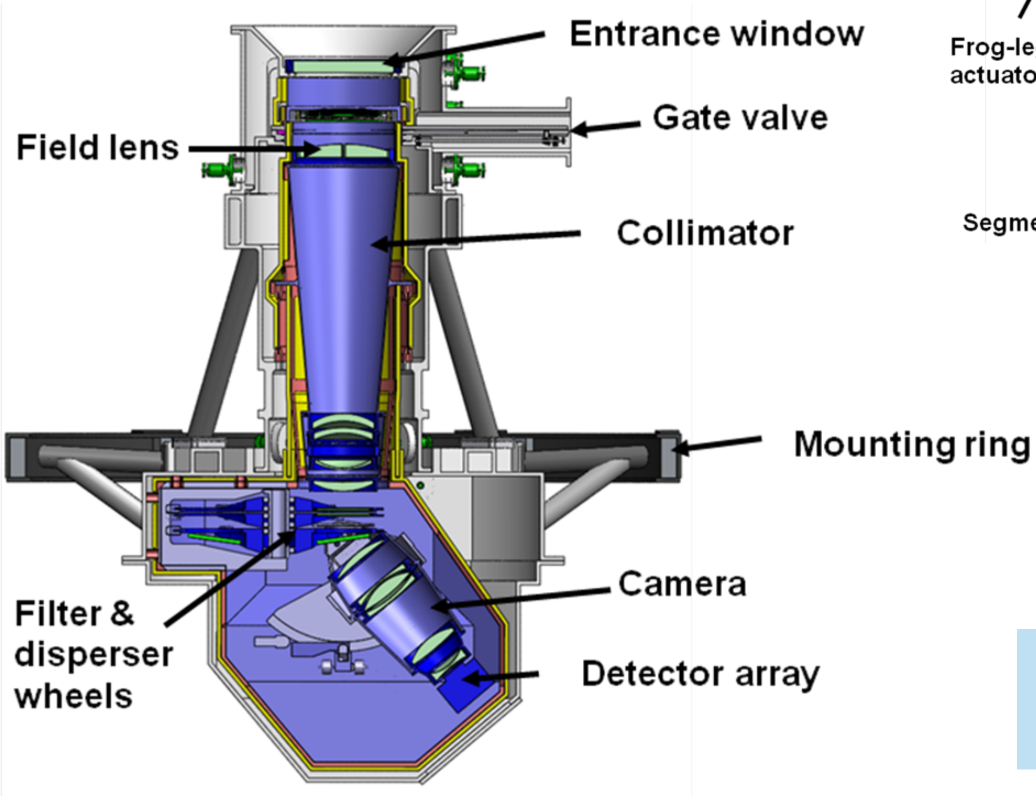
NIRMOS Field of View
35 square arcminutes

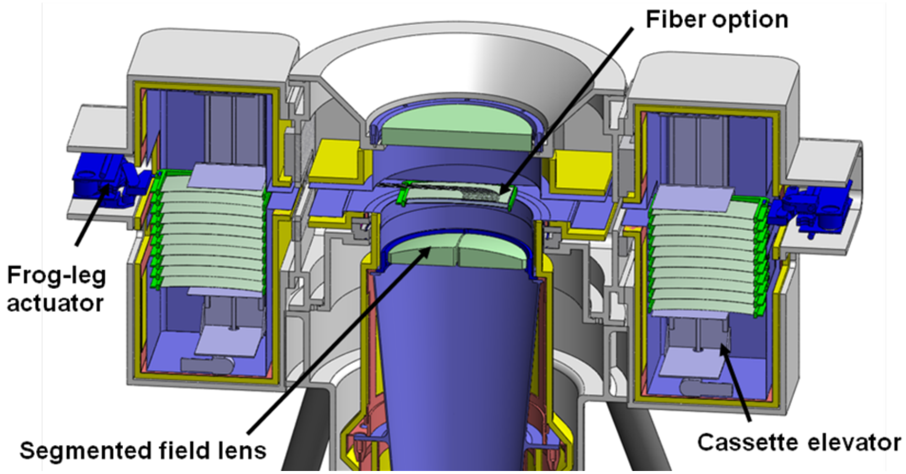
~100 z>2 galaxies!

