IT IS MY GREAT HONOR

To be standing in for

TIM HECKMAN

Why is he the perfect rapporteur (and so well-liked?)

He's genuinely interested in everything that's going on (and how they may be connected)

But he's not easily conned

The Most Exciting Extragalactic Science in the Next Decade Requires…
a Large FIR Space Telescope

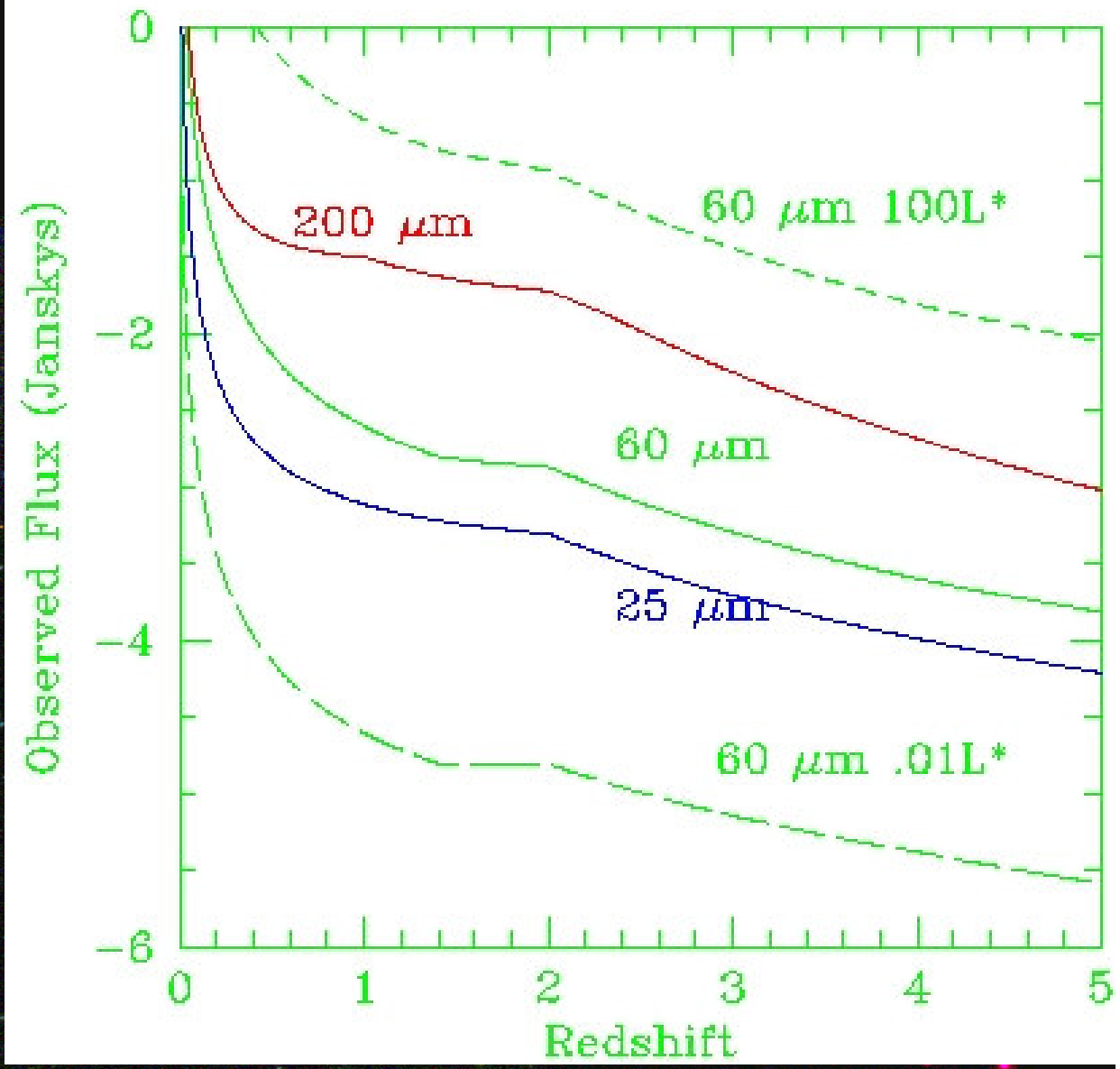
Hercules Deep Field, Colbert et al

Planning Space Missions reminds me of…

- Planning was essential before D-Day (and then worthless once it started)—Genl. Eisenhower
- Q: Why is the White House like Heaven?
- A: Lots of people are always talking about it, who aren't necessarily going to end up there.

