A Wide-Field, Multi-Object, Optical Spectrograph for GMT

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Obviously Korea is the right place to discuss instruments!

Technical Team

- Darren DePoy, PI (Texas A&M)
- Jennifer Marshall (Texas A&M)
- Gary Hill (UT)
- Steve Shectman (OCIW)
- Steve Smee (JHU)
- Robert Barkhouser (JHU)
- Dan Fabricant (Harvard/CfA)

- Matthew Colless (AAO)
- Will Saunders (AAO)

Technical team will lead the Conceptual Design development and interact with GMT Project and vendors

Science Team

- Technical Team Members plus
- Karl Gebhardt (UT)
- Mike Gladders (Chicago)
- Michael Brown (Monash)
- Changbom Park (KIAS)
- Casey Papovich (Texas A&M)
- Dan Kelson (OCIW)
- Daniel Eisenstein (Harvard/CfA; unconfirmed)

- Will provide science input for design choices
- Should eventually become a User's Group
- Provide advice/development of data reduction pipeline
- Will help with evaluation of de-scope options and capability enhancements

Instrument Summary

- Wide Field, Multi-Object, Moderate-Resolution, Optical Spectrograph
- “A spectrometer operating in the visible spectrum (0.32 μm to 1μm) with the capability to observe multiple targets simultaneously is critical to our goals in the areas of star formation, stellar populations and most extragalactic science”