- 0.9 to 2.5 μm imaging spectrograph
- Natural seeing or GLAO
- R=3000 with 0.5″ slit and full J, H, or K coverage
- Superb image quality: worst 80% EE better than 0.15″

Multiplex advantage: NIRMOS can use 84 slitlets each 5 arcsec long

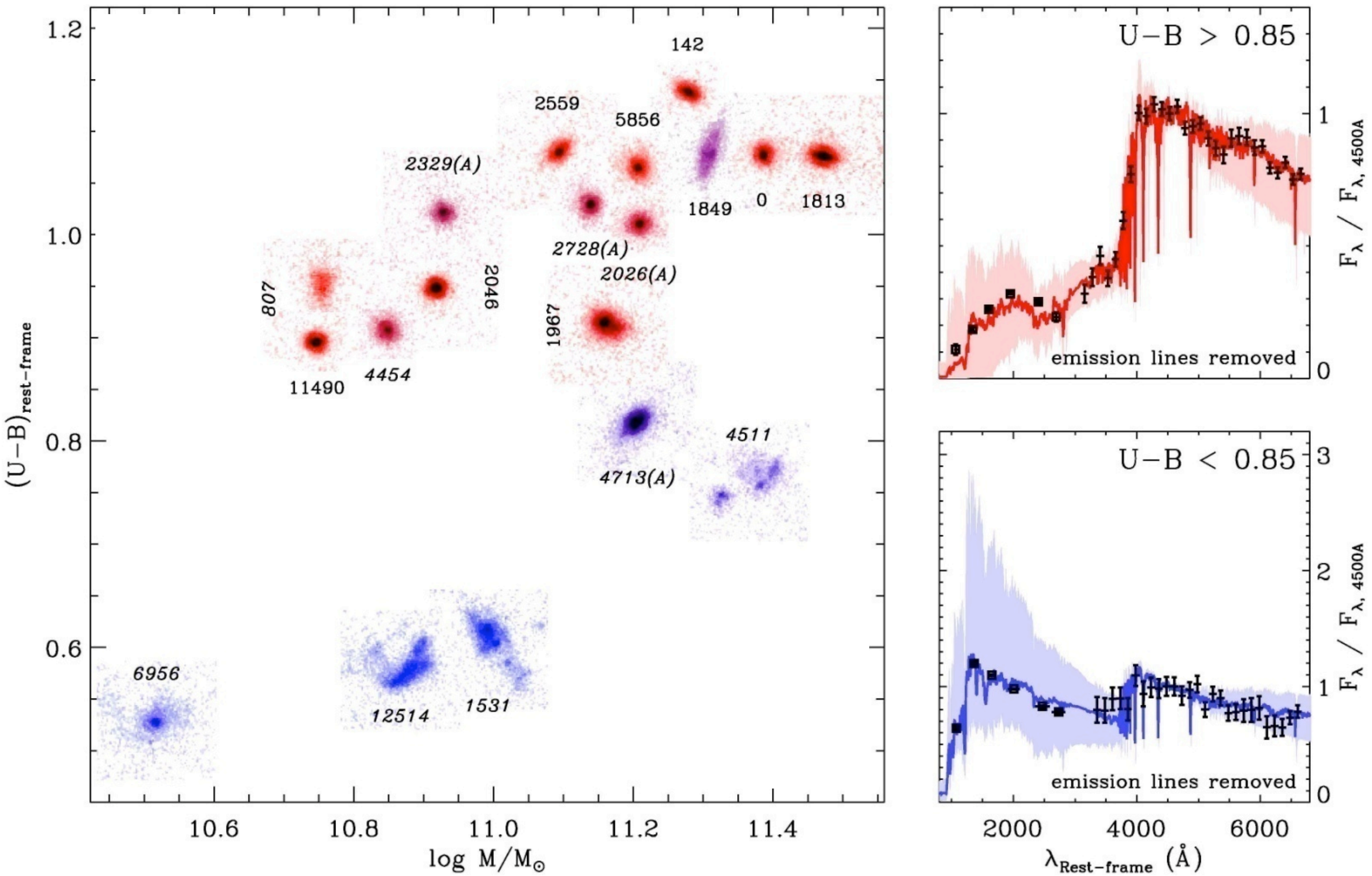
