

# Galaxies

*Sylvain Veilleux*

## ■ My Interests:

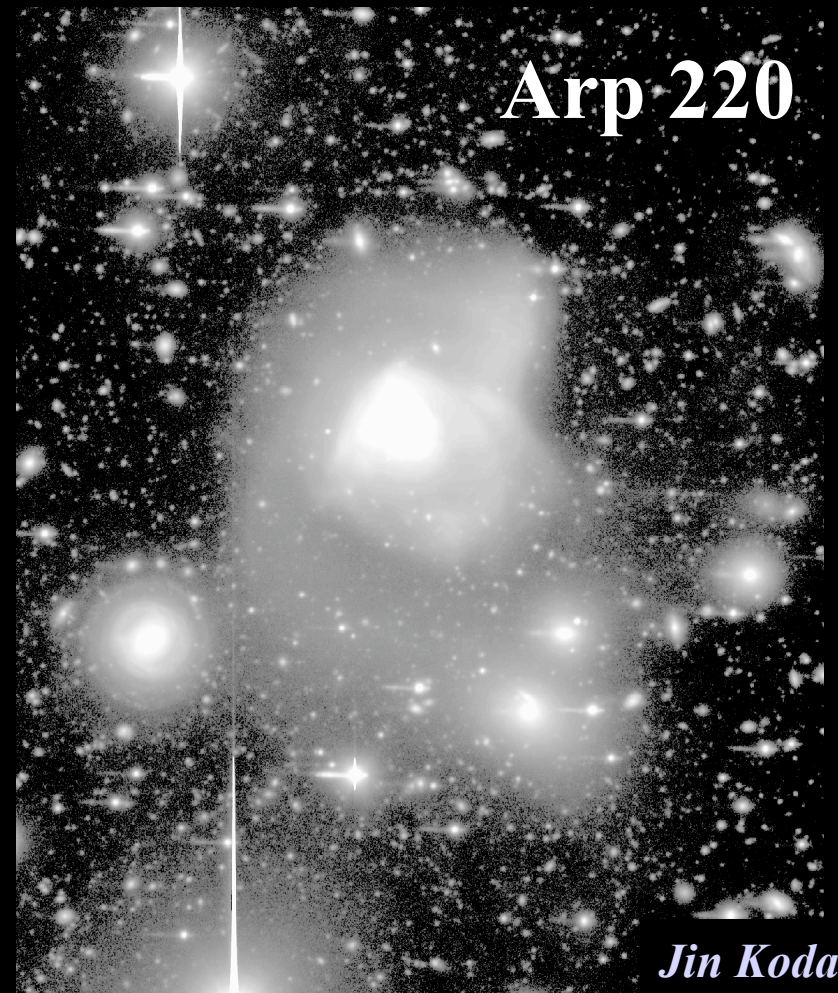
- Galaxy and black hole formation and evolution
  - ❖ Origin of starburst and AGN activity
  - ❖ Role of galaxy mergers
  - ❖ Impact of feedback processes
- Instrumentation for ground-based optical/infrared telescopes
  - ❖ Maryland-Magellan Tunable Filter (MMTF on Magellan-Baade 6.5m)
  - ❖ NOAO Extremely Wide Field Infrared Mosaic (NEWFIRM on NOAO 4m)
  - ❖ Rapid IMager-Spectrometer (RIMAS for DCT 4.3m)

## ■ Current group @ Maryland:

- PhD students: Hannah Krug, Alex McCormick
- MSc students: John Capone (*shared*), Kory Kreimeyer, Alice Olmstead (*shared*)
- Postdoc: Margaret Trippe (*shared*), Marcio Melendez (*shared*)
- Faculty: Stuart Vogel, Rich Mushotzky, Chris Reynolds
- GSFC: Neil Gehrels, Harvey Moseley, Alexander Kuttyrev, John Mather

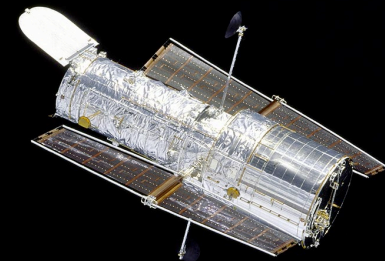
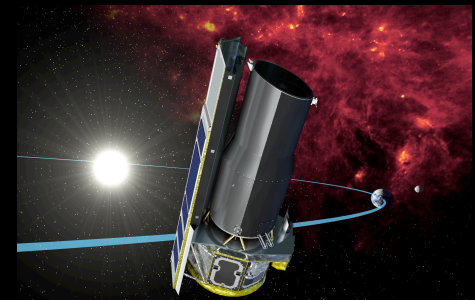
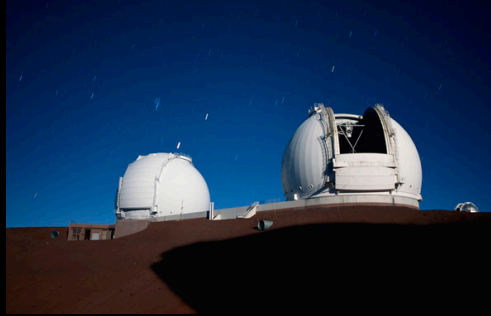
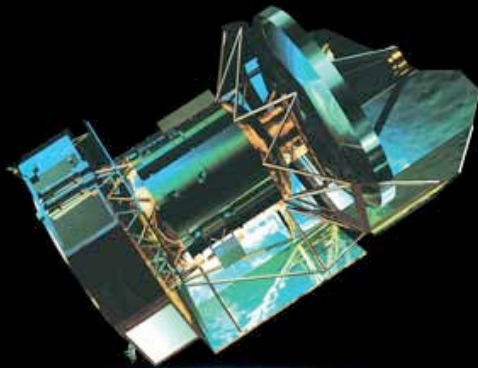
# Important Issues

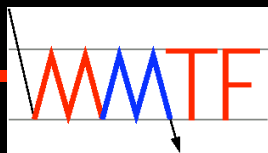
- *Ultraluminous Infrared Galaxies (ULIRGs): near & far*
- *Spheroids in formation*
- *Black hole growth*
- *Galactic winds*



# QUEST: Quasar and ULIRG Evolution Study

- Ground-based optical-NIR images and spectra (*Veilleux et al. 1999, 2002; Rupke et al. 2002, 2005abc; Rupke & Veilleux 2011*)
- VLT/Keck NIR spectroscopy (*Dasyra et al. 2005, 2006*)
- HST/NICMOS imaging (*Veilleux, Kim, et al. 2009a*)
- Spitzer Space Telescope (*Veilleux, Rupke, et al. 2009b*)
- Chandra/XMM/Suzaku (*Teng + Veilleux 2010*)
- Herschel Space Observatory (*Humboldt Senior Award @ MPE*)
- HST/COS UV spectroscopy (*Cycle 19*)
- CARMA, Arecibo, GBT (*Zauderer in prep; Teng in prep*)





# Maryland-Magellan Tunable Filter

(<http://www.astro.umd.edu/~veilleux/mmtf>)

Tunable filter for IMACS on the Baade 6.5m telescope with broad wavelength coverage ( $\sim 5000 - 9300 \text{ \AA}$ ), bandwidth ( $\sim 5 - 15 \text{ \AA}$ ) and wide FOV ( $27'$ )

