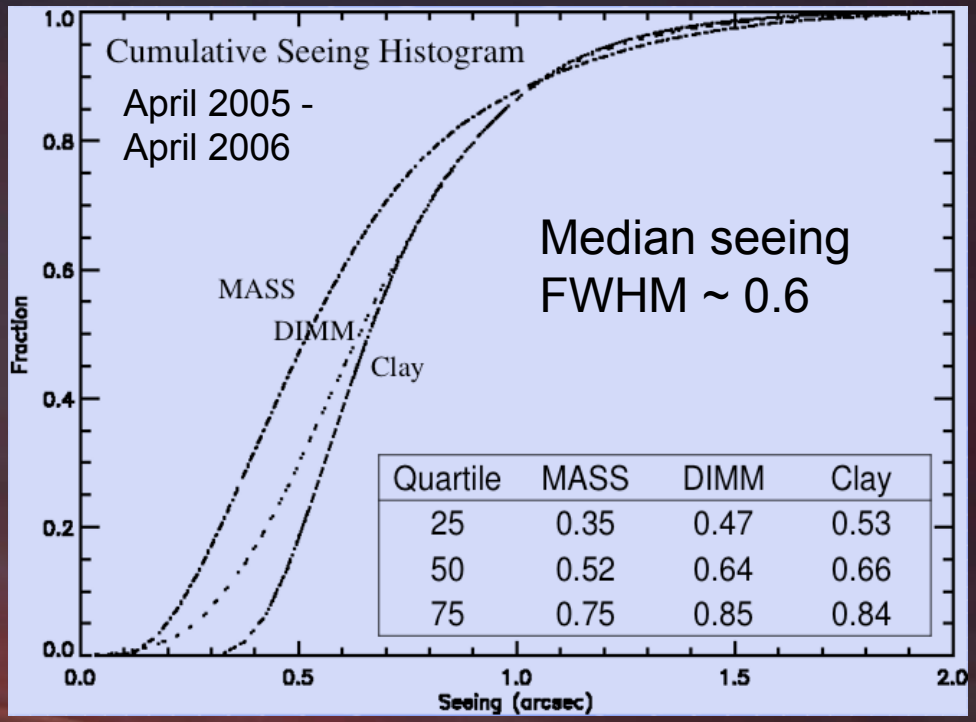
Present and Future Instrumentation at the Magellan Telescopes

Alan Dressler & Wendy Freedman

Carnegie Observatories

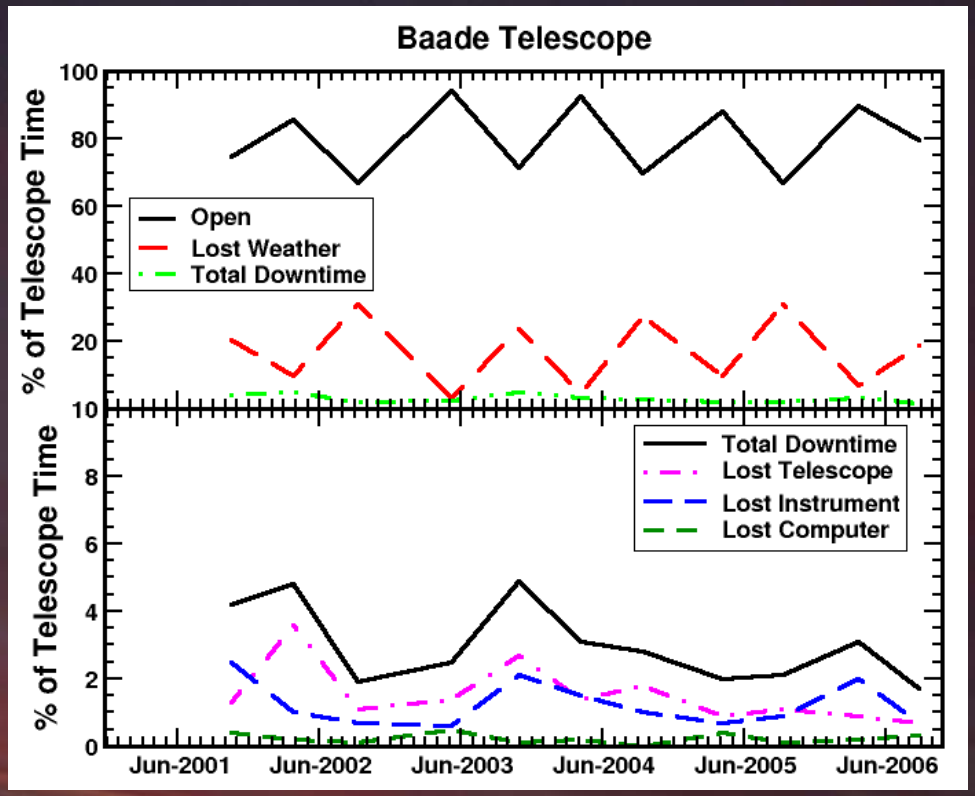
3rd OIR-System Workshop, Nov '06

Performance of the Magellan Telescopes



Quartile	MASS	DIMM	Clay
25	0.35	0.47	0.53
50	0.52	0.64	0.66
75	0.75	0.85	0.84

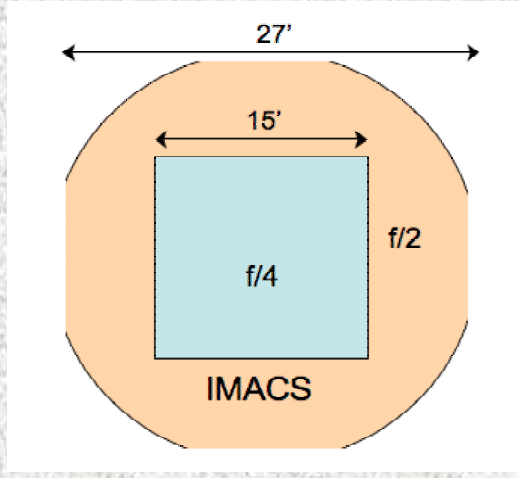
Performance of the Magellan Telescopes



The Magellan Project: Two 6.5-m telescopes shared by Carnegie, Harvard, Arizona, MIT, and Michigan, also participation by Toronto, Durham, Australia