NIRMOS mechanical layout





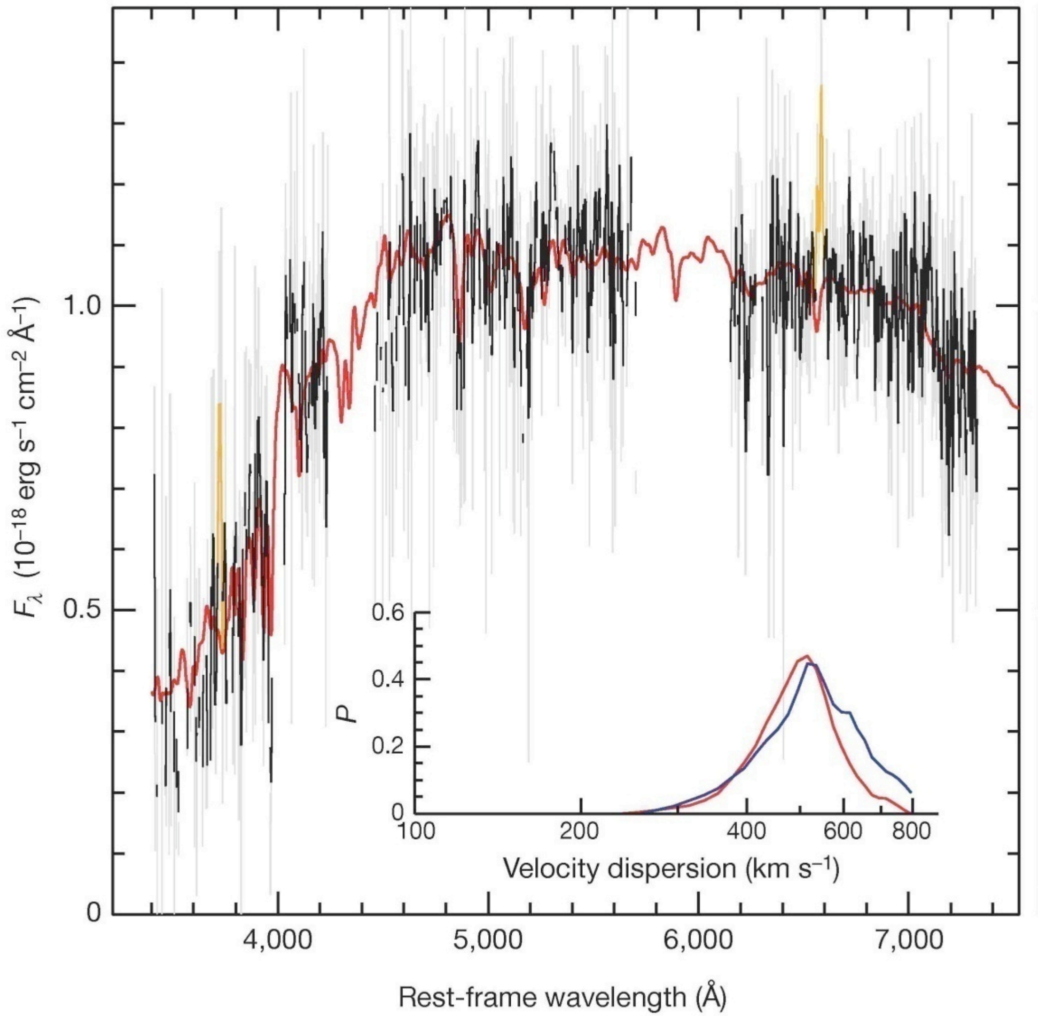
Optics and mechanics cooled to
< 100 K

Weird galaxies are normal at z=2



Kriek et al. 2009

Heroic 29 hr spectrum with Gemini 8 m



Van Dokkum, Kriek & Franx 2009
Kriek et al. 2009

The sky may not be the limit