Reach ***Highest Redshifts*** in the Far-Infrared/Sub-mm, because of negative K-corrections

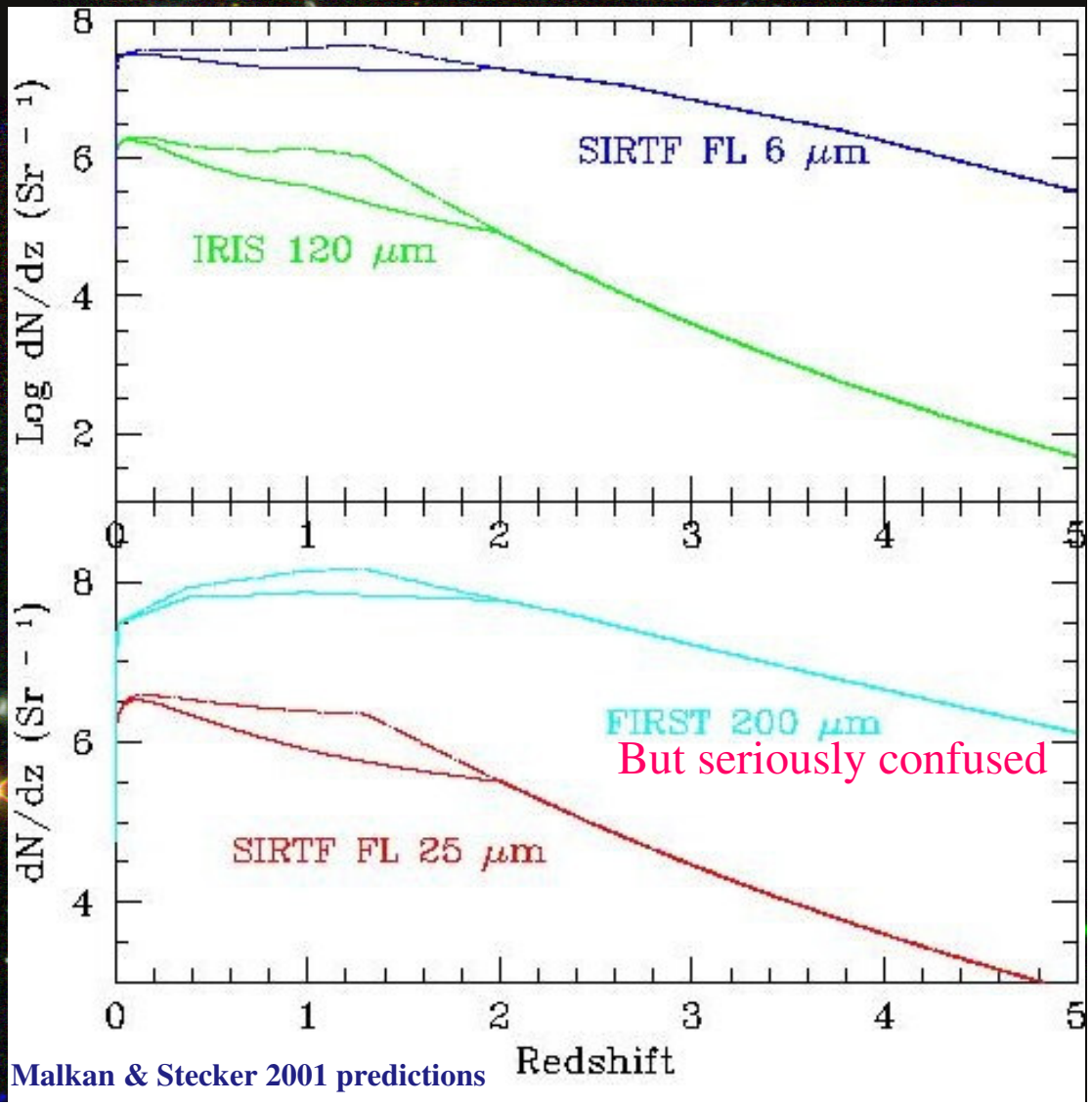
On a Clear Day, You Can See...Almost Forever, since that is where galaxy energy outputs peak