Present Magellan Instrumentation: Baade Telescope

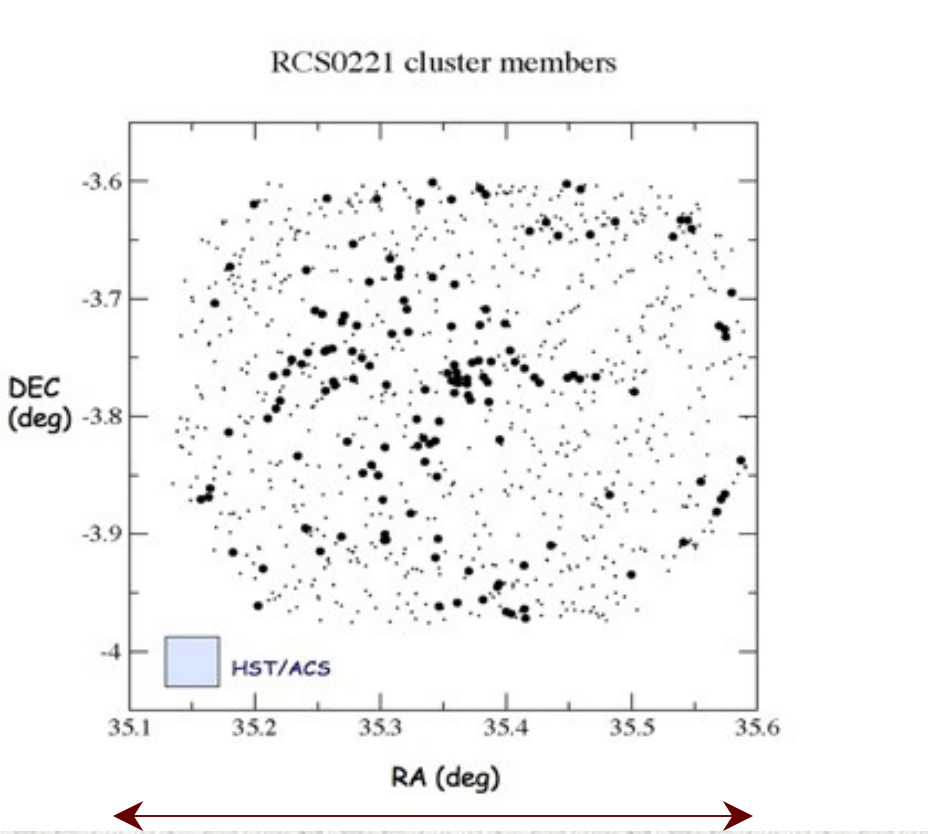
IMACS



Wide-Field Imaging Spectrograph: 670 sq arcmin, biggest in the business

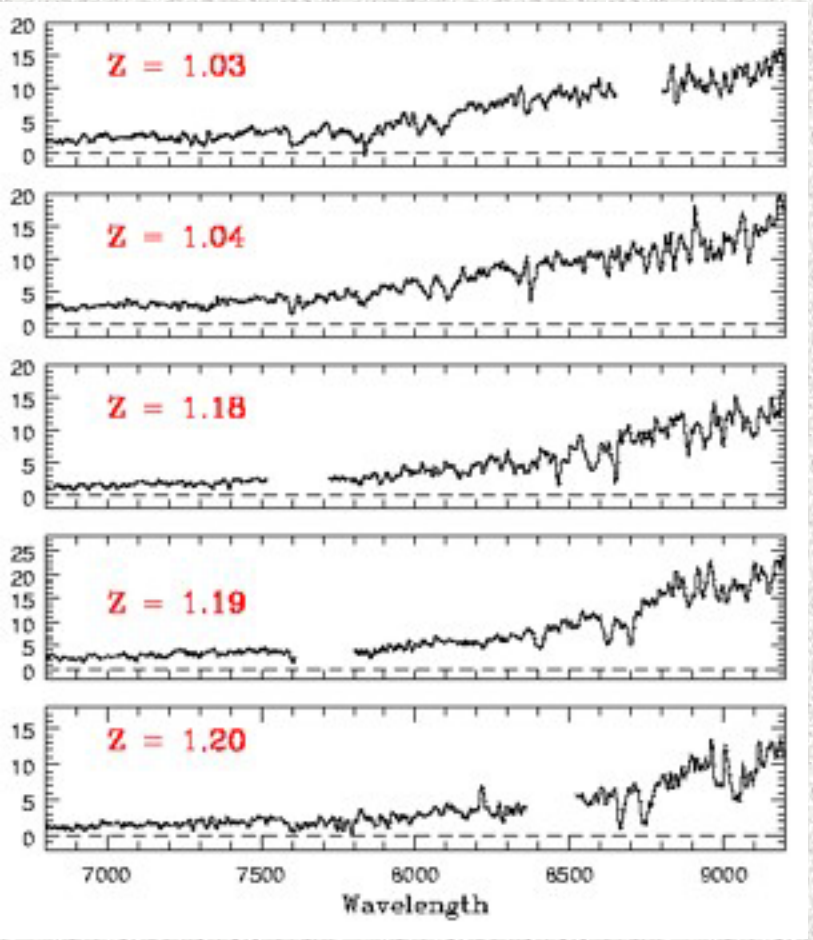
- *Multislit spectroscopy over a wide range of resolutions, R=30 (Low-Dispersion Prism) to R=10,000 (grating)*
- *Durham University Integral Field Unit: 2 - 5"x7", d=0.2"*
- *Multi-Object Echelle: 10-15 objects at R ~ 20,000, full coverage*
- *Maryland-Magellan Tunable Filter: full field, $\Delta\lambda$=6-40Å, 5000-9000Å*
- *GISMO -- field reformatter, expands 4' x 4' area for multislit work*
- *Thanks to **TSIP**, two mosaic CCD cameras (8k x 8K) enable all modes*

IMACS Cluster Building Survey - Dressler, Oemler, Gladders, Poggianti



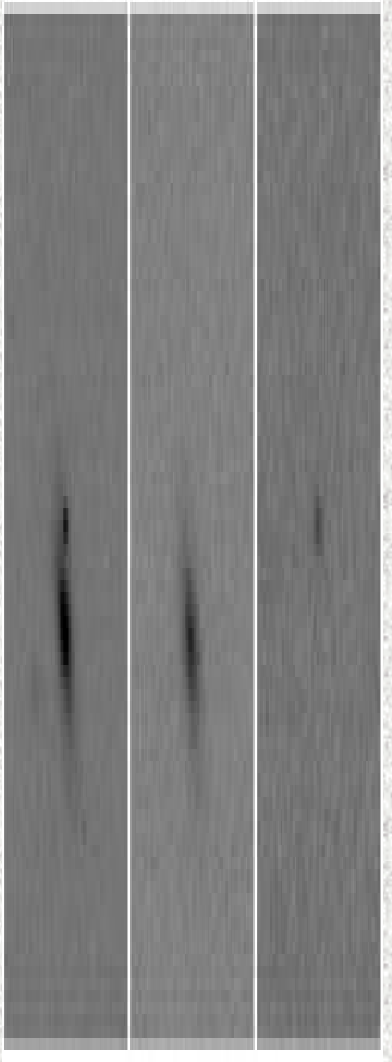
30 arcmin = 10 Mpc
at z = 0.42 cluster

IMACS Deep Survey -- McCarthy & Collaborators



Present Magellan Instrumentation: Baade Telescope

PANIC



J,H,K imager, 1024x1024 Hawaii HgCdTe array

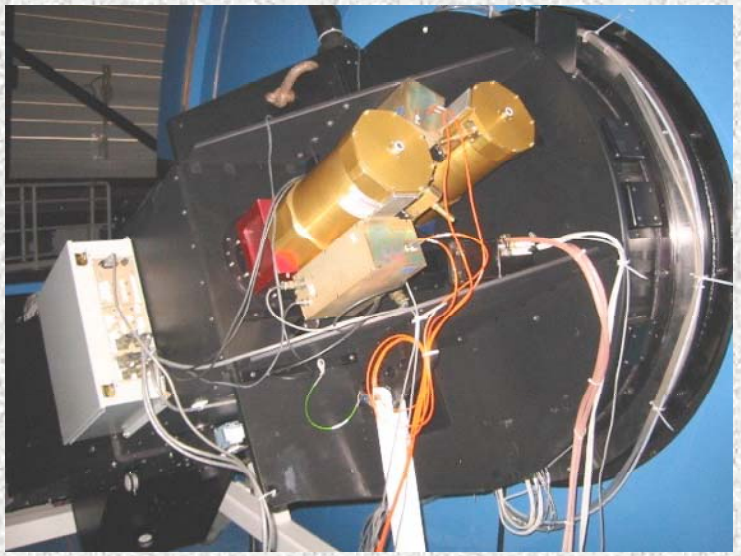
field ~ 2′ x 2′, d=0.125″

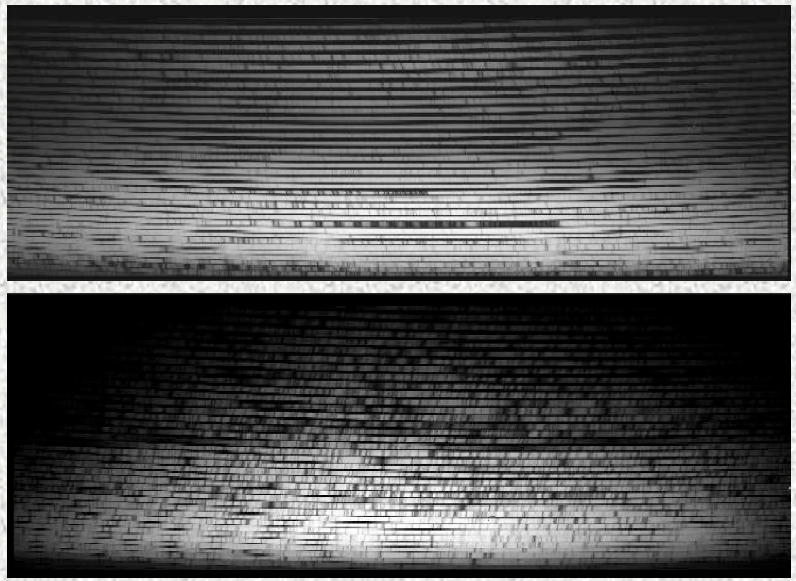
PANIC supports a wide range of programs, including studies of high-z galaxies and the SnIa constortium