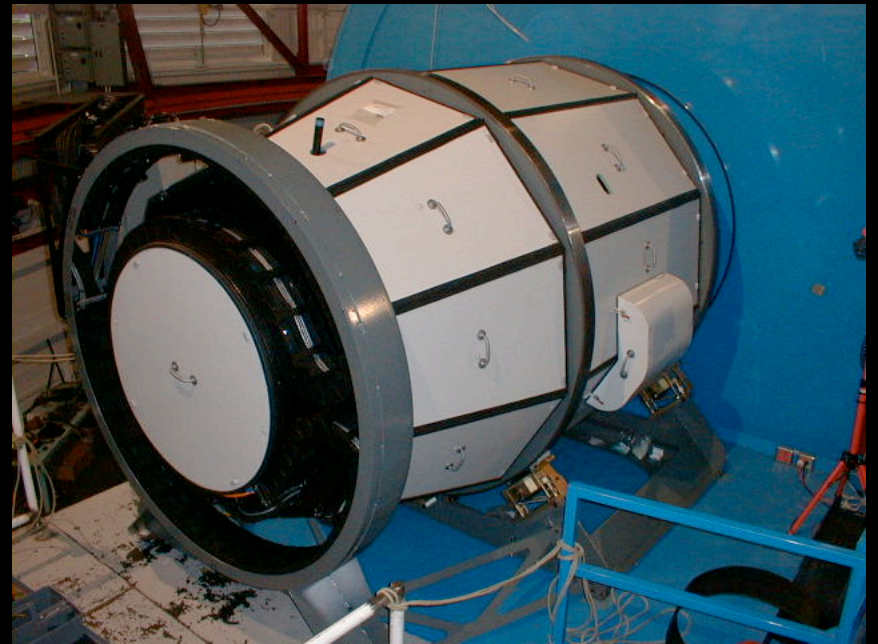
- **PI:** S. Veilleux (U. Maryland)
- **Co-PIs:** J. Bland-Hawthorn (U. Sydney), A. Dressler (OCIW), M. Rauch (OCIW), & S. Vogel (U. Maryland)
- **Co-Is:** B. Bigelow (OCIW / U. Michigan), *M. McDonald (MIT)*, *D. Rupke (Rhodes)*, P. Shopbell (Caltech), B. Sutin (OCIW/Skewray), I. Thompson (OCIW), *B. Weiner (Arizona)*, & R. Weymann (OCIW)
- **Additional Technical Support (OCIW):** A. Bagish, C. Birk, T. Hare, D. Osip, F. Perez
- **Funding Agency:** NSF/ATI (instrument), NSF/EXC (science x 2)





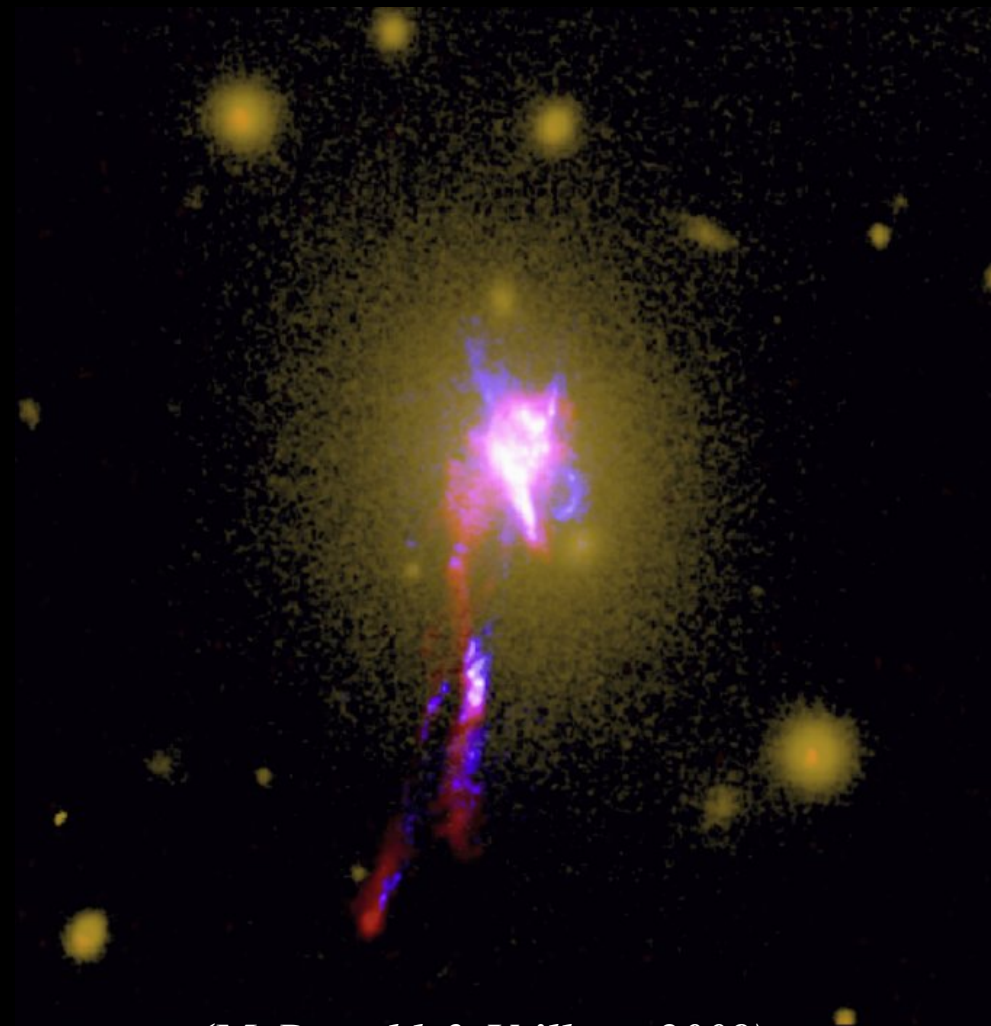
# Magellan Telescope

IMACS



# Galaxy Groups and Clusters

*(PhD Thesis M. McDonald)*



*(McDonald & Veilleux 2009)*

# NEWFIRM is ...

## An infrared camera project

- 28 arcmin field of view
- 0.4 arcsec/pixel resolution
- 1-2.5 micron capability
- 4-m telescopes sensitivity

