GAS: the Galaxy Assembly Spectrograph

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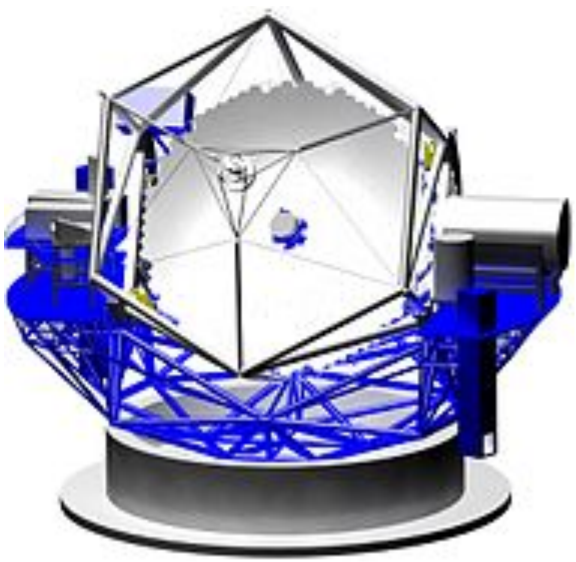
TMT Focal Plane: the Most Expensive Real Estate in the World

- Developers Value TMT Focal Plane at > $1.6B
- 35,000 x Higher Than Most Exclusive Real Estate
- We Need to Maximize Scientific Return!
- One Way: Multi-Object IFU Spectroscopy Near Diffraction Limit



Developers: $13,000 per Square Foot

- Representative Science Cases for Multi-Object IFU Spectroscopy
  - Assembly of Disk Galaxies (see Lemoine-Busserolle et al.)
    - Characterizing Disks, Star Formation Rates, Bulges & Bars, Abundance Gradients
  - Assembly History of Ellipticals and S0s (see Pierce)
    - Velocity Dispersion Distribution Function, Fundamental Plane Population, Complex Internal Velocity Fields, Wet vs. Dry Mergers
  - IFU Spectroscopy of Galaxy Clusters and Strongly Lensed Systems (see Dell' Antonio)
    - Assembly Cluster Populations
    - Magnification of High-z Galaxies
    - Cosmology
  - Many Additional High-z Galaxy Science Cases
  - Nearby Universe As Well
- IRIS Extremely Capable but Large TMT Surveys are Possible with MO-IFUs
  - Requires Multi-Object Adaptive Optics

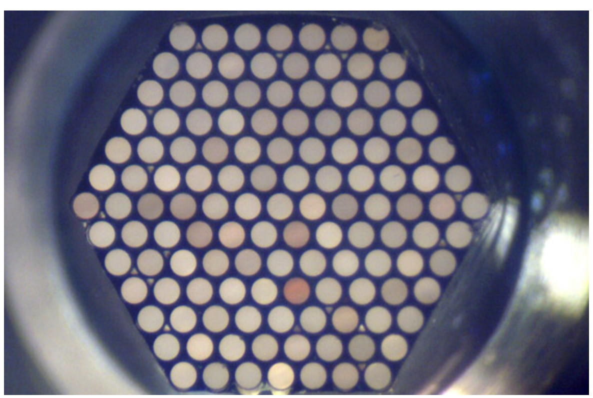
Multi-Object AO Considerations

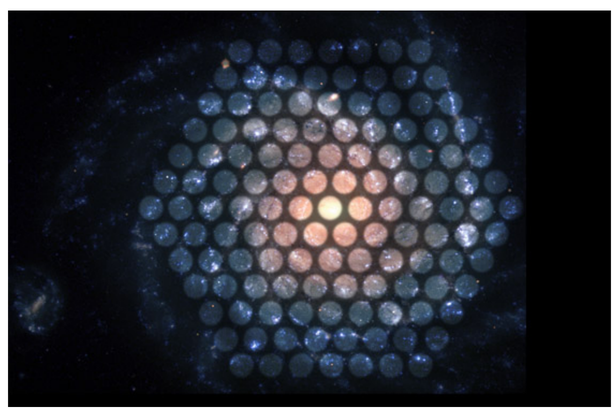
- MOAO: Encircled Energy is 50% within 0.05 arcsec Over Field Radius of 150 arcsec (5 arcmin Diameter, 2’ with NIFIAROS)
- Number of IFUs Depends on Specific Science Case
  - Spectrograph Collimated Beam Will Scale as D_{IFU}^2 (Pseudo Slit Length)
  - Spectrograph Cost Will Scale as D^2_{Beam} or D_{IFU}^4
- Many Science Cases Strongly Benefit from Independently Configurable Spectrographs
- Cost for Spectrographs Scale Linearly (or Less) with Number
  - Cost Trade-off Between Larger IFUs and the Number of IFUs (Spectrographs)
  - Native (f/15) Plate Scale a Poor Match for Fiber IFUs (f/7.5 lenslets)