PANIC will be replaced by a wider-field imager, FourStar, in 2009

Present Magellan Instrumentation: Clay Telescope

MIKE





Double Echelle Spectrograph

Blue side: 3350-5000Å, R = 28,000 (1" slit), QE = 37%

Red side: 4900-9000Å, R = 20,000 (1" slit), QE = 20%

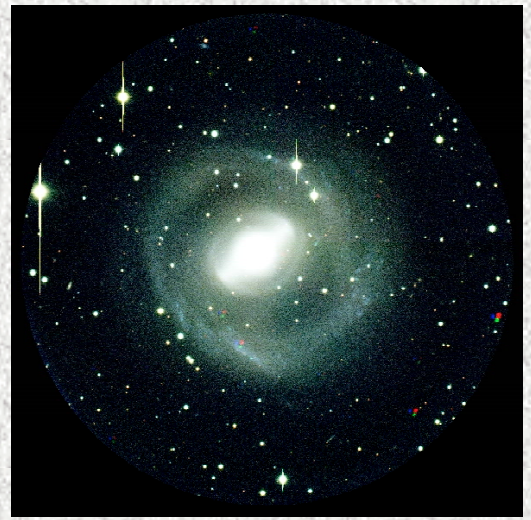
Also includes fiber feed system (Mateo) for single order spectra

Widely used -- radial velocities (eclipsing binaries, planets), stellar abundances, IGM -- QSO (Lyα forest)

Present Magellan Instrumentation: Clay Telescope

LDSS-3

LDSS-2 from Durham U.



Moderate-field, multi-slit low-to-med resolution imaging spectrograph

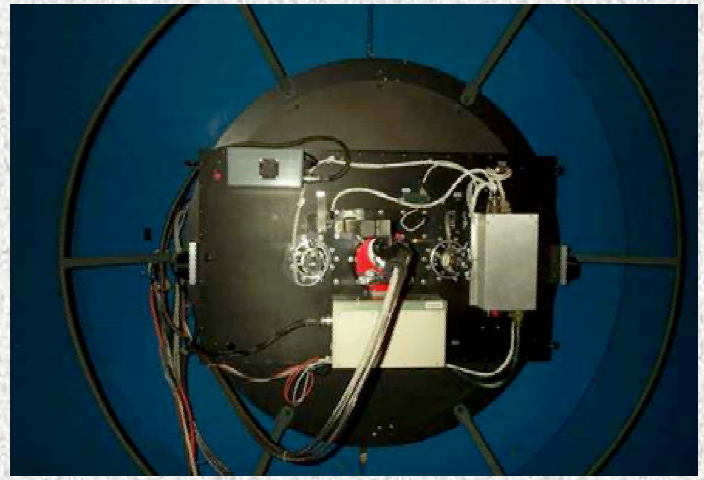
Field of view: 8.3′ dia, d = 0.19″/pix

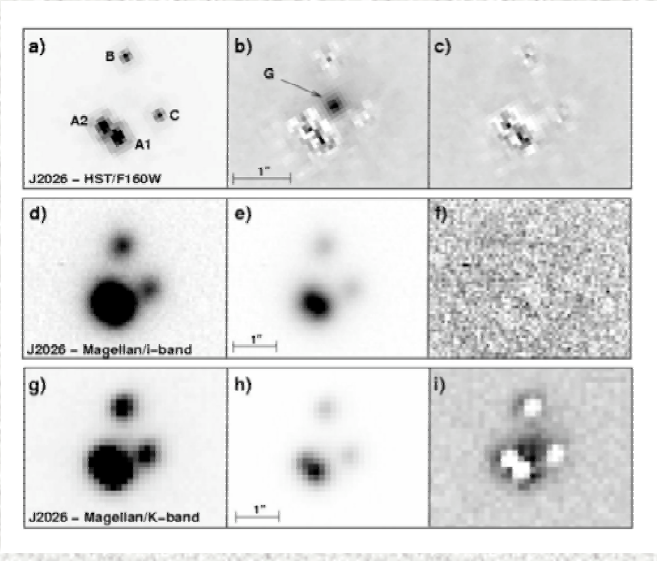
VPH grisms (red and blue) for R ~ 2000; **QE = 30-40% !!**

Similar to GMOS on Gemini, LDSS-3 provides a complement to IMACS for mutli-slit spectroscopy of high-z galaxies and arcs, search for Lyα emission, globular clusters in nearby galaxies, SnIa spectroscopy

Present Magellan Instrumentation: Clay Telescope

MAGIC





Morgan et al. 2004 AJ

Small-field optical imager

Field of view: 2.4′ x 2.4′; d = 0.07″/pix

"Instant imager" at folded port

MAGIC provides a rapid, high resolution (well-sampled) imaging capability. It has been especially useful for targets of opportunity -- GRB, Sne -- and for long-term monitoring of time variable sources, for example, gravitational lenses like the quad lens shown above.

Magellan Instrumentation:

What's missing? Obvious lack of capability for near-IR spectroscopy and mid-IR imaging and spectroscopic.

Four new IR instruments will be commissioned in the next three years:

- FourStar -- f/11 "wide-field" near-IR -- replaces PANIC
- FIRE -- f/11 near-IR Echellette
- MMIRS -- near-IR spectrograph, fed by f/5 secondary (clone of MMT) now under construction for Clay (mid-2007)
- MIRAC4-BLINC -- Mid-IR camera/nuller fed by f/16 AO (adaptive) secondary also built for Clay (early 2009)