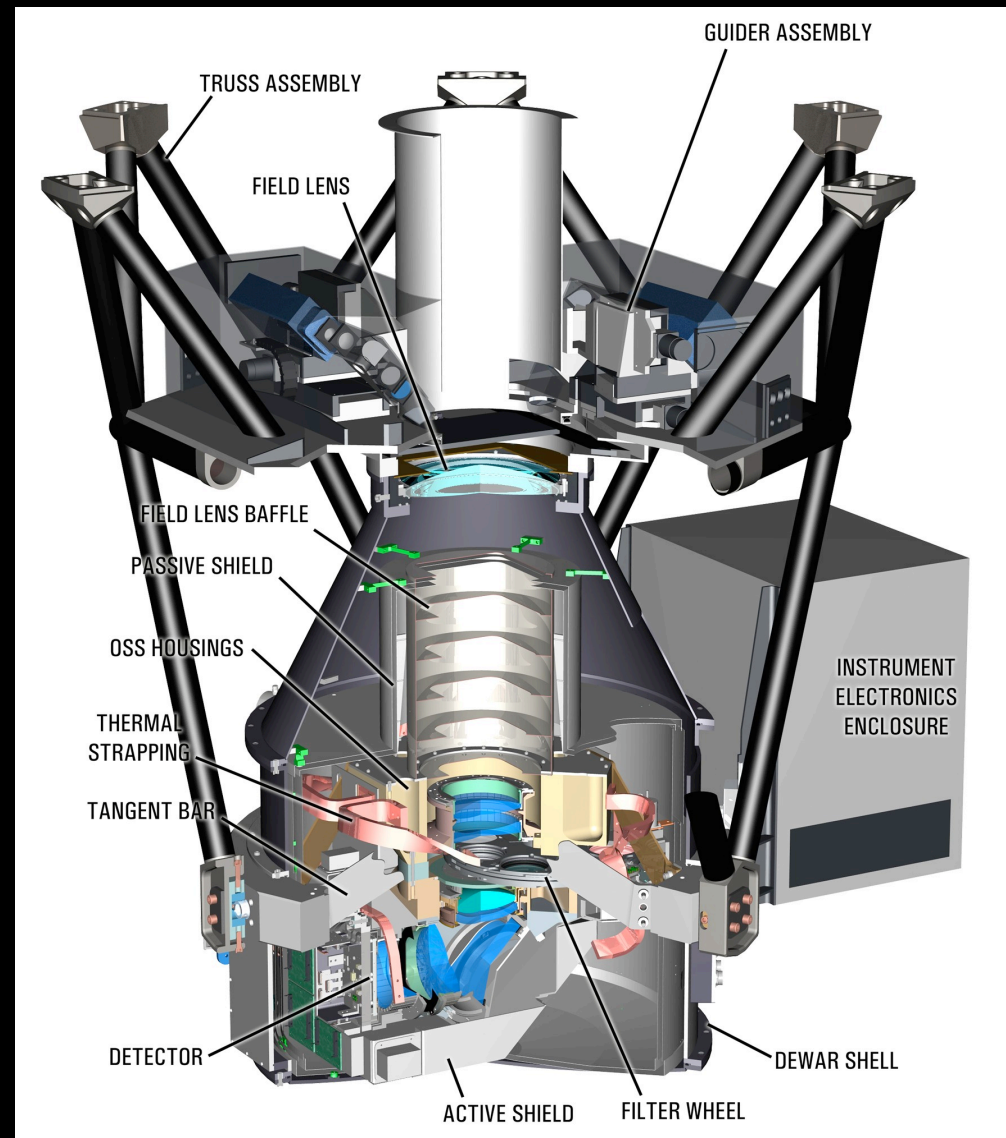
## Integrated with other projects

- ORION
- MONSOON
- Pipeline (*Maryland*)
- Science archive (*Maryland*)

## To form a system for

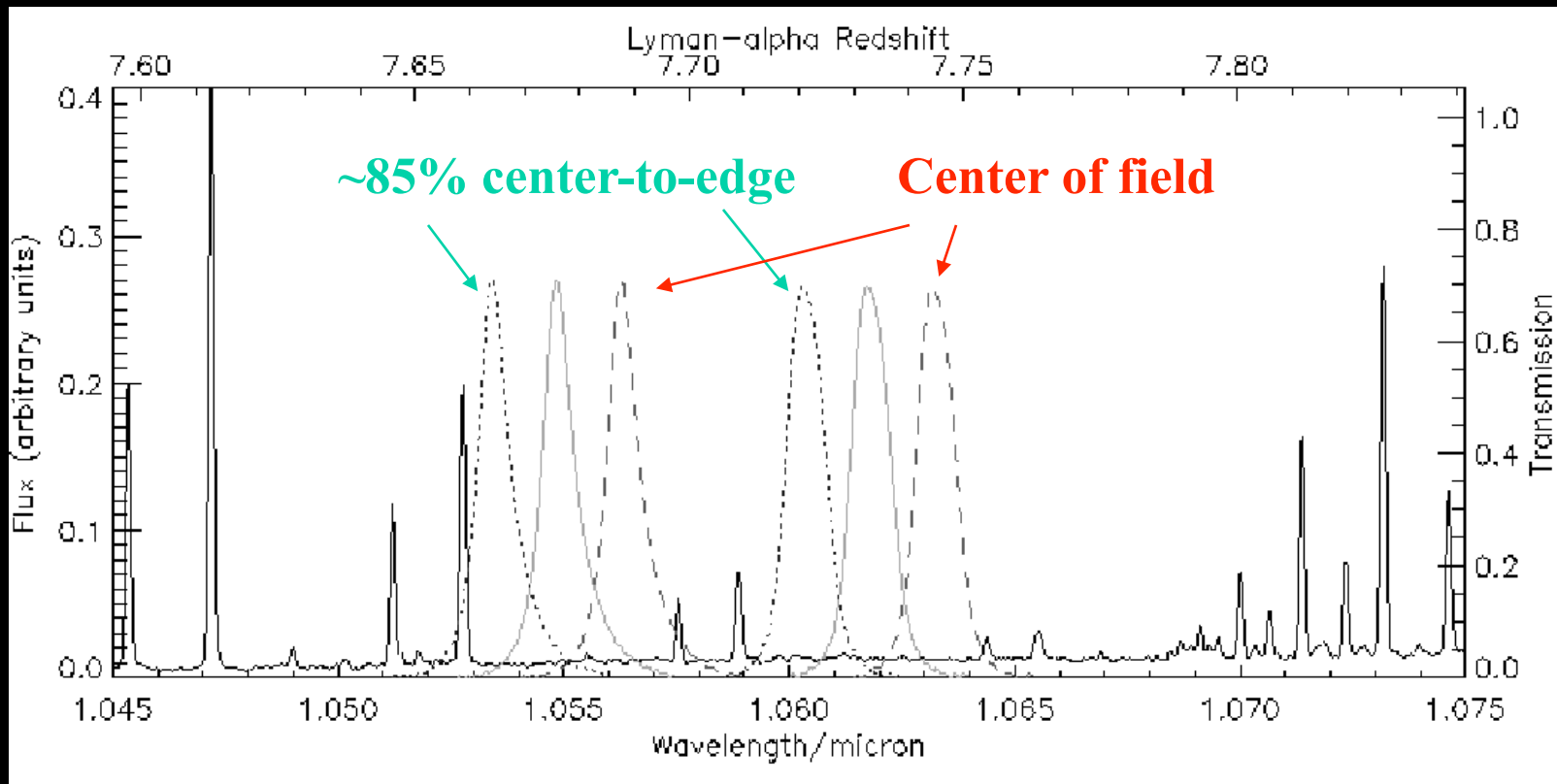
- Deep wide field surveys
- High efficiency observing
- Rapid data turnaround
- Public data access

(PI: R. Probst, NOAO;  
*Maryland-NOAO Collaboration*)



# Search for $z = 7.7$ Ly $\alpha$ emitting galaxies using ultra-narrowband filters

(PhD Thesis of H. Krug)