Malkan and Stecker 2001 model predictions

Needed: Deep IR Field Surveys + Redshift Estimates

- As mentioned by Martin W and Mark D, Herschel will have tremendous cosmological "reach": very high surface densities of z>2 galaxies will show directly how the their LF evolves, even when very dusty
- Frayer poster has beautiful 70um maps with best ever number counts: "Confusion" (8 beams/source) is 2.5mJy, in 3hrs integration



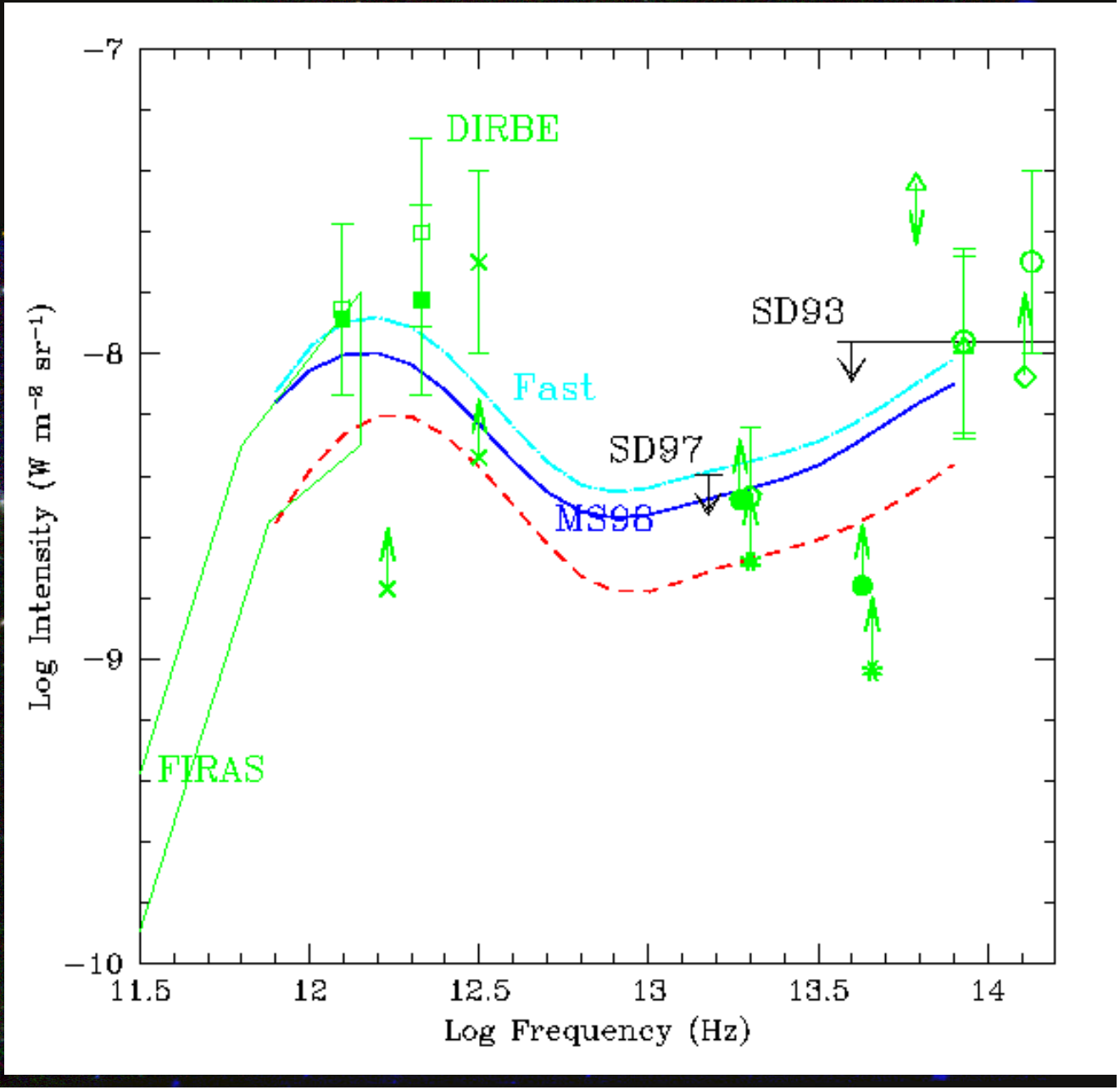
Malkan & Stecker 2001 predictions

Strong CIB detected, mostly COBE

FIR Peak comparable to O/NIR peak
→globally, dust must have absorbed almost half of all *stellar* photons:

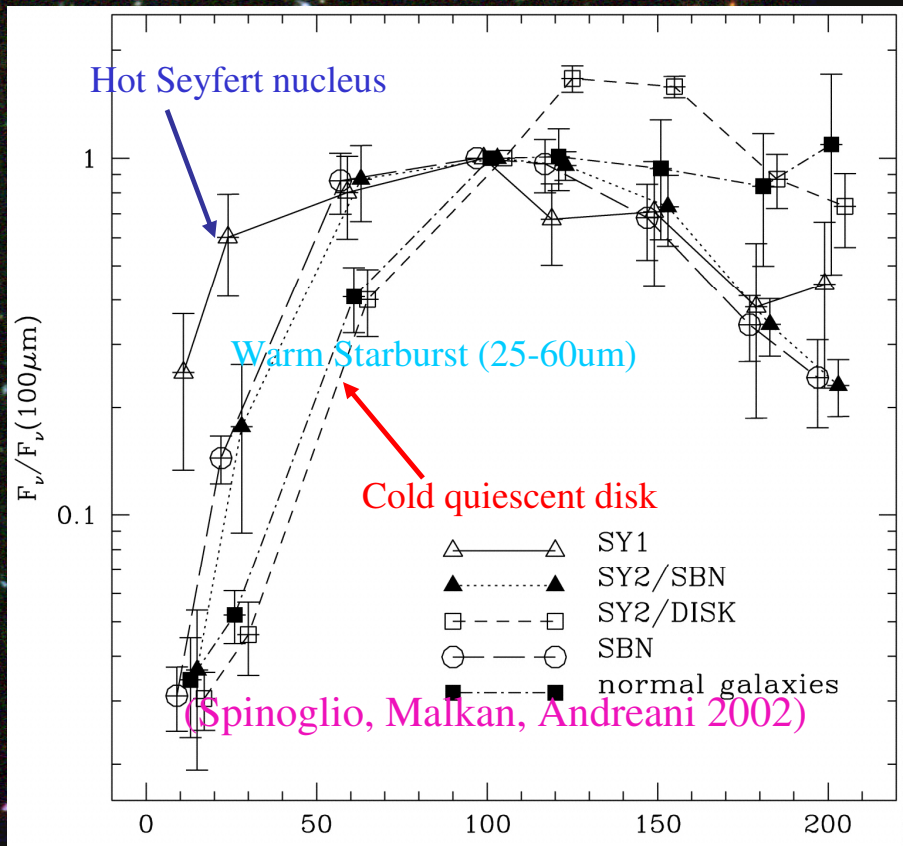
We can't understand energy production in the Universe if we don't observe half of it

MODELS, from Malkan & Stecker, with L(IR) ~$(1+z)^{3-4}$, most emission from $z<\cong 1$
versus (green) observations



You do NOT know the bolometric luminosity of any galaxy until you get photometry out to 200um, past its peak

- Mark D: 24um observations don't nail down LIR
- Rigby poster: "ULIRGs" at z=1+ may be quite different from local ULIRGs, not necessarily compact/buried star formation driven by mergers
- Seyfert 1's have much hotter dust (nuclei dominate at 12--20um),
- but Seyfert 2's can resemble (moderately warm) starbursts *or* normal disk galaxies
- AGN gives NO CONTINUUM SIGNATURE longward of 60um



FIR offer limited morphological info fuzzy "Baby Pictures" of Galaxies:

They are cute, make great NASA publicity,

but have limited astrophysical information

Astronomical Discoveries are 10% Survey; 90% Follow-up

- IMAGING is great for SURVEYS, but
- WE CANNOT DO WITHOUT SPECTROSCOPY (colors and morphologies are not enough!)