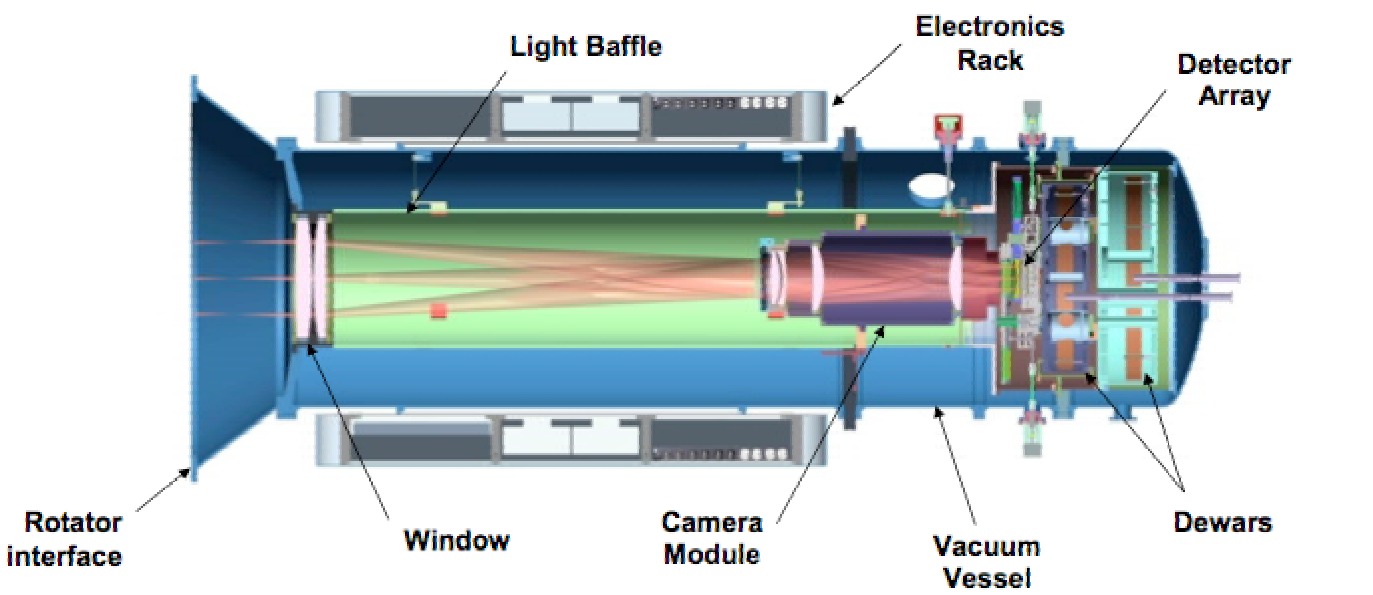
Magellan Instrumentation: future -- mid 2009

FourStar -- PI Eric Persson, OCIW, collaboration with JHU

A 2 x 2 mosaic of Hawaii 2RG 2k x 2k detectors

J,H,K and narrow-band imaging 11' x 11' @ 0.16" per pixel

Science: high-redshift galaxy evolution, star formation in nearby Milky Way star clusters, added to Spitzer -- galaxy SED's

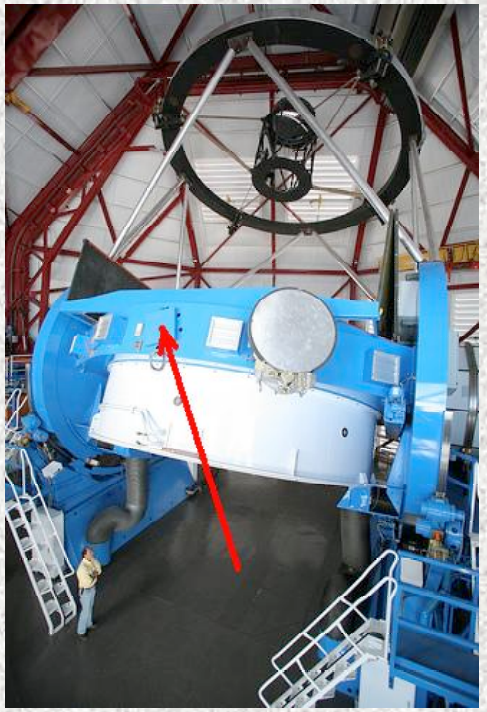


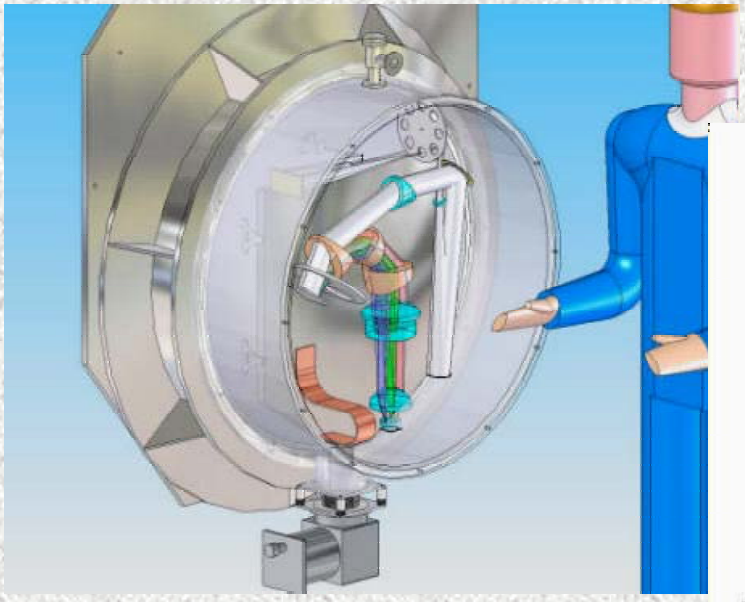
Magellan Instrumentation: future -- late 2008

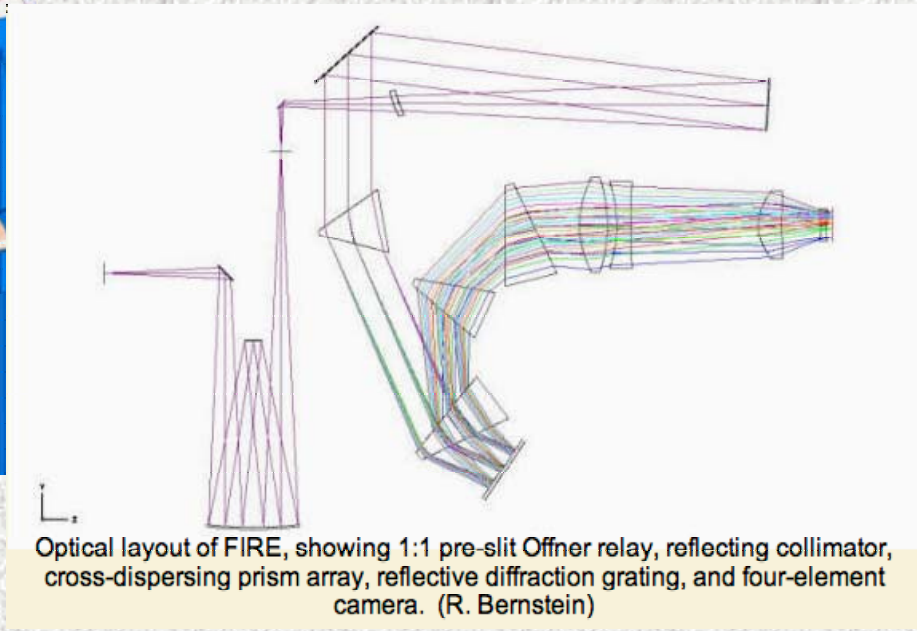
FIRE: Folded-port Infra-Red Echellette

-- support from NSF MRI

MIT: Simcoe, Burgasser, & Schechter
Michigan: Bernstein & Mateo
Rochester: Pipher, Forrest, & McMurtry







Optical layout of FIRE, showing 1:1 pre-slit Offner relay, reflecting collimator, cross-dispersing prism array, reflective diffraction grating, and four-element camera. (R. Bernstein)

Small-field, single object enables compact design

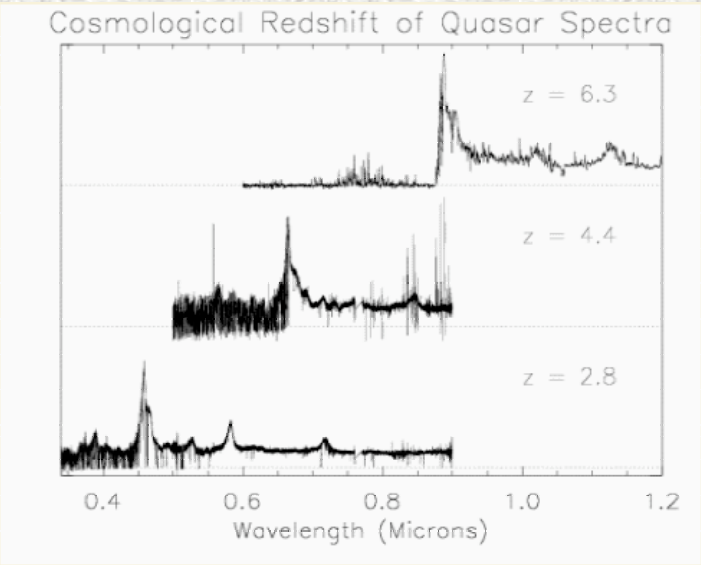
Magellan Instrumentation: future

FIRE (cont)