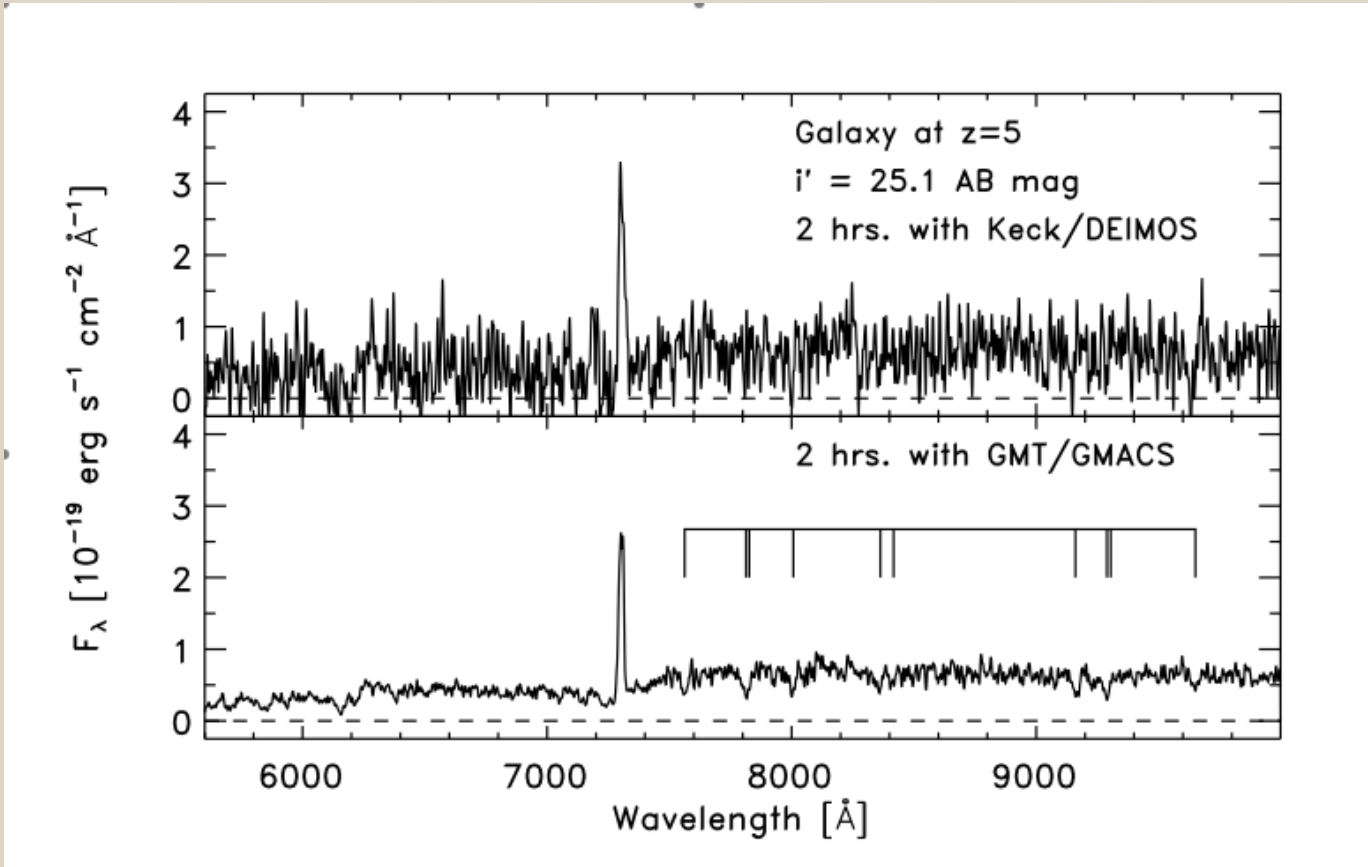
Instrument requirements

- High throughput
- Accurate and precise sky subtraction
- Multi-object capability
- Wide field
- Broad wavelength coverage
- Moderate resolution
- Seeing limited operation

Estimated Sensitivity

- System throughout roughly 30%
- In 1 hour in dark sky
  - S/N = 10 for 24-26 mag (y – u)
- Good S/N spectrum of anything in current sky surveys
  - G dwarf Ca H&K in LMC
  - F dwarfs in Local Group
  - Giants in Virgo
  - PN in z=0.5 clusters
  - L* galaxy at z=4
- GMACS will never run out of targets!

Optical spectroscopy with the GMT will be crucial in the era of DES, LSST, JWST, etc.



The upper panel shows the spectrum of a z ≈ 5 galaxy that could be taken with DEIMOS on Keck; the redshift of the galaxy is shown by the Lyman-α emission around 7300Å. The lower panel shows the same spectrum, as would be obtained with the GMT optical spectrograph. Ly-α is detected at high S/N and other ISM/stellar absorption features from the galaxy are also seen (marked by lines above).