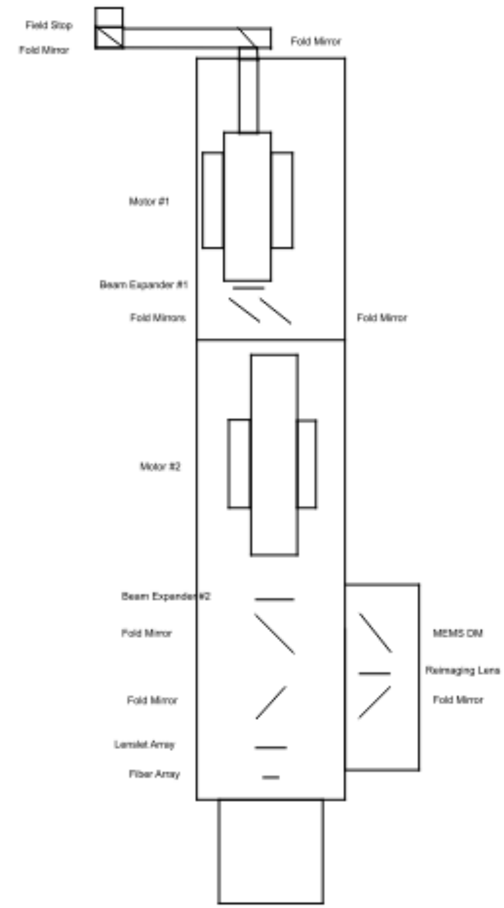
Detector	Pixels	# Spect.	IFU Spax.	IFU Size (120 μm Fibers)
Hawaii1	1024/18	204	14 x 14	1.54” x 1.54”
Hawaii2	2048/18	408	20 x 20	2.20” x 2.20”
Hawaii4	4096/15	819	28 x 28	3.08” x 3.08”

GAS Concept

- Infrared (K-band) Transmitting Optical Fibers
  - Historically Exotic and Expensive
  - Recent Development of Extremely Low OH Fibers from PolyMicro
- Adopt DESI Robotic Fiber Positioners ($\theta-\theta$)
  - Addition of Ball Lenses to Couple Fibers to Telescope Pupil
  - Adapt Positioners for Cryogenic Operation
  - Build DMs into Positioners
  - Manga-like IFUs Instead of Individual Fibers (+Lenslets)
  - Cool Fiber Cables and Feed Individual Spectrographs
  - Build Commodity Spectrographs
- Concept Completely Scalable
  - Build a Some Now and More Later

