Present and Future Instrumentation at the Magellan Telescopes

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Carnegie Observatories
3rd OIR-System Workshop, Nov ‘06
Performance of the Magellan Telescopes

Median seeing FWHM ~ 0.6

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<th>Quartile</th>
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<th>DIMM</th>
<th>Clay</th>
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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 $R \sim 20,000$, full coverage
- **Maryland-Magellan Tunable Filter**: full field, $\Delta \lambda=6-40 \text{Å}$, 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 consortium

*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 multi-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**

**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

Small-field, single object enables compact design

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

FIRE (cont)

**Echellette mode:** $R = 6000 \ (0.6'' \ \text{slit}); \ 0.89 \mu < \lambda < 2.51 \mu \ -- \ all \ in \ "\text{one go}"$

**High-Throughput Prism Mode:** $R_{J,H,K} = 2500, \ 1300, \ 900; \ 0.89 \mu < \lambda < 2.51 \mu$

Science motivation: “...identify the most distant objects in the universe, penetrate dust obscuration, study chemical composition of planetary atmospheres...”
Magellan Instrumentation: future

FIRE (cont)

Very high redshift GRB’s

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

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)

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)

The LBT Design for 585 Magellan ASM

Top flange
336 DSPs and 585 drivers
Cap sensor electronics
Static “hexapod”
Cold plate
Reference body
Thin 1.5mm thick shell

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 (Augereau 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

$R = 40,000 \text{ arcsec}^{-1} (R4), 3900 \AA < \lambda < 6200 \AA$
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 $\lambda < 3600\text{Å}$

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…

- $z \sim 5.99$ & $6.28$
- 30 min exposures with Keck/ESI
Magellan Instrumentation: now, PI instruments

Time resolved photometry:

**POETS -- Portable Occultation Eclipse and Transit System**

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

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

**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
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.**