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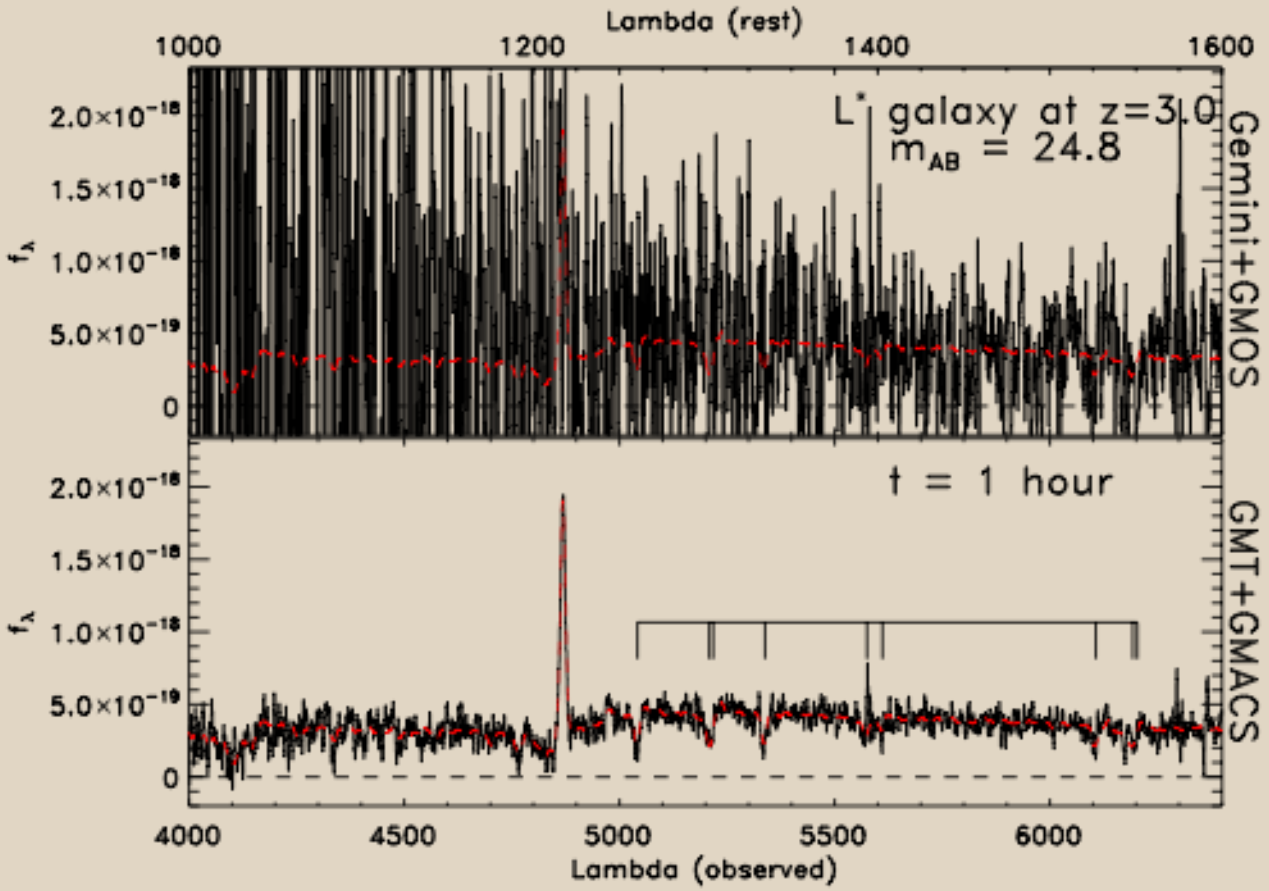
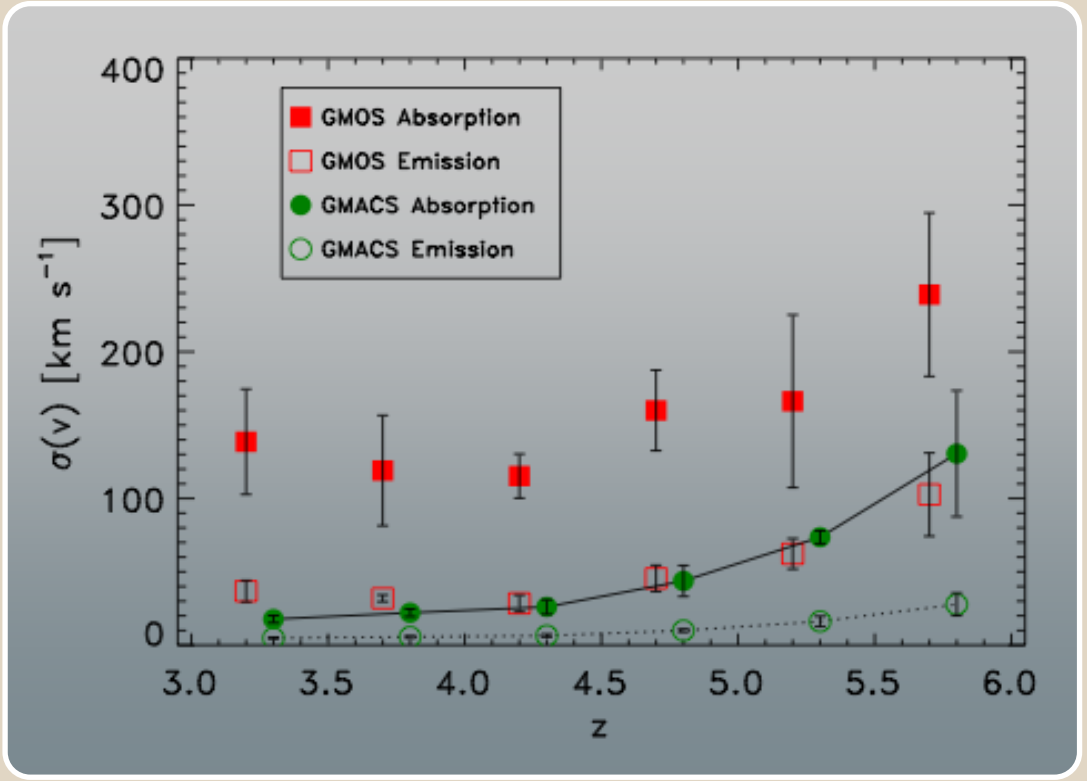


