PFIS/NIR Upgrade

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Investigators

• P.I.: Andy Sheinis
• Co-I.s: Ken. Nordsieck,
• Matt Bershady,
• John Hoessel,
• Ron Reynolds,
• Ed Churchwell,
• Jay Gallagher,
• Amy Barger,
• Eric Wilcots
Design Team

- Andy Sheinis, project manager
- New Hire, project scientist
- Harland Epps, optical design
- Mike Smith, mechanical design
- Jeff Percival, Software
- Ken Nordsieck, polarimetry
- SAL, engineering and fabrication

Summary

- Lyman alpha Galaxies (Z~10?)
- Low metallicity superstar clusters in the SMC
- Chemistry of the Galactic Bulge
- Brown dwarfs/ circumstellar disks.
- Magnetic field mapping of the Galactic center
- 900 nm- (1.5-1.7? um)
- Broad-band Imaging
- Narrow-band Imaging: Dual etalon
- Low-Moderate spectroscopy (R~1000-5000) (1.25 sec slit)
- R ~ 10,000 with image slicer?
- Narrow-band polarimetry
- Spectro-polarimetry
Science goals : NIR
Narrow-band imaging

- Cosmological studies of $z > 6$ galaxies:
  - The key goal is to map the evolution of the luminosity function of more than 100, $z > 6$ galaxies to compare to WMAP results and determine if the change in the ionization state of the IGM can be seen in a reduction of the luminosity functions at some redshift.
  - In an observed 100 Angstrom range at 8000-9000 Angstrom, the current narrow-band surveys typically find about 100 galaxies per square degree with Lyman-alpha line fluxes of a few times $10^{-17}$ ergs/cm$^2$/s.
  - NIR Fabry-Perot imaging of pre-determined small range of $z>6$ redshift space scanning through 100-200 Angstroms will find the higher redshift counterparts of these Lyman-alpha emission lines in the natural dark regions in the sky between the OH lines.
  - NIR Fabry-Perot imaging will give higher resolution than the current narrow-band surveys. Furthermore, with long exposure times, the sensitivities will be higher.
  - With a delta-lambda of a few Angstroms PFIS/NIR can cover the 100 Angstrom bin in 10-20 steps. Several hours/step will likely be required for good S/N resulting in an overall scan of 20-40 hours for a particular field.

Science goals : NIR
Moderate R Spectroscopy

- The First Stars: NIR spectroscopy of star forming regions and superstar clusters in the Small Magellanic Cloud will provide new data on low-metallicity star formation processes. This topic will allow comparison to star-formation models of the first stars in the universe.

- Star and Planet formation. A remarkably hot topic is the study of Brown dwarfs, young stars and circumstellar disks. Observations of the NIR excess in the spectra of brown dwarfs will allow us to determine whether this excess is due to circumstellar disks of planet-forming material.
Science goals: NIR Spectropolarimetry

- Simultaneous visible/NIR spectropolarimetry will be unique at this aperture:
  - Rapidly variable polarimetric objects
  - Magnetic cataclysmic variables
  - Pre-main sequence stars
  - Novae, supernovae
  - Gamma ray bursts (longitudinal advantage)
- The NIR spectropolarimetric imaging:
  - Magnetic field mapping of regions of the Milky Way.
  - Fabry-Perot spectropolarimetry of scattered emission lines in dusty starburst galaxies will allow 3-D reconstruction of outflow from these galaxies.

Minimize Risks

- PFIS/Visible significant engineering overlap
- Extensive performance modelling up-front.
- Very experienced lens designer.
- Band-limit at the detector > semi-warm spectrograph.
- Cool camera (not cryogenic) temperatures > warm pupil with no internal pupil relay.
- Experienced VPH partner (UNC)
- Experienced etalon partner (Rutgers)
- Existing instrument frame.
- Re-use mechanical design (articulating mechanism, insertion mechanism, mounts etc….)
Constraints

- Visible optical design, sharing collimator
- Thermal constraints
- Weight budget
- Dispersion (collimator diameter and camera angle)
- All transmissive
- VPH gratings
- FOV

System Parameters: First Guess

- Blue cut-off ~850nm, based on optical design constraints.
- Red cut-off ~1.4-1.7 um, dependent on modeling results
- FOV: 8 arc minutes
- Single 2K X 2K chip
- Plate scale: 6 pix/arcsec = 108 um/sec
- Camera EFL: 302 mm
- Beamsize: 149mm
- Final F/#: F/2.02
- No cold stop
- Low emissivity warm-stop
- Cooled cam (-20 to -80C)
- Band-limited detector
## Existing or Planned Systems

<table>
<thead>
<tr>
<th>Name</th>
<th>Instrument</th>
<th>Detector</th>
<th>FOV</th>
<th>Resolution</th>
<th>Imaging Method</th>
<th>Fabry Perot</th>
<th>Polarimetry</th>
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## Performance Modelling

![Performance Modelling Diagram](image)
2nd Offendor, warm enclosure

Performance Modelling
Performance Modelling:
Sample imaging output

- Input parameters:
  - Filter start=1480 nm
  - Filter end=1500 nm
  - Cold optics temp=253K
  - Warm optics temp=273K
  - Det. band =900-1500nm

- Output: (photo-electrons/sec)
  - total sky noise = 23.0
  - in-band sky noise = 16.7
  - j-band sky noise = 4.3
  - h-band sky noise = 22.5
  - dewar noise = 1.55e-18
  - telescope emission = 7.7
  - warm optics noise = 2.2
  - cold optics noise = 0.57
  - readnoise = 7.50
  - Det. noise(dark cur) = 0.31
  - Inst. noise (imaging) = 10.9

Performance Modelling:
Sample Spectroscopic output

Tc=253 K
Tw=273K
Performance Modelling:
Sample Spectroscopic output

Tc=233 K
Tw=233K

Optical Design

SSWG May 9, 2005
Optical Design

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Optical Design

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Enabling Technology: VPH Gratings

• Partner with UNC, discussion with Chris Clemens.
• Test facilities at SAL and UNC
• Other vendors: KOSI, Ralcon, Wasach, CSL

\[ m\lambda = \Lambda n \sin(\alpha) \]
Good News

Transmittance of dichromated gelatin as a function of wavelength for a 15 \( \mu \)m thick layer which has been uniformly exposed and processed. As measured by KOSI, courtesy Sam Barden.

Sample Gratings

- Modeled efficiency (Chris Clemens)
- 560 l/mm
- 40 degrees (alpha + beta)
- \( dn=0.1 \)
- Thickness = 6.4 um
- Throughput > 90% from 1140-1360
Sample Gratings

- Modeled efficiency (Chris Clemens)
- 990 l/mm
- 87 and 63 degrees (alpha + beta)
- dn=0.1
- Thickness = 6.4 um
- Throughput > 80% over 100nm bands

Sample Gratings

- Modeled efficiency (Chris Clemens)
- 1119 l/mm
- 110, 96, 77, and 65 degrees (alpha + beta)
- dn=0.1
- Thickness = 6.4 um
- Throughput > 70% over 100nm bands
Enabling technology: Fabry-Perot etalons

- Partner with Ted Williams; Rutgers
- Two possible vendors, Queensgate and Michigan Aerospace have given verbal bids.
- Mechanics and insertion mechanisms will share technology with PFIS/VIS
- Optical testing at SAL: (Sheinis optical lab)

Facilities

- SAL
- Sheinis lab
- Bershady lab
- UNC
- Rutgers
- Other partners?
- We would welcome discussions with other potential collaborators within the consortium.
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