- Most science comes from multiple line RATIOS, so wide spectral range (up to a factor of 2) gives invaluable synergy
- SPICA spectroscopy gains 3 orders of magnitude over Herschel/PACS

Spectroscopy of *newborn* galaxies

- ISO-LWS and Spitzer/IRS confirmed our predictions (SM '92) of powerful diagnostic emission lines from 10μm to 158μm (almost 1% of bolometric luminosity)
- at Z=3--15, these are redshifted to 100—400um
- Martin W (Fig.1 in SM92) : Beautiful full range of I.P./n_{crit} diagnostic EFS lines, at all redshifts

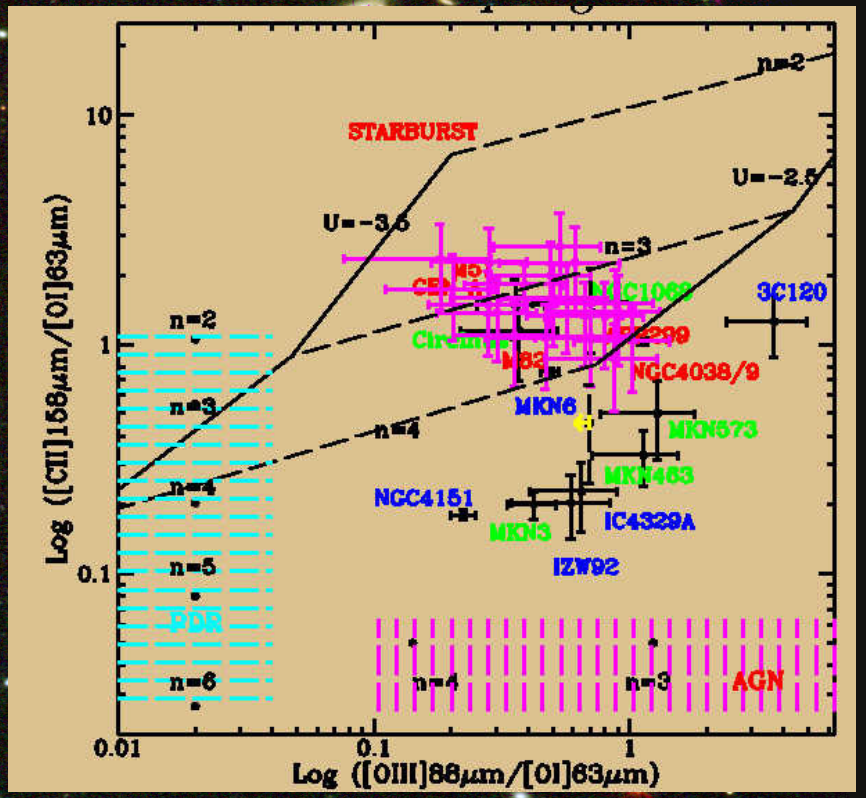
Strongest IR Lines give emission diagnostics

Models: quiescent galaxies are PDR-dominated, starbursts produce more O++, while Seyfert has O I from denser gas [MM et al]

More data: [Armus,Helou,Brauher poster] [O I]63um becomes dominant in (hotter) ULIRGs

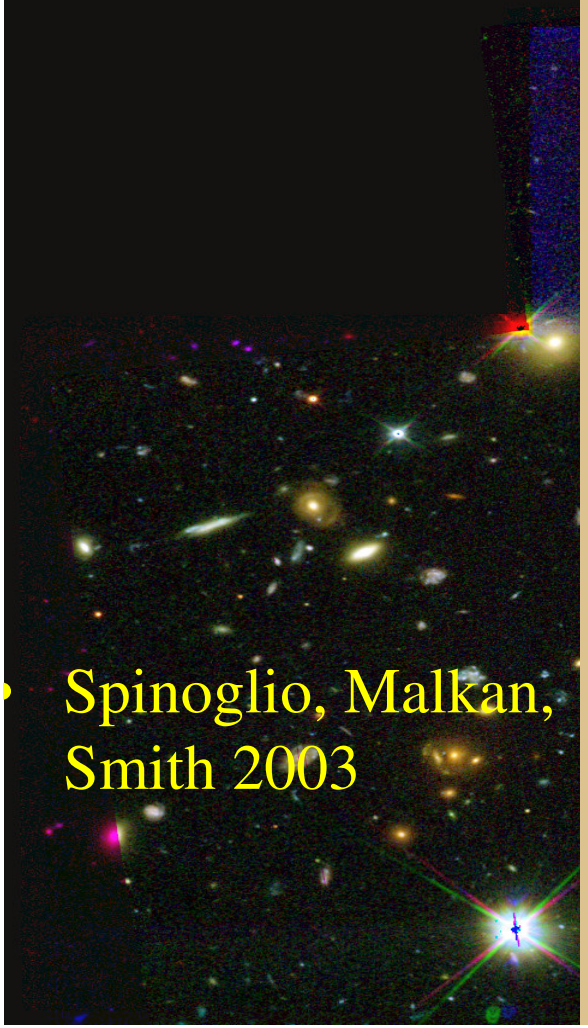
Better models: [Fischer poster, Tommassin et al 2008 ApJ 676, 836] FIR EFS lines sort out ionization level (AGN vs starburst): higher ionization parameter can explain "[CII] deficit"