Absorption Line Science

- **Metallicities at z>3**
  - Measure faint emission lines from C, O
    - Compare to Lyman lines for gas abundances
  - Measure absorption lines of various elements
    - Arise in stellar photospheres
    - Abundances in early stellar population
- **Stellar populations at z>3**
  - Look for P-Cygni profiles in HeII lines
    - Measures WR star numbers
    - Independent check of high mass SF rate
  - Other absorption lines probe other populations

Measuring velocity dispersions and flows

- GMT can measure the radial velocities and dispersions of these spectral features
- Impossible with any existing instrument



Absorption Line Science

- **Galaxy feedback and assembly process**
  - Measure robust outflow velocities.
    - Actually measuring differences in redshift between Lyα and ISM absorption lines, where $\Delta v = z_{Ly\alpha} - z_{ISM}$.
    - Typical values of Δv = 100 - 600 km s^{-1} (Shapley+03, Bielby+10).
    - How precise are these measurements?
      - Bielby+10 used 3 hours of VLT/VIMOS spectroscopy on z = 3 LBGs. Found $\sigma(v)_{emission} \approx 400$ km s^{-1}, and $\sigma(v)_{absorption} \approx 850$ km s^{-1}.
      - Thus its difficult to measure the velocity offset in individual galaxies to any significance.
        - » This is important to study weaker outflows, as well as to correlate outflow velocity with star-formation rate, etc.