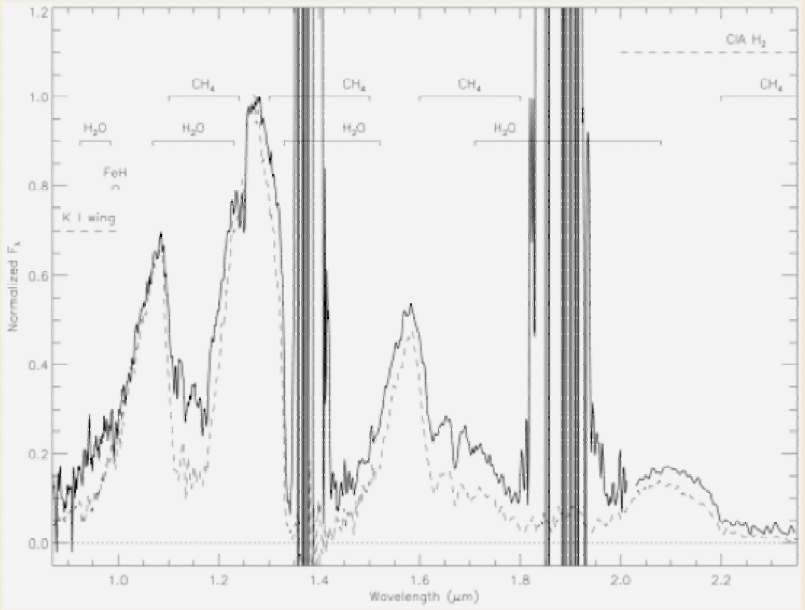
Echellette mode: R = 6000 (0.6" slit); 0.89μ < λ < 2.51μ -- all in "one go"

High-Throughput Prism Mode: $R_{J,H,K}$ = 2500, 1300, 900; 0.89μ < λ < 2.51μ

Science motivation: "…identify the most distant objects in the universe, penetrate dust obscuration, study chemical composition of planetary atmospheres…"



Spectra of three high-redshift quasars, illustrating that for redshifts above z ~ 6, the observed energy distribution is shifted to l > 0.9 microns (R. Simcoe)

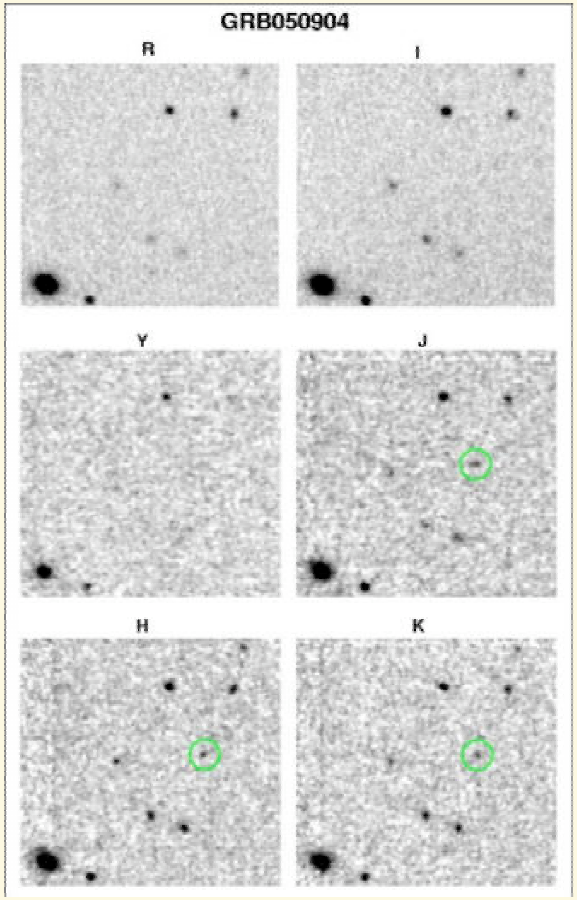


Infrared spectrum of a bright brown dwarf, illustrating an abundance atmospheric features from steam and methane. (A. Burgasser)

Magellan Instrumentation: future

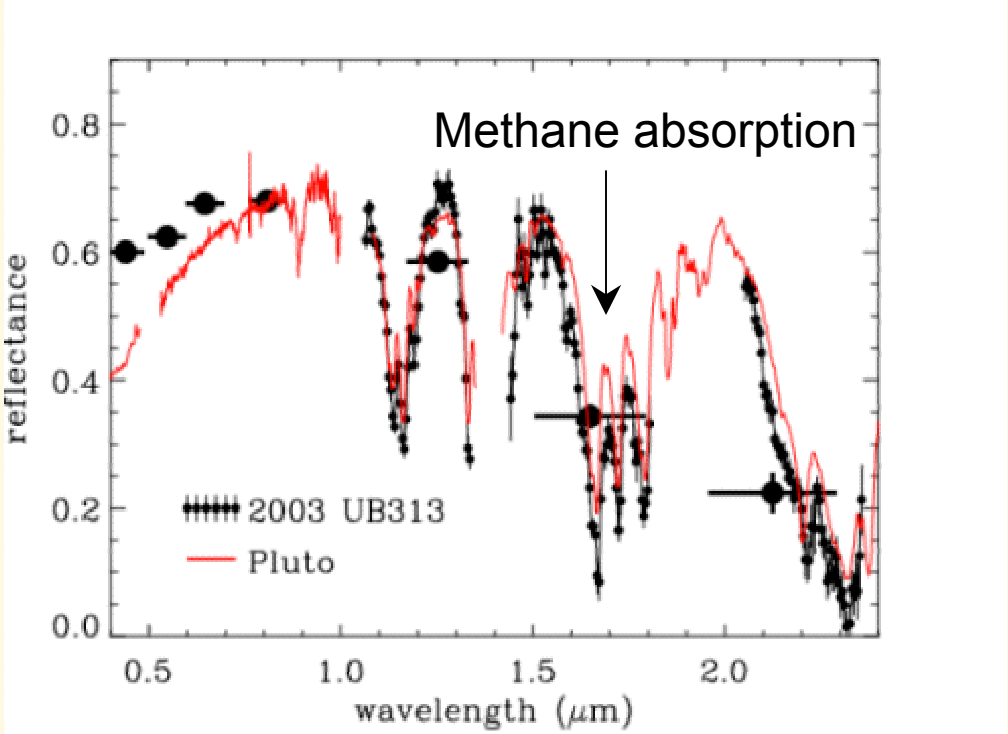
FIRE (cont)

Very high redshift GRB's



Optical (R,I) and near-IR (Y,J,H,K) images of GRB050904, a burst whose redshift was estimated at 6.28 from its lack of optical flux. (L. Cowie)