M 82

## Galactic Winds

- *Veilleux, Cecil, & Bland-Hawthorn, 2005, ARAA, 43, 769*



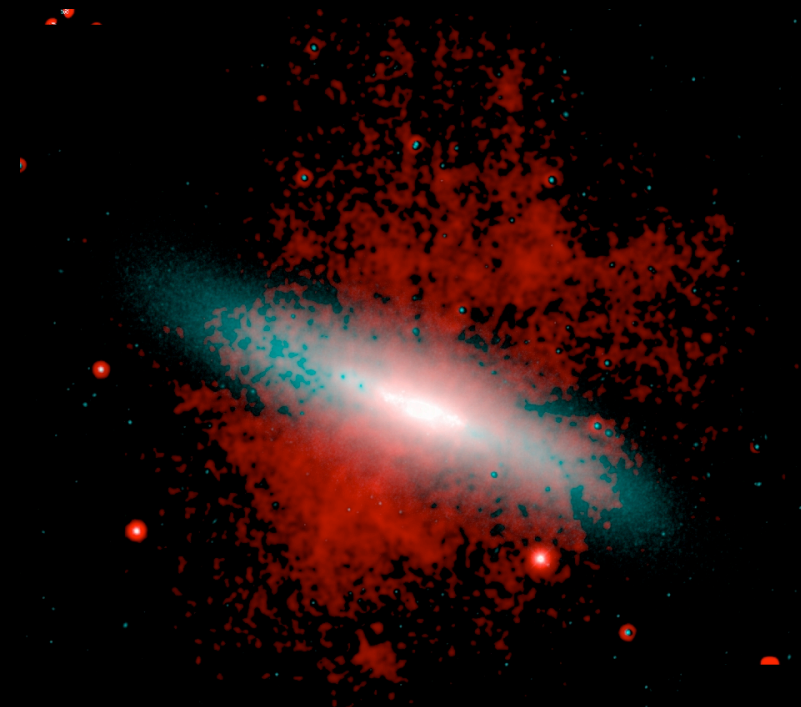
# Molecular Gas in Galactic Winds

Archetype: M82



Ionized Gas

*(Smith, Gallagher, & Westmoquette '05)*



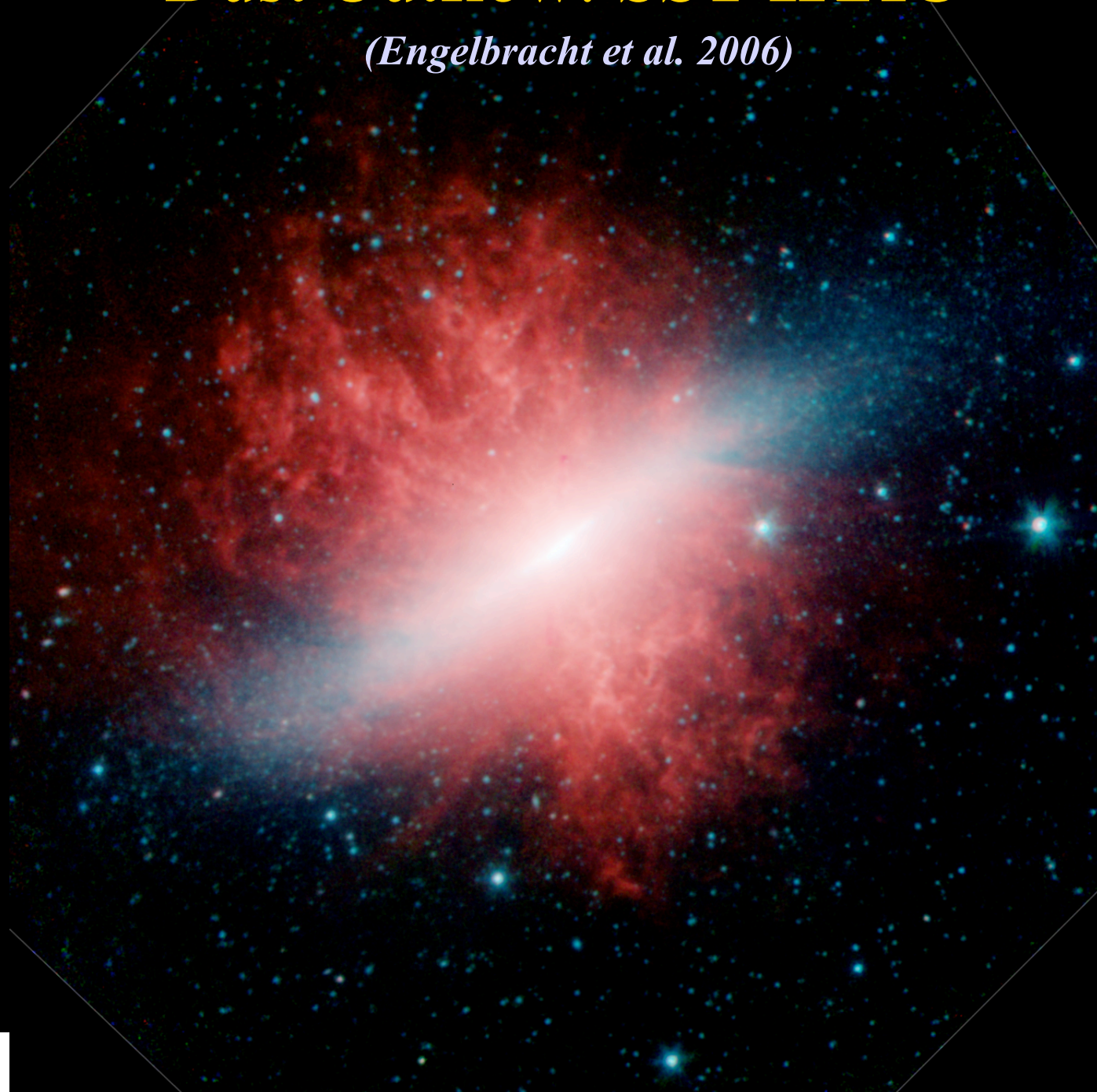
Warm Molecular Gas

*(SV, Rupke, & Swaters '09)*



# Dust Outflow: SST IRAC

*(Engelbracht et al. 2006)*



# Molecular Outflows

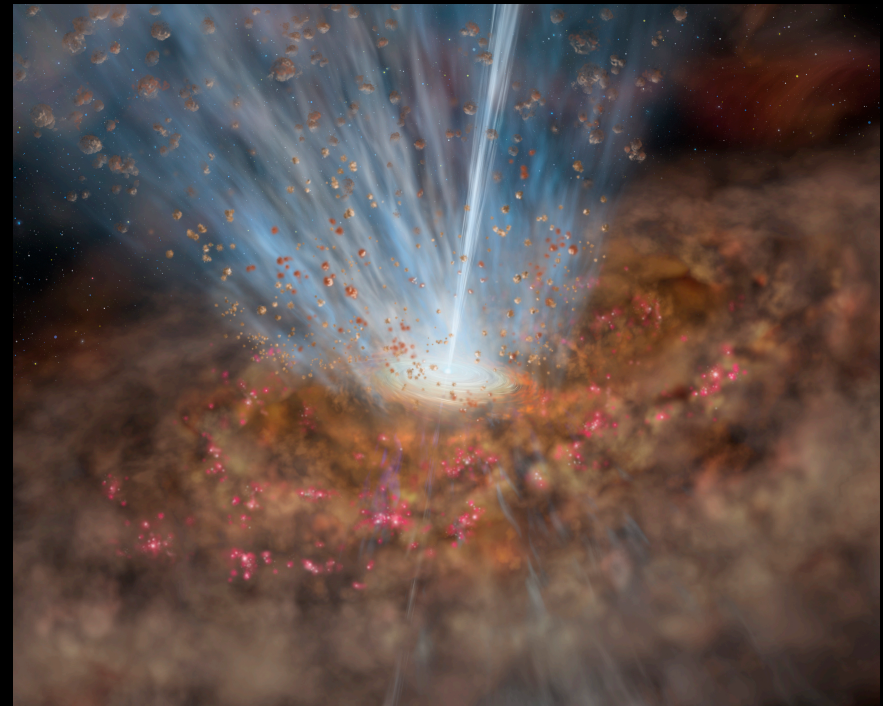
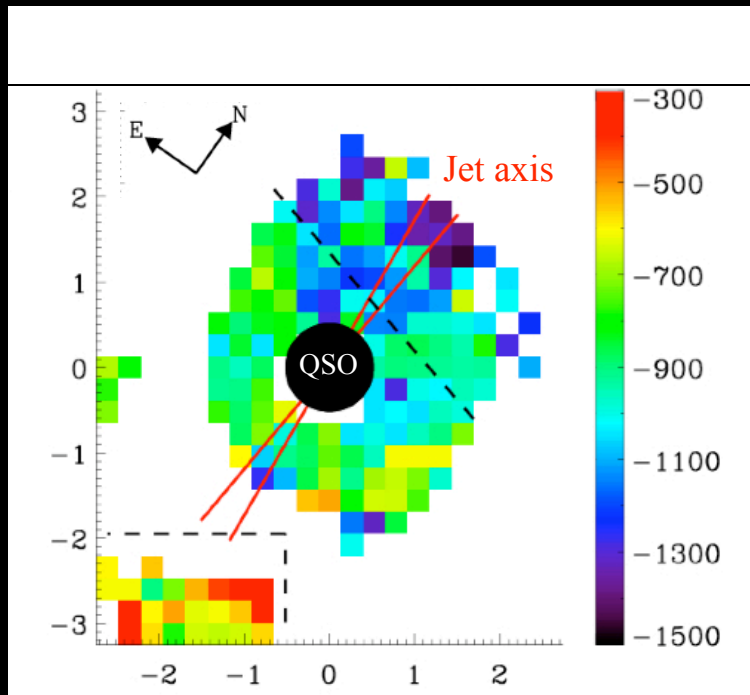
*(PhD thesis of A. McCormick)*

- *Spitzer* IRAC survey [on-going]