Photon counting

Detector + OH Suppression

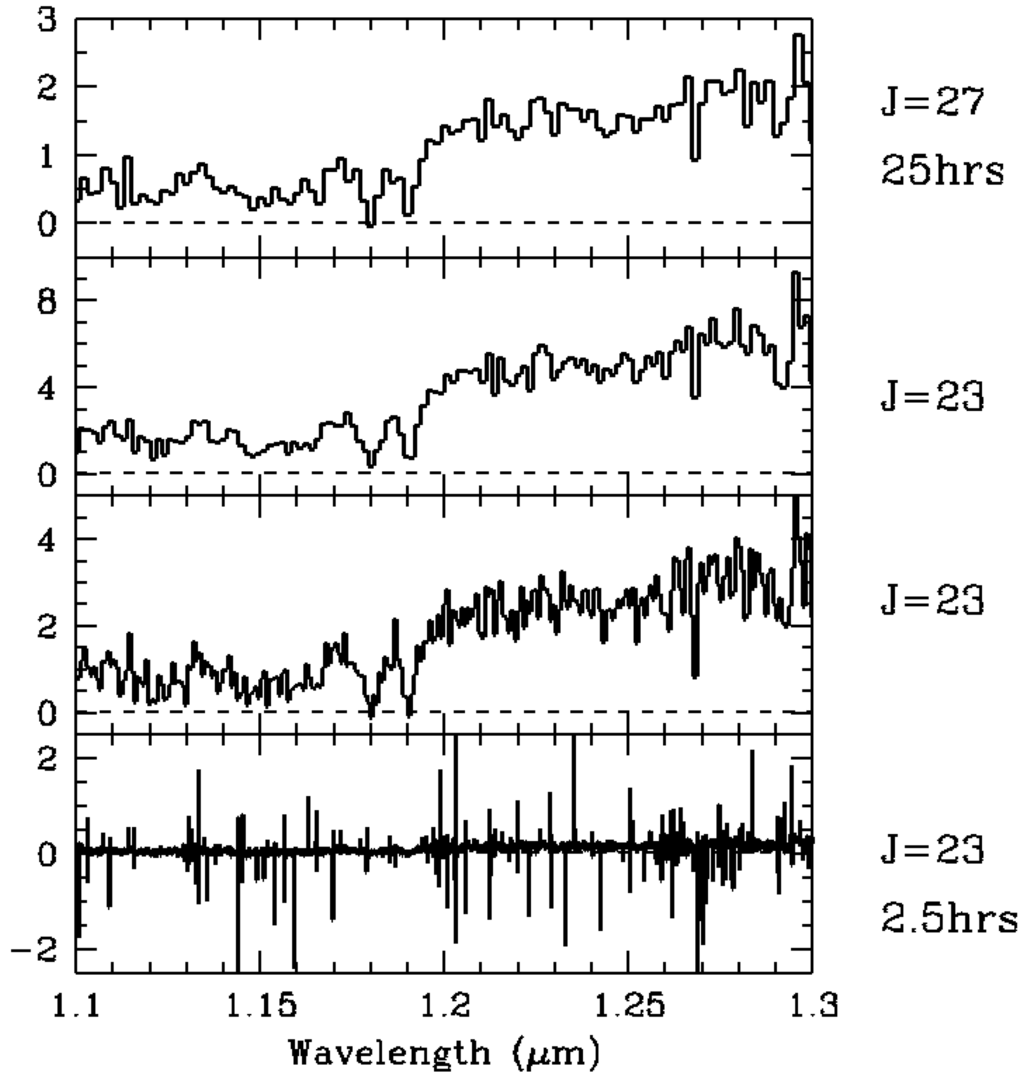
OH suppression

Before dispersion

OH removed in

Post processing

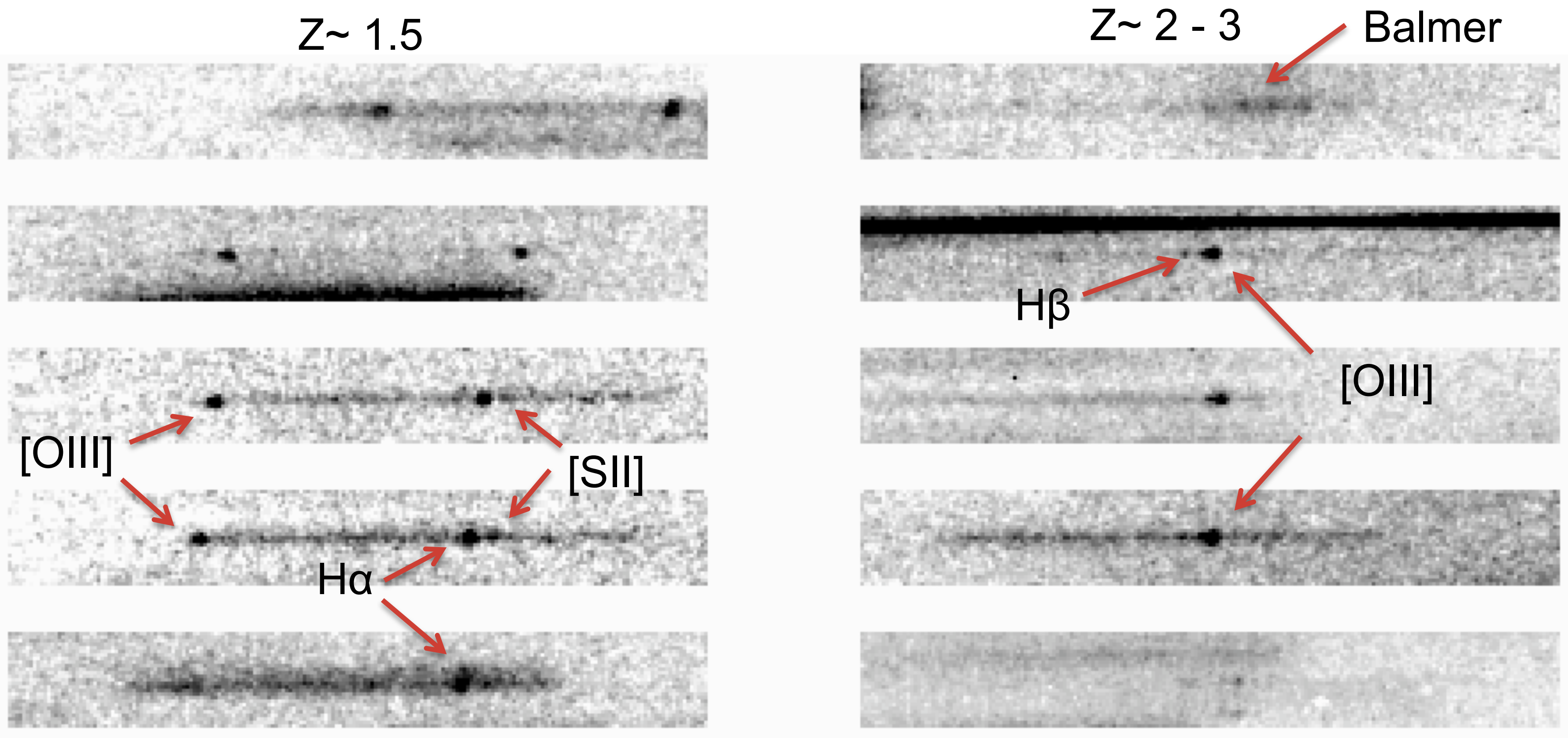
Sky subtracted



Z = 1.5

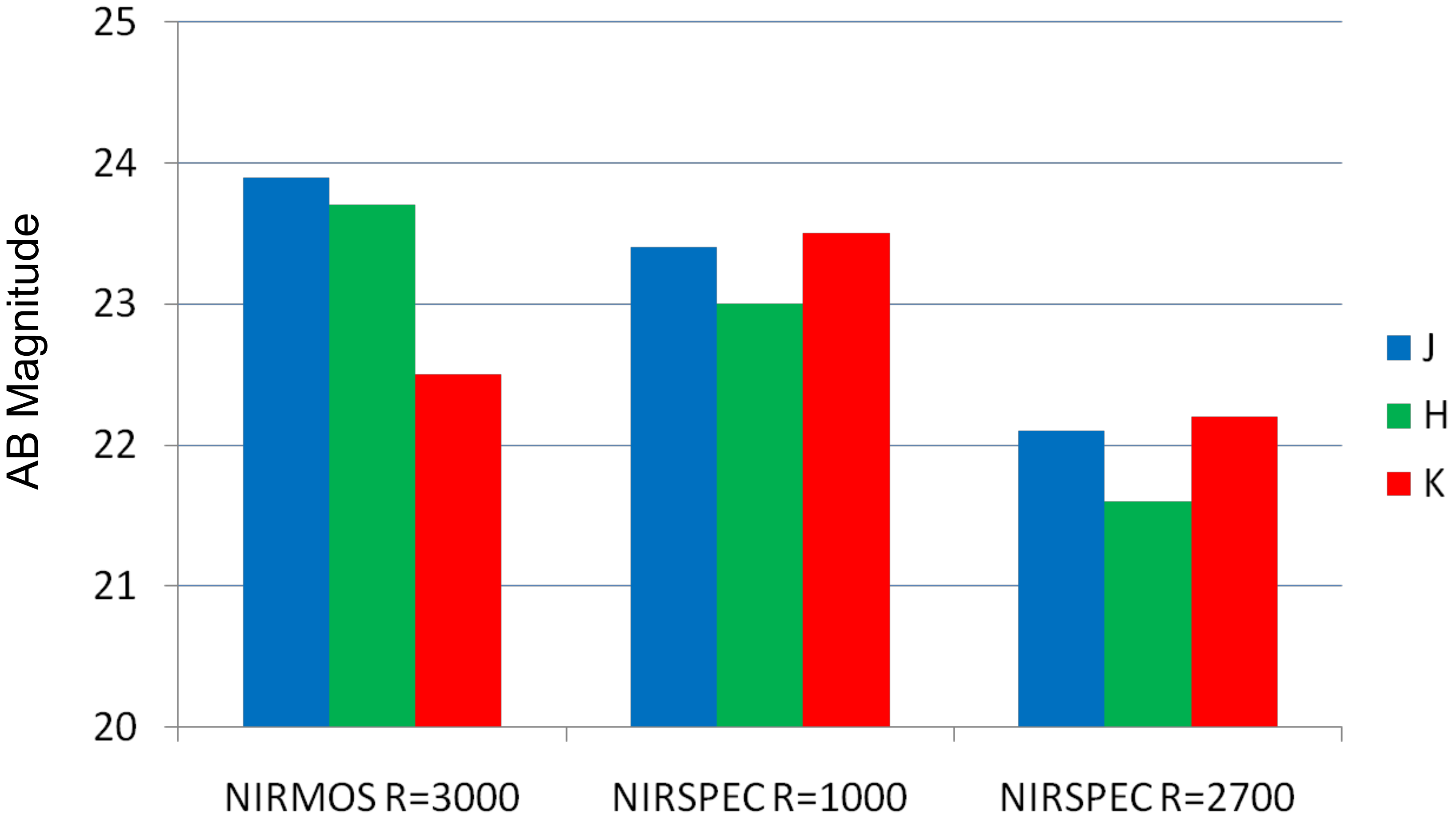
Old Galaxy