Atmospheres and surface composition of planets, moons, asteroids, comets…

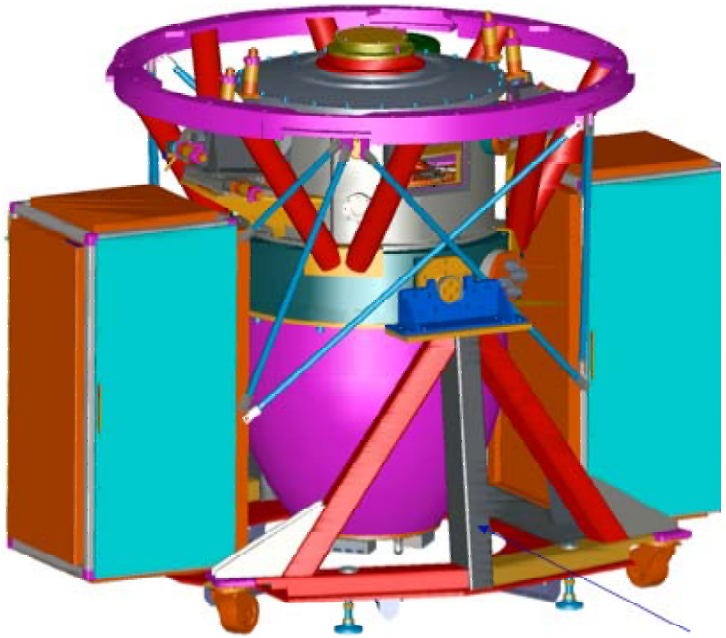


Spectra of sunlight reflected from the surface of Pluto (red) and 2003UB13, the so-called "10th planet" beyond Pluto's orbit. Both show signatures of methane absorption in the near-IR. (M. Brown)

Magellan Instrumentation: future -- late 2008 (including MegaCam)

MMIRS: a multi-slit near-IR spectrograph for the soon-to-be-added f/5 configuration of the Clay Telescope

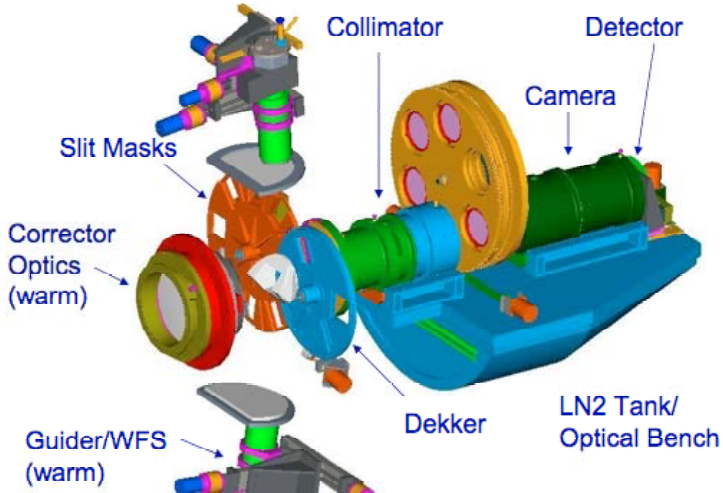
--- PI Brian McCleod, CfA -- TSIP funding!



- Imaging
  - 7 x 7 arcminute FOV
  - 0.2 arcsecond pixels
  - Y, J, H & K wavelength coverage
- Spectroscopy
  - Multi-slit (4'x7') or longslit (7')
    - J, H, K @ R=3000
    - J+H, H+K @ R=1400

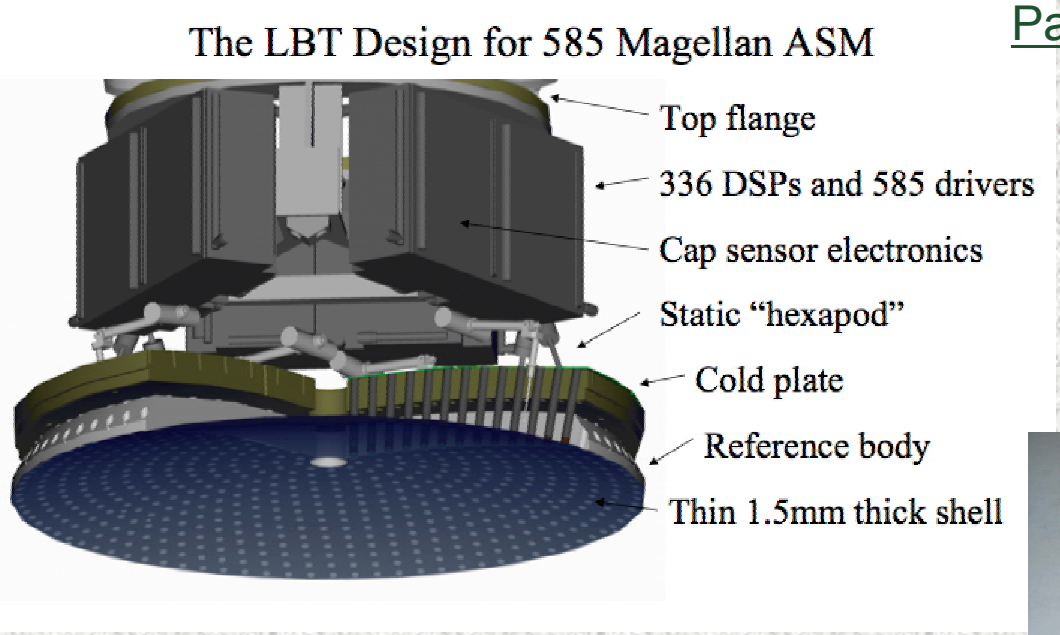
Similar to MOSFIRE under construction for KECK.

f/5 "campaigns" with MMIRS and Megacam



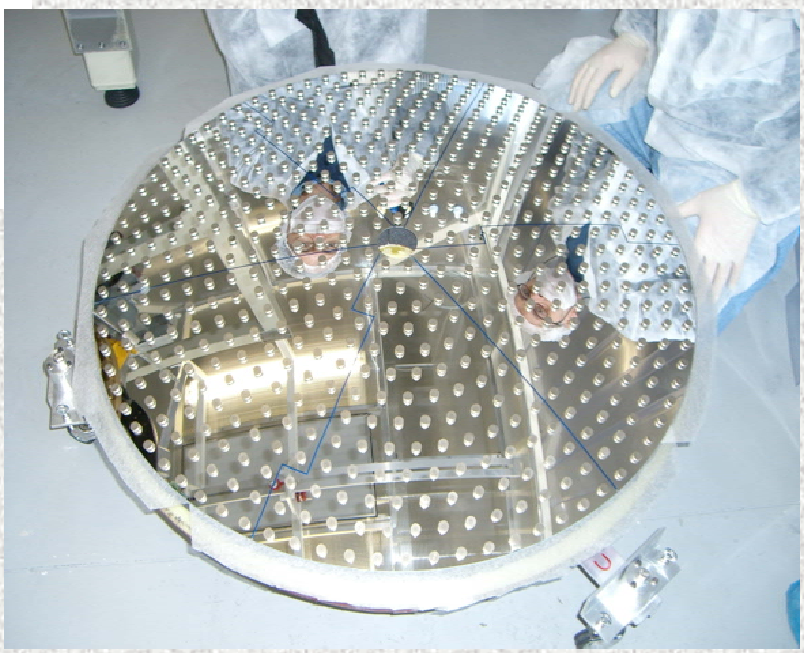
Magellan Instrumentation: future -- early 2009

Adaptive Secondary -- Laird Thompson & Victor Gashow (Arizona)



Partial NSF funding

Present Magellan effort is "piggybacking" on LBT adaptive secondary development



AO secondary will provide diffraction-limited images to upgraded mid-IR camera MIRAC4-BLINC (camera, coronograph)

Intention to add a front-end wavefront sensor and camera for a near-IR AO system, but no definite plans as yet.