- Search for warm H<sub>2</sub> in local galactic winds from deep NEWFIRM imaging [Data already obtained]
- Very deep *Herschel* images on local galactic winds [NEW!]



# Powerful Quasar-driven Wind in Mrk 231

(Rupke & SV 2011)



*Gemini Press Release*

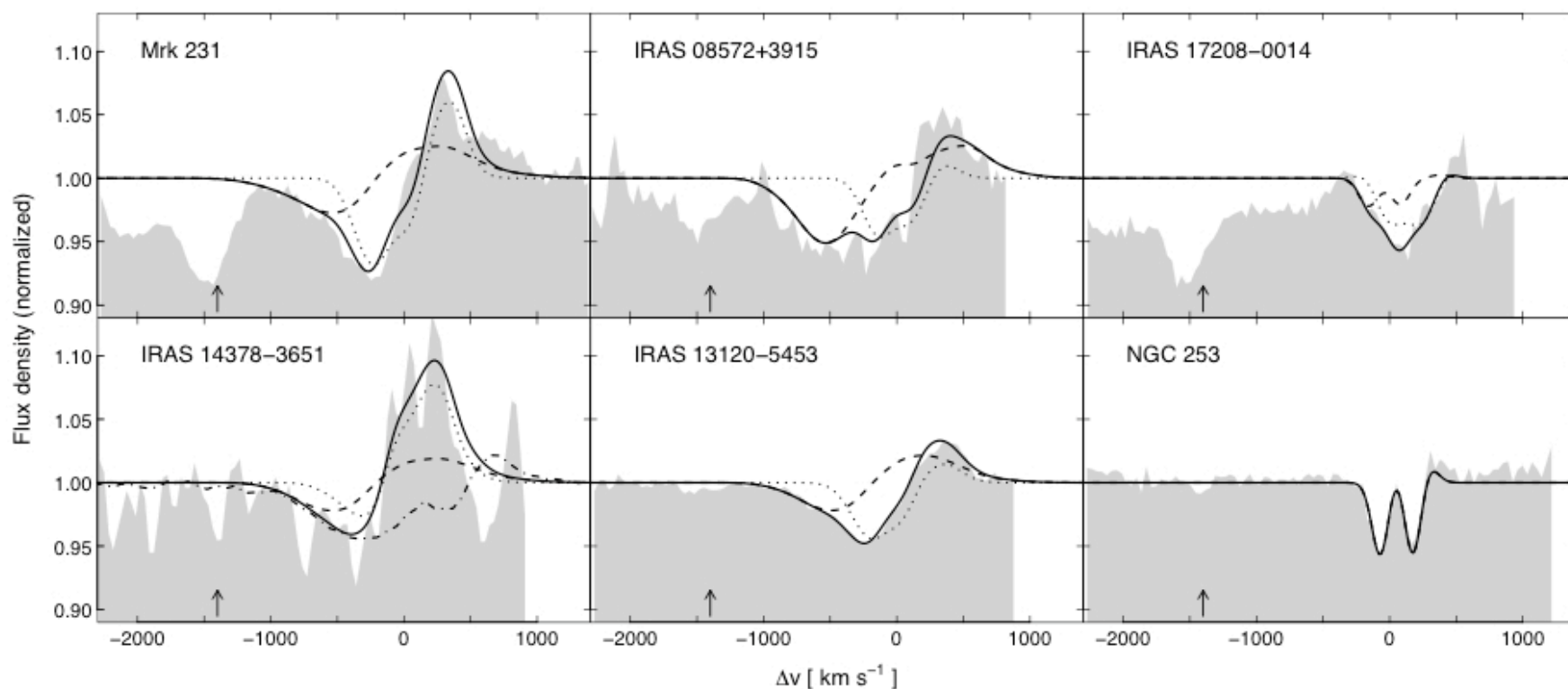
- Gemini/IFU: Na I absorption
- $V_{out} \rightarrow 1100 \text{ km s}^{-1}$
- $> 2\text{-}3 \text{ kpc}$  from nucleus
- $dM/dt > 400 M_{\text{sun}} \text{ yr}^{-1} \sim 2.5 \times \text{SFR}$
- $dE/dt > 10^{44} \text{ ergs s}^{-1} \sim 2.5 \times dE_{*}/dt \sim 0.7\% L_{\text{AGN}}$