The Benefits of Low Resolution – WFC3 Grisms



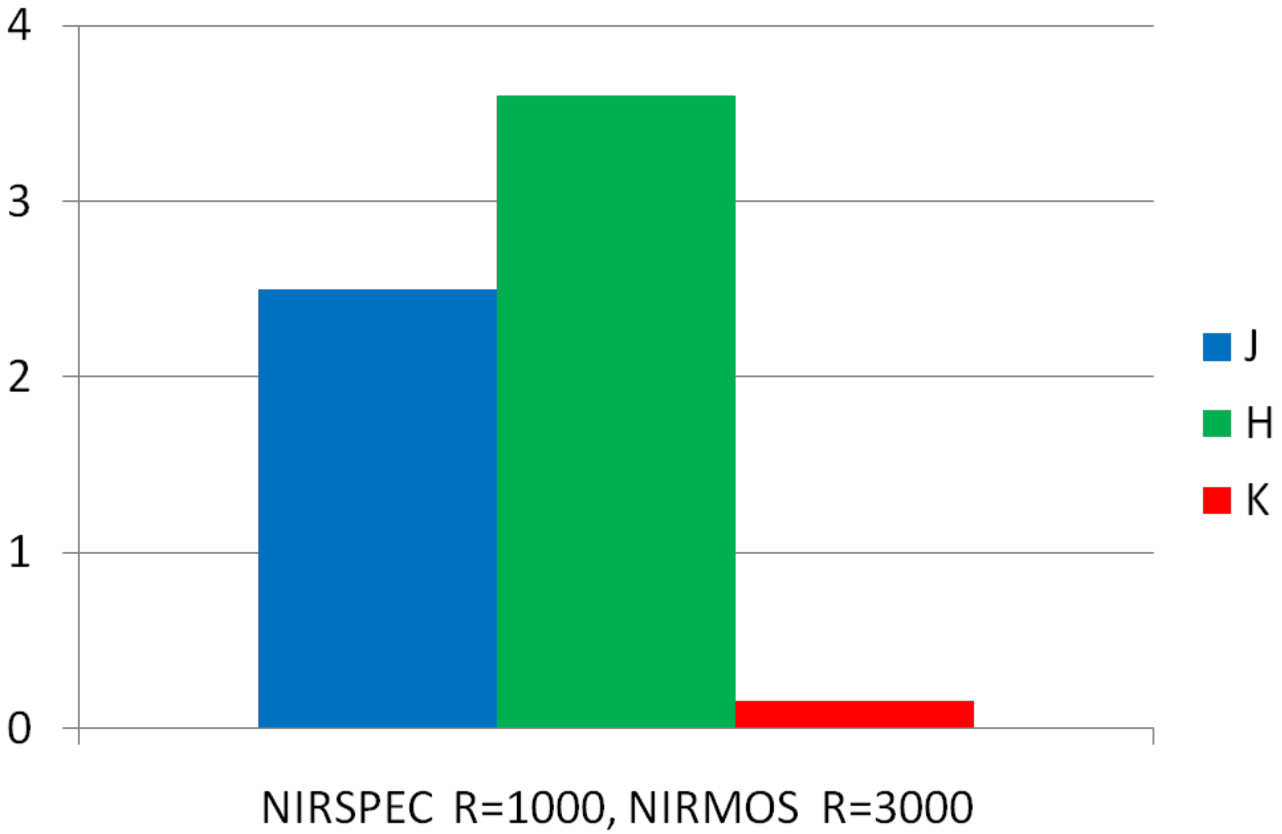
Malkan, PM, et al. 2010

Estimated NIRMOS and NIRSPEC Sensitivities

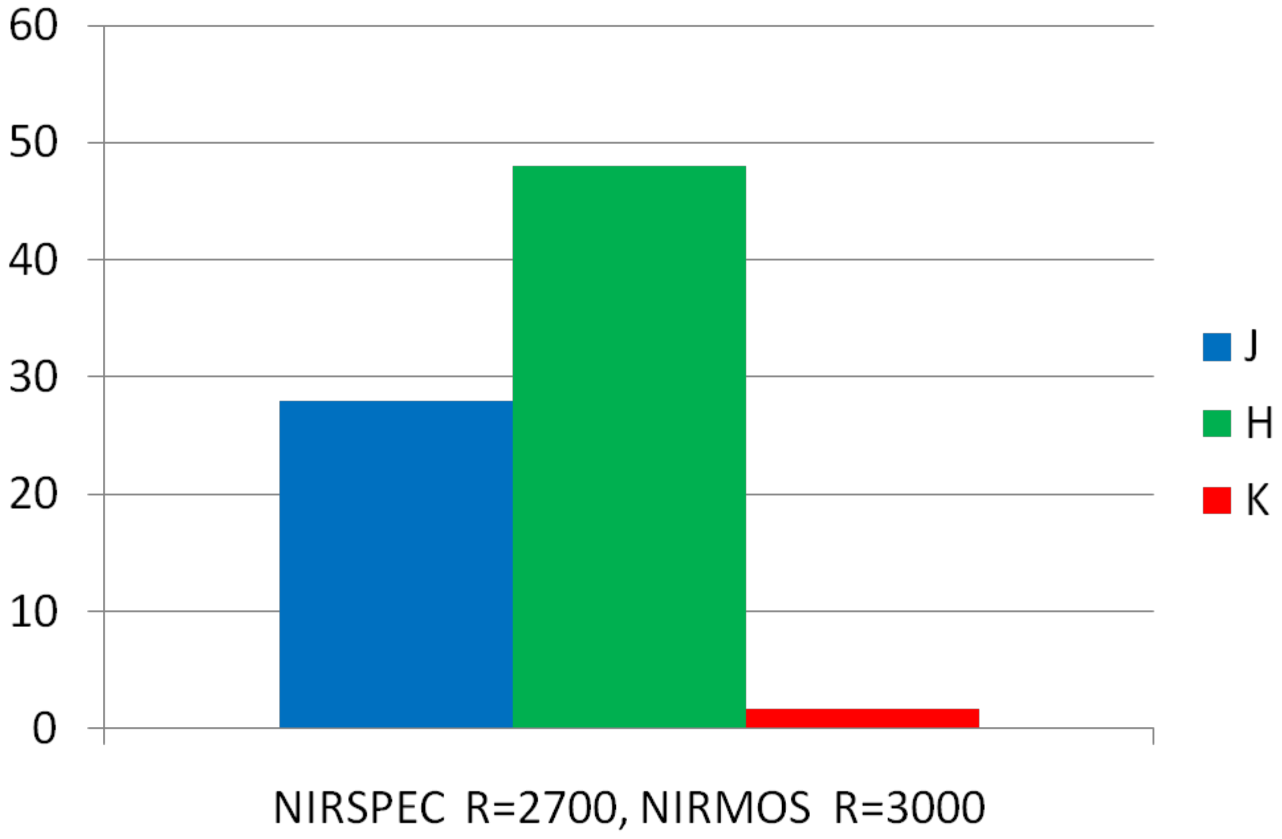


Sensitivity at S/N=10 in 1 hour

Ratio of NIRSPEC/NIRMOS Integration Times