Magellan Instrumentation: future -- late 2009

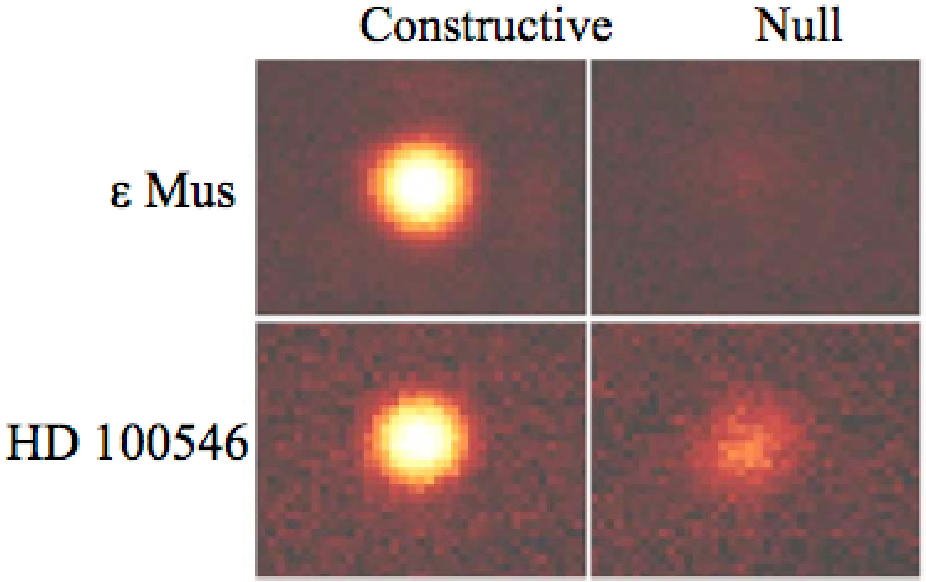
MIRAC4-BLINC -- Phil Hinz, Bill Hoffman -- U. of Arizona)

Diffraction-limited 8-25μ imaging with 256x256 Si:As array.

Variable field size: 19" & 38" @4.5μ; 34" & 68" @8.1μ

BLINC is the "nuller" component of MIRAC4

HD100546 -- a young stellar system?



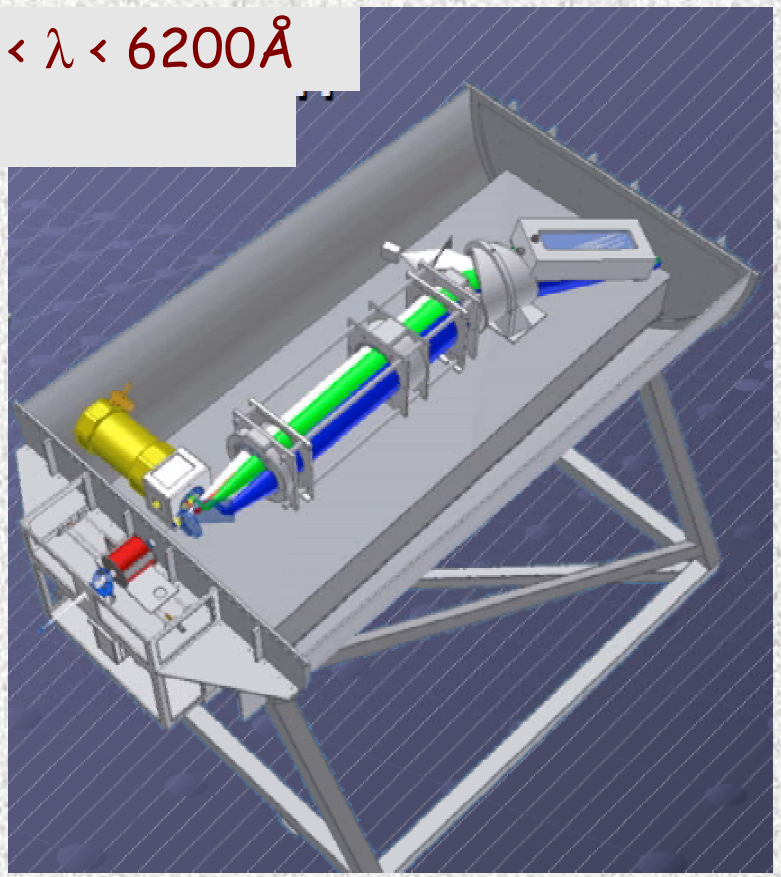
- Disk approximately 25 AU in diameter.
- Inclination and PA are consistent with NIR scattered light images (Augureau et al., Pantin et al.)
- Disk similar in size at 11 microns and 24.5 microns.
- Consistent with an inner hole? (Bouwman et al.)

Magellan Instrumentation: future -- early 2007

Planet Finding Spectrograph -- Crane, Shectman, Butler (Carnegie)

-- a spectrograph optimized for planet finding. Compared to MIKE, higher resolution, better optics, thermal control, careful slit and pupil illumination. Iodine cell method to achieve ~1 m/s

R = 40,000 arcsec^{-1} (R4), 3900Å < λ < 6200Å



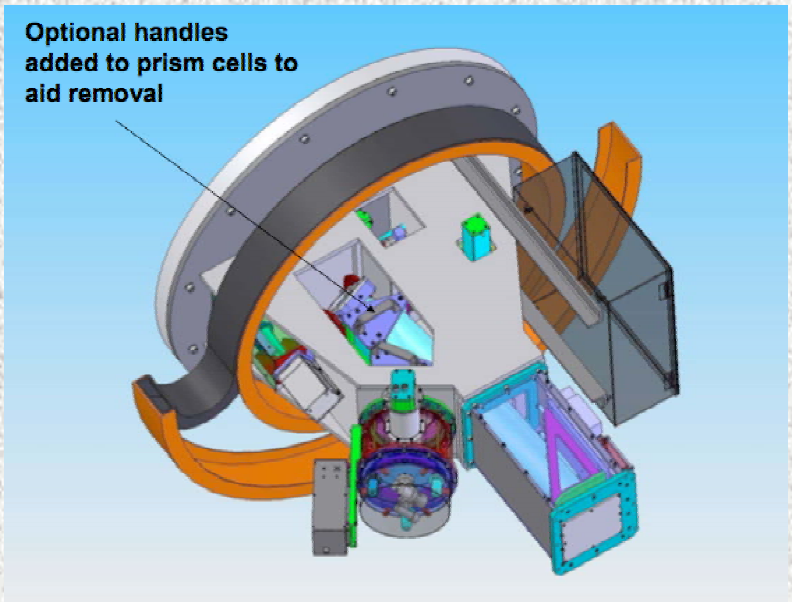
Magellan Instrumentation: future -- mid-2007

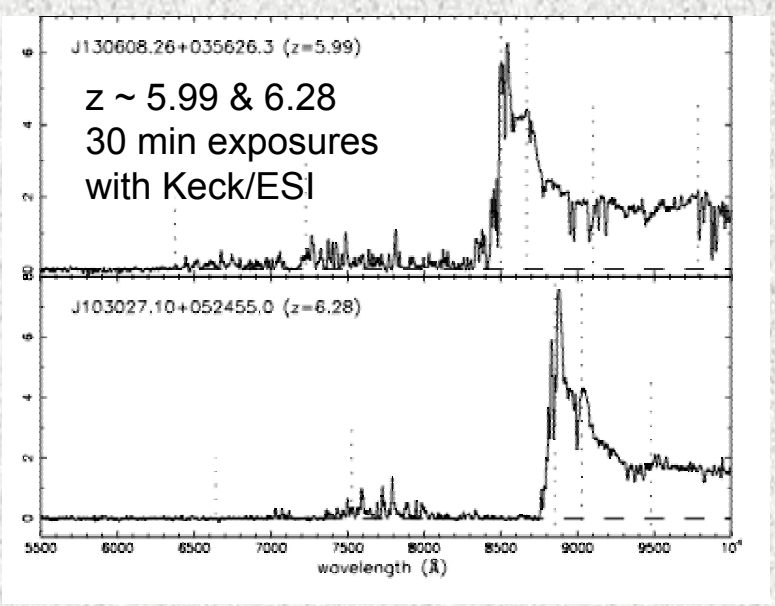
MES -- Magellan Echellette Spectrograph -- NSF MRI funding
Burles, MIT, Thompson, Shectman, OCIW

MES is a medium dispersion echellette, 5000 < R < 12000, optimized for ultraviolet λ < 3600Å

Medium order 8 < n < 24, large quartz prism cross-disperser, Schmidt Camera -- will reach S/N > 10 in one hour for AB=22!