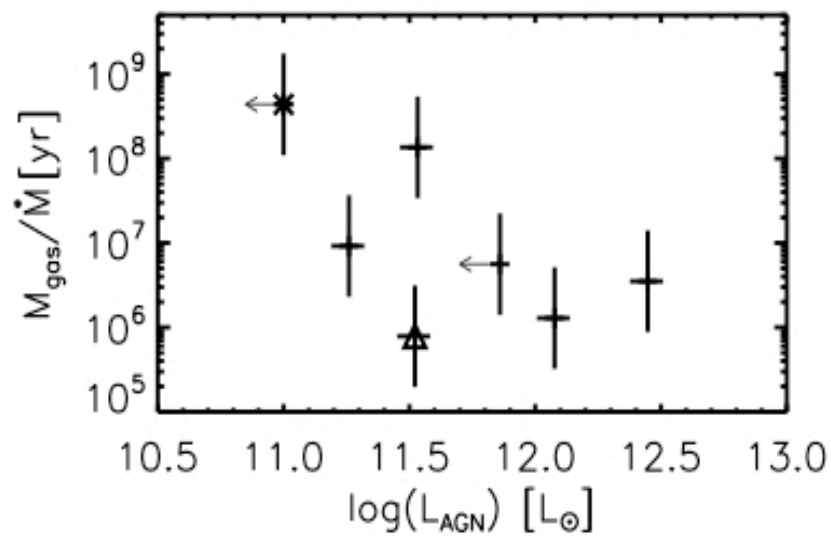
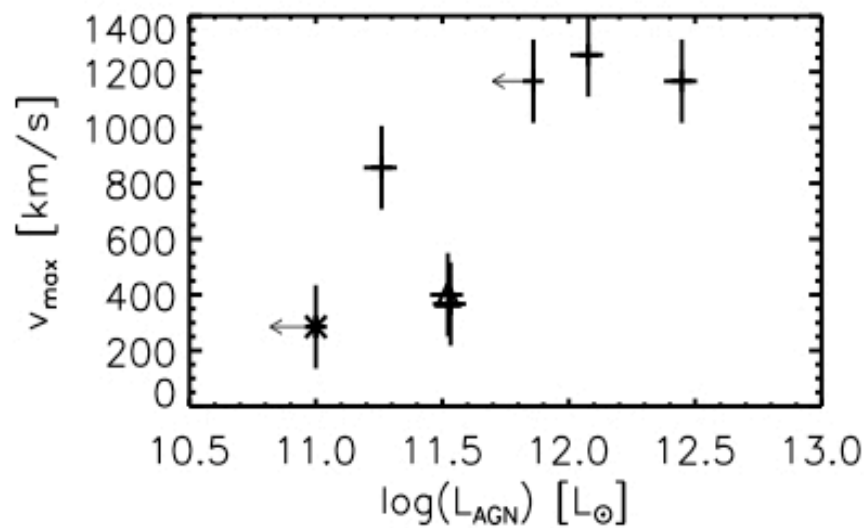
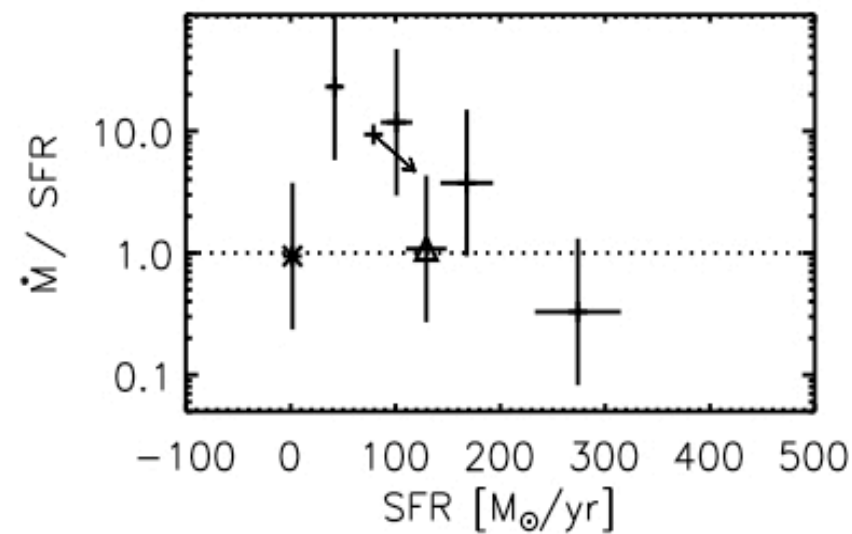
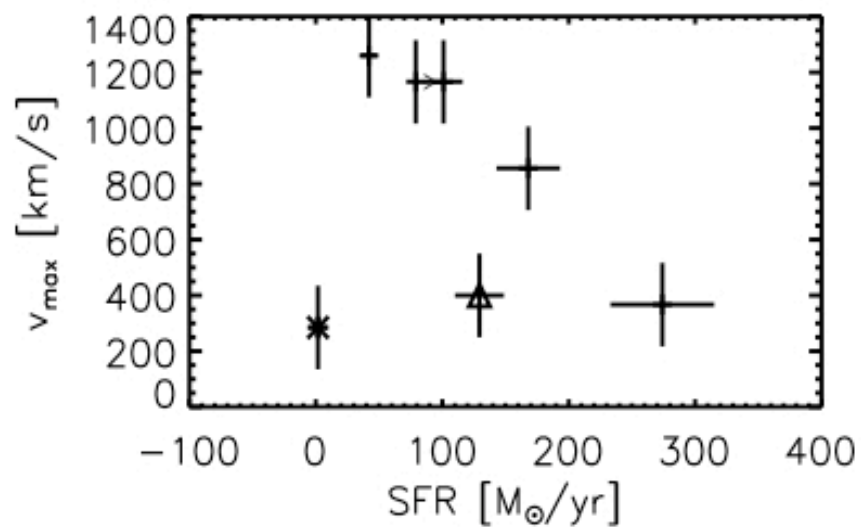
**Consistent with QSO feedback models**  
(e.g., Hopkins & Elvis 2010)

# Massive Molecular Outflows in ULIRG/QSOs

*(SHINING: Sturm et al. 2011)*

Herschel/PACS spectra of OH 79 / 119  $\mu\text{m}$  transitions: P-Cygni Profiles