Ratio of NIRSPEC/NIRMOS Integration Times



Summary

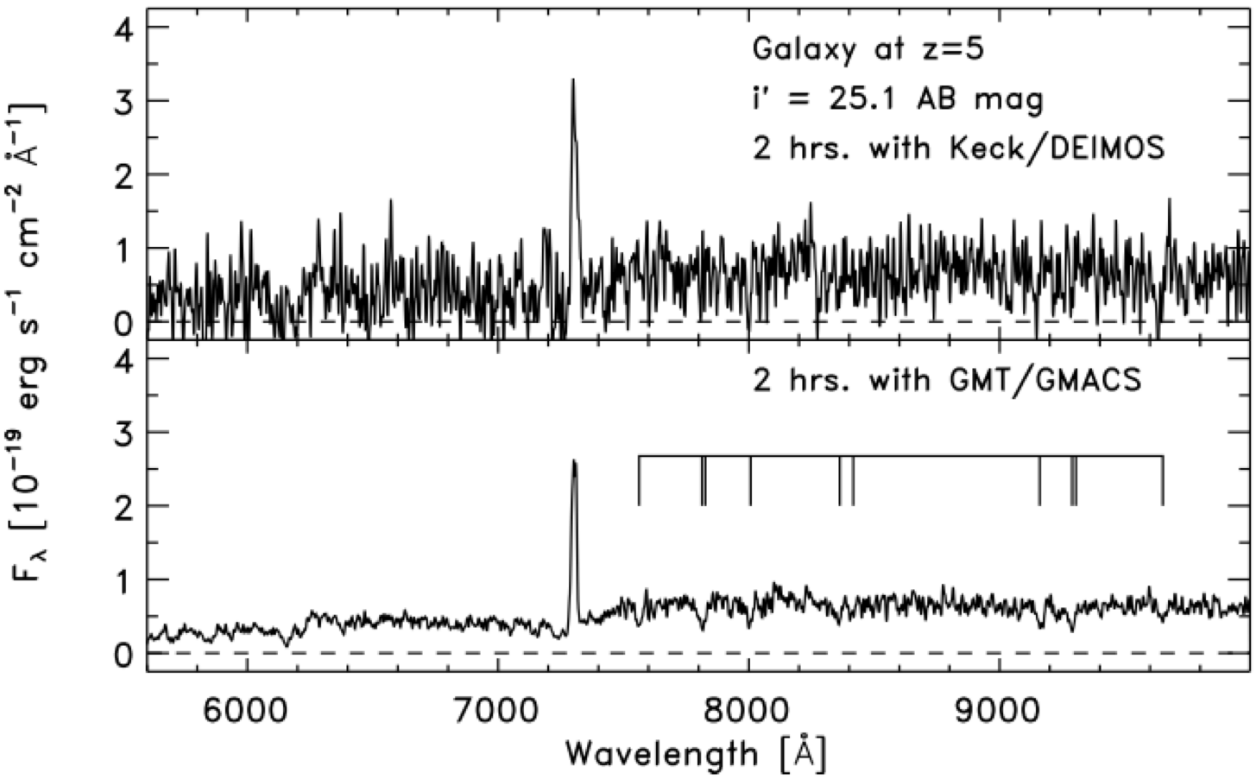
GMT is making great progress:

- Funding outlook is good
- Staff is growing
- Primary mirror development is progressing
- Powerful suite of science instruments under development

On track for start of construction in 2012 …

…. First light in 2019

Lyman-α Galaxies with GMT



Strengths of the GMT Design

Wide-Field Seeing Limited Mode

20 arcminute diameter corrected field of view

Fast Primary, Fast Gregorian

Compact design, two reflections to the focal plane, low IR footprint

Gregorian Adaptive Secondary

Low-background wide-field AO operations

Complementarity with Webb

High Angular resolution, large collecting area, short wavelengths
Flexibility, instrument/AO evolution

Weakness compared with Webb

High Background (Foreground!)

Narrow AO fields