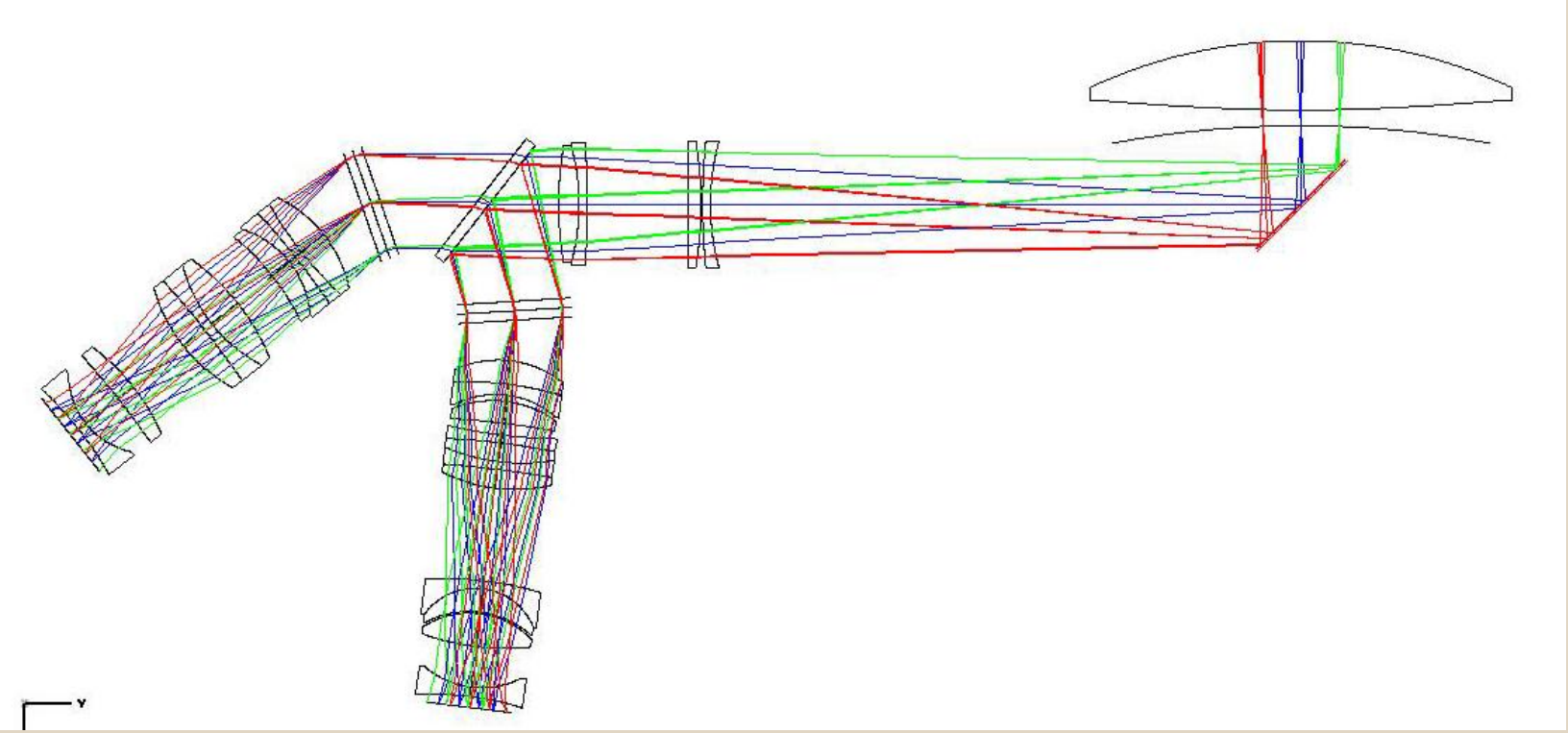
GMACS Description

- Wide-Field
  - 8’x18’ (full configuration and wavelength coverage)
- Multi-object with multi-slits
  - 0.7 arcsec width
  - Large number of slitlets and masks available during night
- Moderate resolution
  - Roughly 2000
    - R=2700 at 850nm
    - R=1400 at 500nm
  - Other resolutions possible and will be investigated
- Optical wavelengths
  - Simultaneous coverage using separate red & blue channels
    - 400-900nm
  - 340-1100nm goal