# Discovery Channel Telescope

First Light: Spring 2012

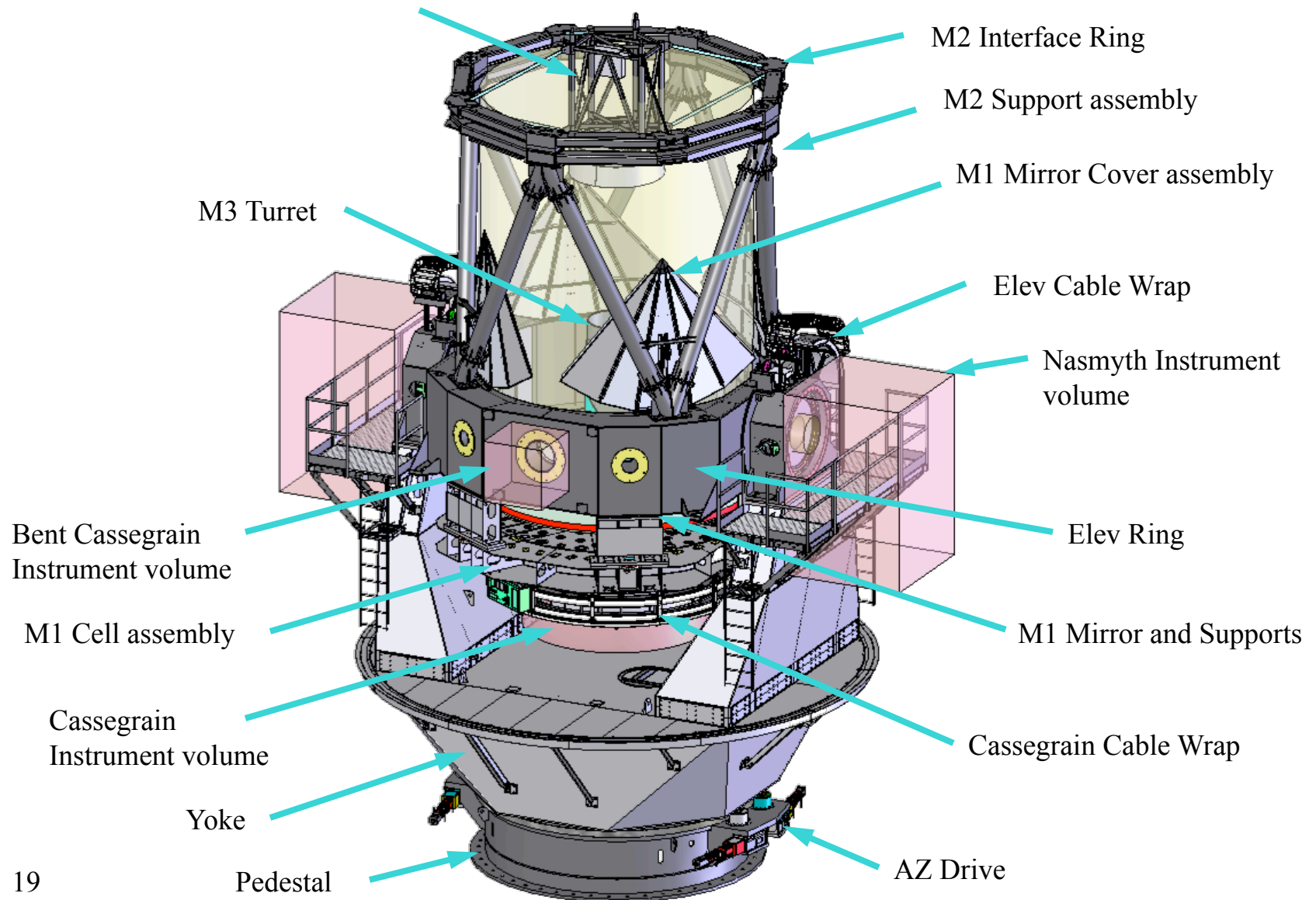


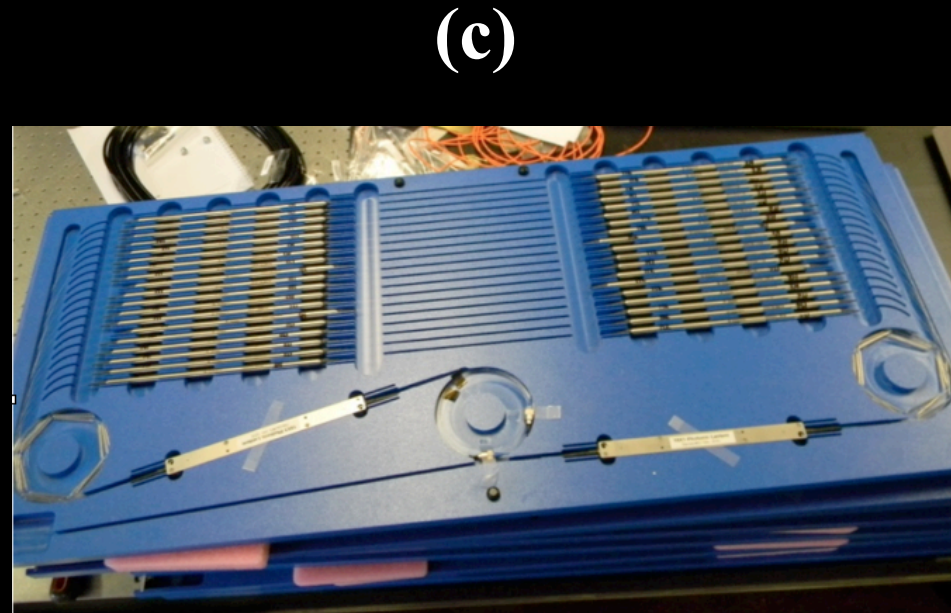
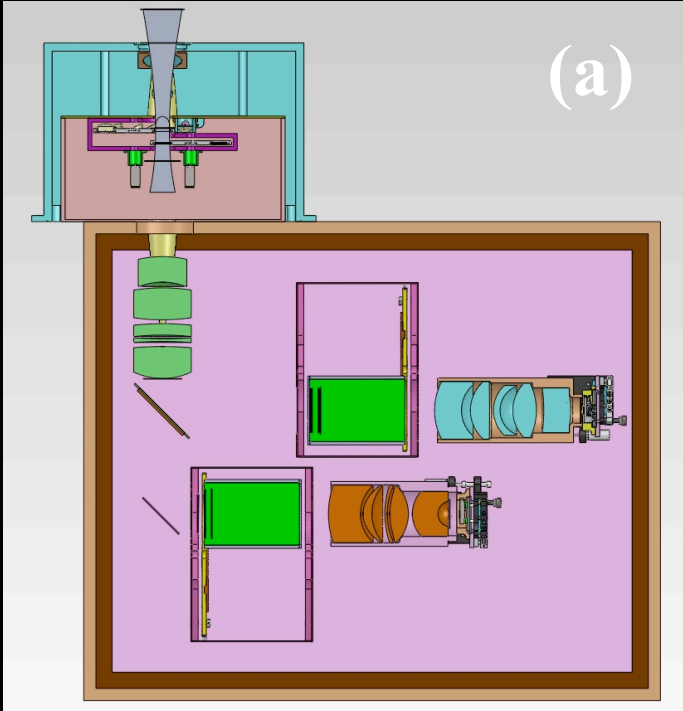
First Science: ~Fall 2012