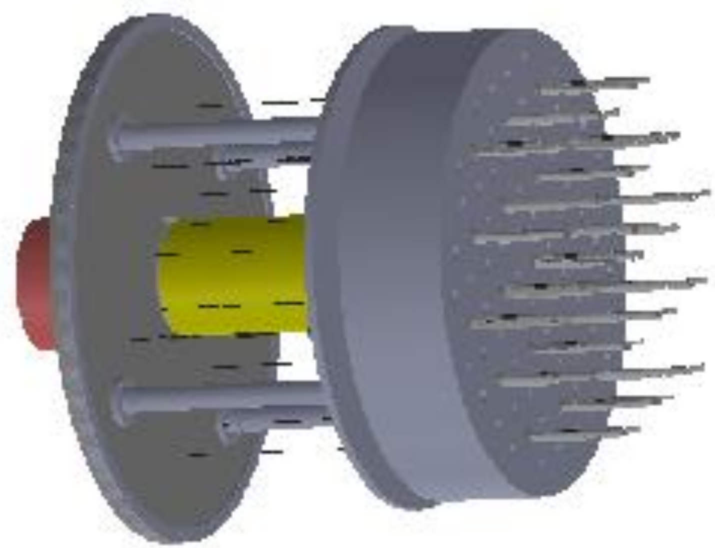






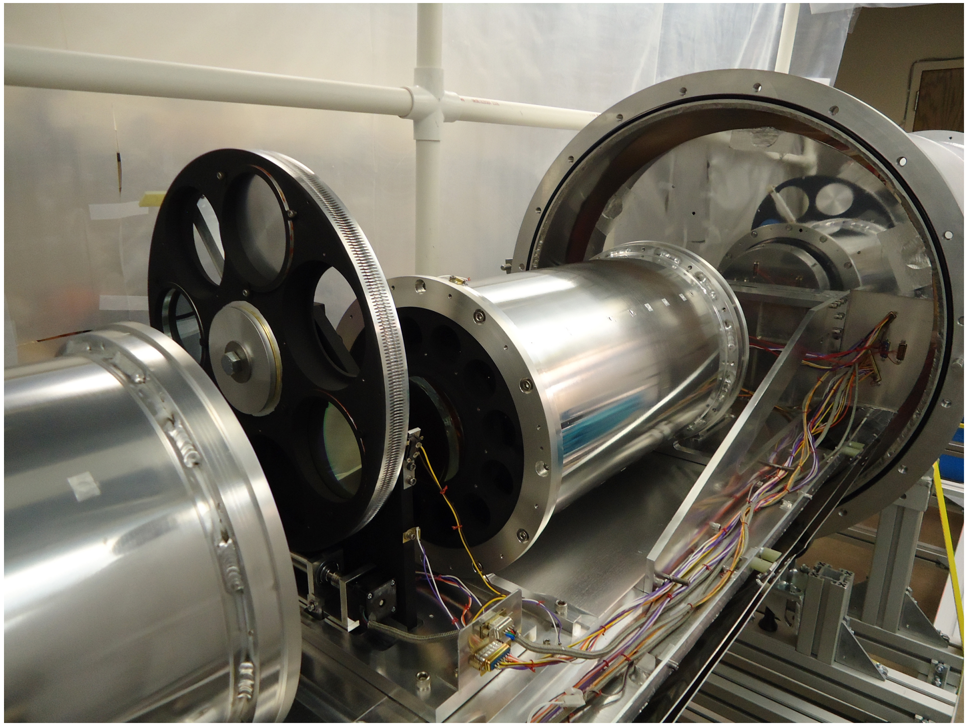
GAS MOAO Focal Plane

- **NIFIRAOS+GAS**
  - **GAS Would Use DESI/PFS Positioner θ−θ Design but Larger Diameter (50 vs. 6 mm)**
  - **MOAO Still Requires Low-Frequency Correction and Tip-Tilt (NIFIRAOS)**
  - **GAS DMs Provide Higher-Order Correction**
  - **Will D = 15-20mm (30 x 30) DMs Provide Sufficient Correction? (Target = 50% Enc. Energy, within 0.05”)**
  - **GAS Positioners within Large Diameter (650mm) Dewar with Cryo-Cooling**
  - **Design Fully Scalable**
  - **GAS Would Allow Up to ~ 30 IFUs**
  - **Only Positioner Dewar Rotation**
  - **Question: Should Wave-Front Sensors Be Located on Each Positioner?**
  - **Is NIFIRAOS Only Option for Low-Order Correction?**
    - **TMT-AGE Wider FOV (5’)**



GAS Spectrographs

- **Spectrograph Design**
  - Based on FLAMINGOS (Florida) and NIIS (Wyoming)
    - 4 Element Collimator
    - 6-8 Element Camera
  - Multiple VPH Gratings (R > 3500)
  - Fiber Cable Forms Pseudo-slit
    - Backlighting of IFUs for Targeting
- **Number Depends on IFU ForeOptics:**
  - NIFIRAROS: 30 IFUs, (2.2" x 2.2")
  - TMT-AGE: 180 IFUs, (2.2" x 2.2")
- **Modular Design**
  - Separately Configurable for Each Target (Resolution, λ, z)
  - Suitcase Spectrographs
    - Stacked for Small Platform Footprint
    - Easily Changed Out



Wyoming's Near Infrared Camera

Summary

- **GAS Could Provide MO-IFUs**
  - **2 arcmin FOV limited by NIFIRAOS**
  - **TMT-AGE Fore-Optics Would Allow 5 arcmin FOV (see Akiyama et al. Poster)**
- **θ−θ Positioner Design from DESI**
  - **Manga-like IFUs (20 x 20, 0.1 arcsec fibers)**
  - **Patrol Radius 18 arcsec, 28 arcsec pitch)**
  - **Size (e.g., 2.2" x 2.2") and Number Scales with FOV**
- **Spectrographs**
  - **Traditional Collimator-Camera Transmissive Design**
  - **Based on FLAMINGOS (Florida) and NIIS (Wyoming)**
    - **4 Element Collimator**
    - **6-8 Element Camera**
  - **Y, J, H, K Coverage with Multiple VPH Gratings (R: 3500+)**
  - **Fiber Cable Forms Pseudo-slit**
    - **Backlighting for Targeting**
  - **Separately Configurable (Resolution, λ, z)**
  - **Suitcase Spectrographs**
    - **Stacked for Small Footprint**
    - **Easily Changed Out**
- **Concept Paper Planned for 2017 Call (Collaborators Welcome)**