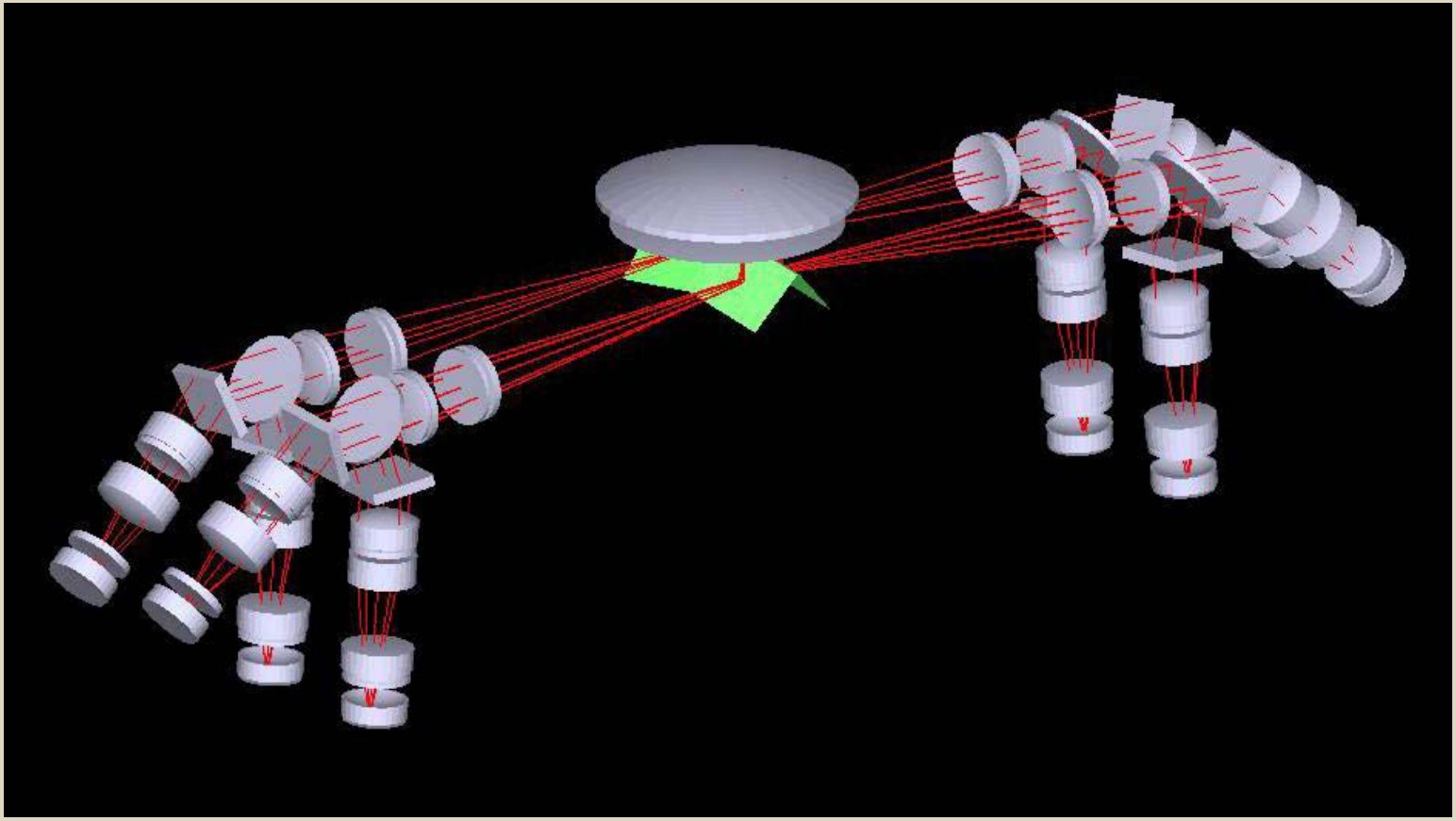
GMACS Basic Layout

- Refractive collimator and cameras
  - Two channels to maximize throughput and image quality
  - Good image quality over full field
    - Roughly 0.2 arcsec RMS
- Four arms for full field coverage
- Large focal plane
  - Roughly 280mm x 160 mm
    - About 25 2K x 4K CCDs per channel

GMACS Layout of one arm



GMACS 3D Optical Layout



On-going design effort

- Technical team is working on advancing the instrument design
  - New mounting/packaging concept
    - Structural design
    - Positioning mechanisms
  - Assessment of critical technologies
    - Glass blanks
    - Flexure compensation
    - Gratings
  - Optimization of optical design
  - Focal plane lay-out and capabilities
    - Field acquisition
    - Calibration

On-going design effort

- Other work
  - Exposure time calculator
  - Data reduction and analysis pipeline
  - Schedule and cost estimates
    - Full instrument will not be inexpensive!
  - Investigation of deployment and de-scope options
    - Could initially deploy reduced capability
    - Permanent de-scopes possible

De-scope/staged deployment options

- Several obvious descope options exist
  - Single arm, single channel (red or blue)
  - Single arm, both red and blue channels
  - Two arms, each with both blue and red channels
  - Four arms, but with only one channel
- Single arm, but in center of field
  - 10 arcminute × 10 arcminute field?
  - 8 arcminute × 8 arcminute field?
  - Will seek Science Team advice on minimum interesting field

On-going design effort

- Possible enhancements of capability
  - Imaging modes
  - Fiber feeds
  - Additional resolutions
    - Low
      - Particularly very low-resolution prism mode
    - High
  - Use with GLAO in the far red
  - Simultaneous use with NIR Spectrometer

Optical Spectroscopy with GMT

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- Crucial science capability
  - Galaxy formation and assembly
  - Dark energy
  - First light and reionization
- Information content very high
  - Most basic capability required for any telescope
  - Expect that use will spread across a wide spectrum of topics
    - Metallicity/dynamics of halo stars
    - Star formation at z=2
    - Mineralogy of KBOs
- Any science project with more than a few targets per sq. arcminute