Applications: IGM + faint QSO = re-ionization, high-z galaxies, ultra-metal-poor Galactic stars, GRBs, Kuiper Belt objects and asteroids…

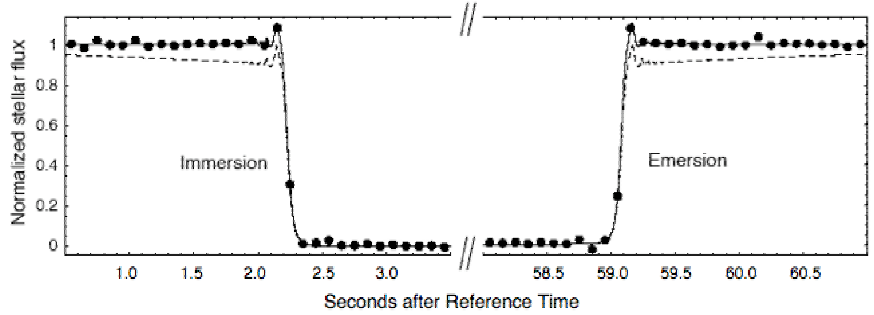




Magellan Instrumentation: now, PI instruments

Time resolved photometry:

POETS -- Portable Occultation Eclipse and Transit System



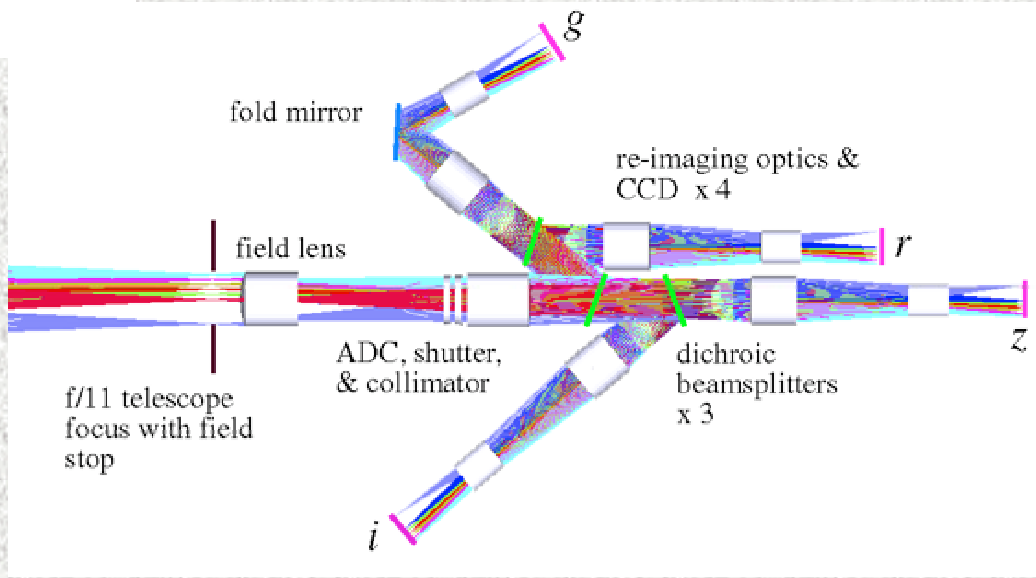
- 0.1 sec cycle time
- SNR: ~90 (in 0.1 sec)
- First Fresnel diffraction fringe detected
- Modeled with diffraction plus thin atmosphere

-- PI Jim Eliot, MIT.
POETS has a 10 hz sampling rate, for solar system objects and other rapidly varying sources

PISCO

-- PI Chris Stubbs, CfA
Simultaneous g,r,I,z photometry, 10 sec low-noise readout

Sample application -- photo-z's for 1000's of galaxy clusters



Magellan Instrumentation: summary

Instrument	Description	Type	PI	Early Date	Port	Tel
MIKE	Optical echelle	Facility	Shectman	NA	NAE	Clay
IMACS	Optical MOS	Facility	Dressler	NA	NAW	Baade
PANIC	NIR imager	Facility	Persson	NA	NAE	Baade
MagIC	Optical imager	Facility	Elliot	NA	FP3	Clay
LDSS-3	Optical MOS	Facility	Mulchaey	NA	NAW	Clay
MMFS	MIKE fibers	User	Mateo	NA	MIKE	Clay
MMTF	IMACS tunable filter	User	Veilleux	NA	IMACS	Baade
POETS	Optical imager	User	Elliot	NA	?	?
F/5 WFC	MegaCam corrector	Facility	Szentgyorgyi	2007A	Cass	Clay
GISMO	IMACS reformatter	Facility	Dressler	2007A	IMACS	Baade
PFS	Planet finding spectrograph	User	Butler	2007B	NAE	Clay
FP rotator/guider	Commission existing equip	Facility	Uomoto	2008B	FP2	Baade
MagE	Optical echellette	User	Burles	2007B	FP2	Clay
Cass rotator	F/5 rotator	Facility	Uomoto	2008A	Cass	Clay
Mosaic2	IMACS CCD dewar	Facility	Dressler	2008A	IMACS	Baade
F/5 secondary	Secondary mirror	Facility	Uomoto	2008B	NA	Clay
FIRE	NIR echellette	Facility	Simcoe	2008B	FP2	Baade
PISCO	4-channel griz photo-z imager	User	Stubbs	2008B	FP?	?/FP?
MMIRS	NIR MOS	Facility	McLeod	2009A	Cass	Clay
F/16 AO	AO secondary	Facility	Close	2009A	?	?
MegaCam	Wide field CCD imager	Facility	McLeod	2009A	Cass	Clay
FourStar	NIR imager	Facility	Persson	2009A	NAE	Baade
MIRAC4/BLINC	IR imager & interferometer	User	Hinz	2009B	NAE?	?

When Magellan began, there was much concern about having sufficient instrumentation. Now, thanks to its industrious partners, our cup runneth over.

With all 10 f/11 ports instrumented and scheduled f/5 campaigns, we might just be able to provide all these capabilities for Magellan users. However, as of this moment, we do not have the resources to do this.

6 ports up-and-running?

Cycling instruments in/out of service?

More operations funding?

Summary:

Magellan has begun with:

2 deep imaging/spectrographs, one with a very wide field and many “accessories” and another with very high efficiency

1 efficient echelle spectrograph

2 small field cameras, one IR, one optical

Consistent with the conclusions of the first OIR system workshop, on the way are four new infrared instruments:

FourStar -- wide field JHK imager

MMIRS -- multi-object near-IR spectrograph and camera

FIRE -- infrared (JHK) echelle

MIRAC4+BLINC -- mid-IR camera and nuller, fed by AO secondary

…and 2 new high-dispersion optical spectrographs:
Planet Finding and *Magellan Echellette*

Postscript:

- *Most of the Magellan Instrumentation programs have been supported by NSF funding through MRI, ATI, or TSIP -- these are good examples of public/private partnerships*
- *Most of the Magellan instruments are rapidly accessible (5-10 minutes), allowing important follow-up to transient events -- a program to image SWIFT GRBs is a current example*
- *Magellan has no plans for very high spectral resolution near-IR or mid-IR spectroscopy, as yet, and has not pursued near-IR AO, for imaging or spectroscopy. The latter is an example of "non-duplication" of expensive capabilities that the OIR System has emphasized.*