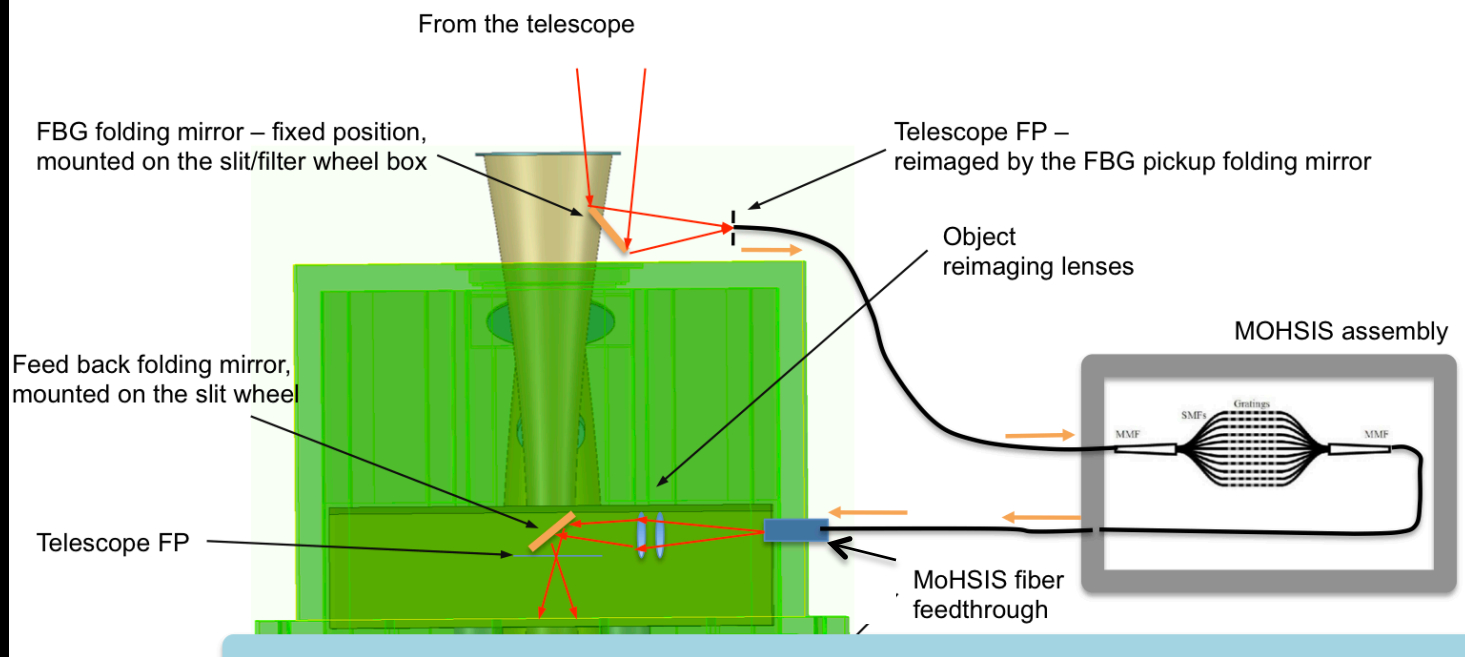


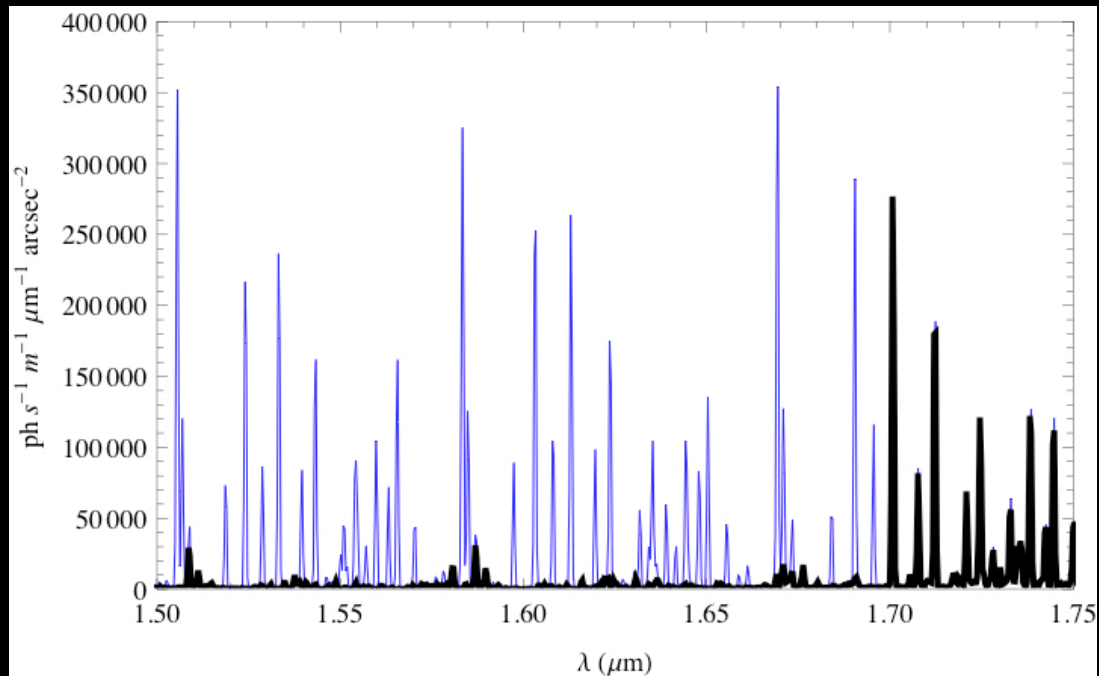
# Discovery Channel Telescope



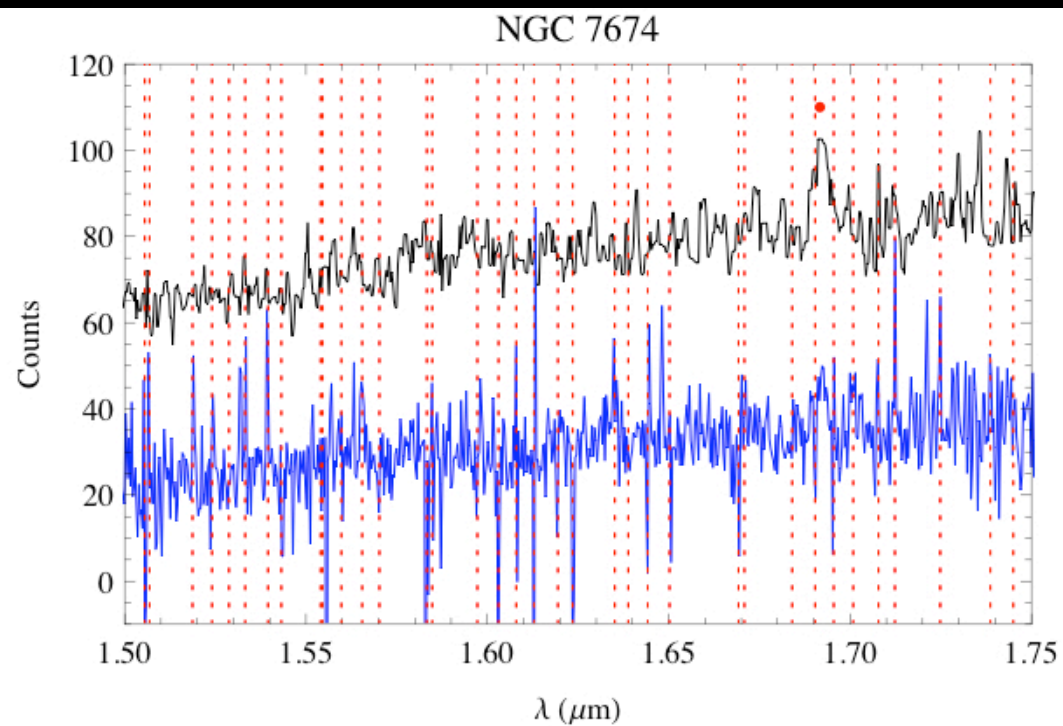


(b)





# The Magic of Astrophotonics!



# Possible Second-Year Research Projects

- Galactic winds with
  - Herschel (FIR spectroscopy; *on-going + proposed*)
  - HST (UV spectroscopy; *on-going*)
  - Mayall 4m telescope (optical spectroscopy; *proposed*)
- Instrumentation for DCT
  - RIMAS = Rapid IMAger-Spectrometer (*on-going*)
  - Astrophotonics → OH Suppression with RIMAS (*proposed*)