[ALMA shouldn't bet everything on that line…]



Don't forget FIR molecules!

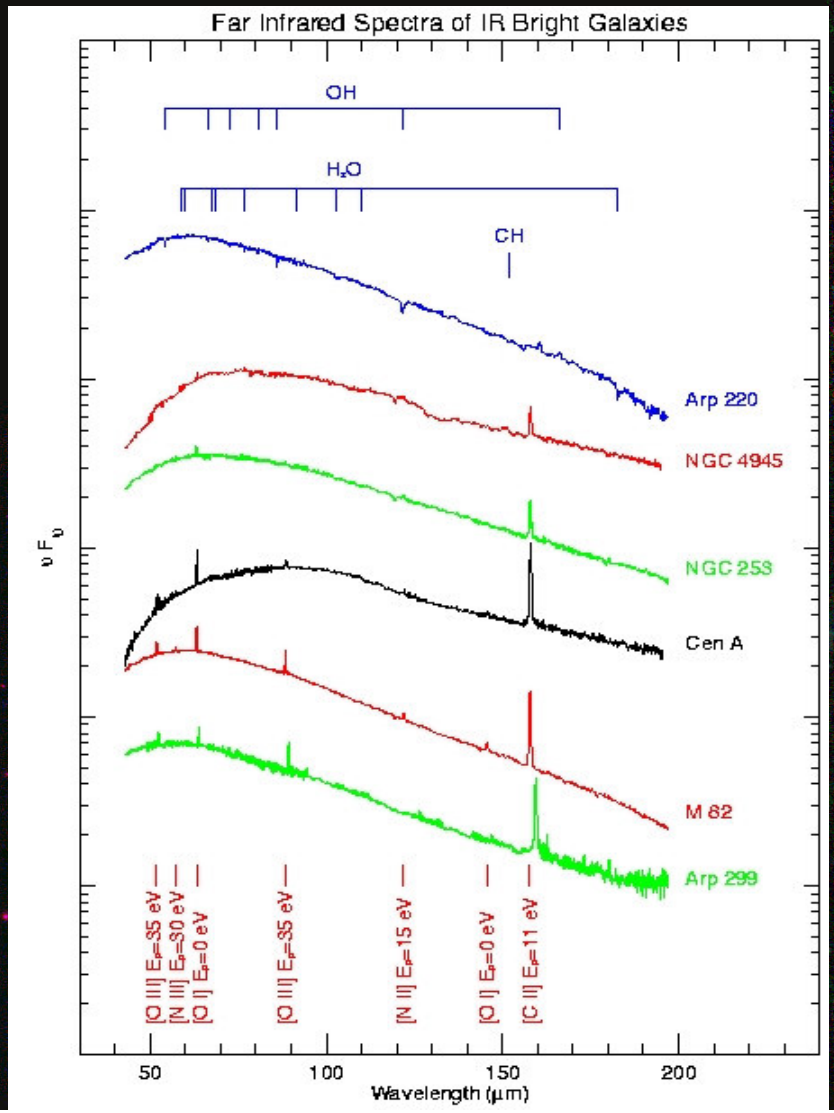
OH Lines in *Emission* only in the archetypical Seyfert 2 galaxy, NGC 1068!



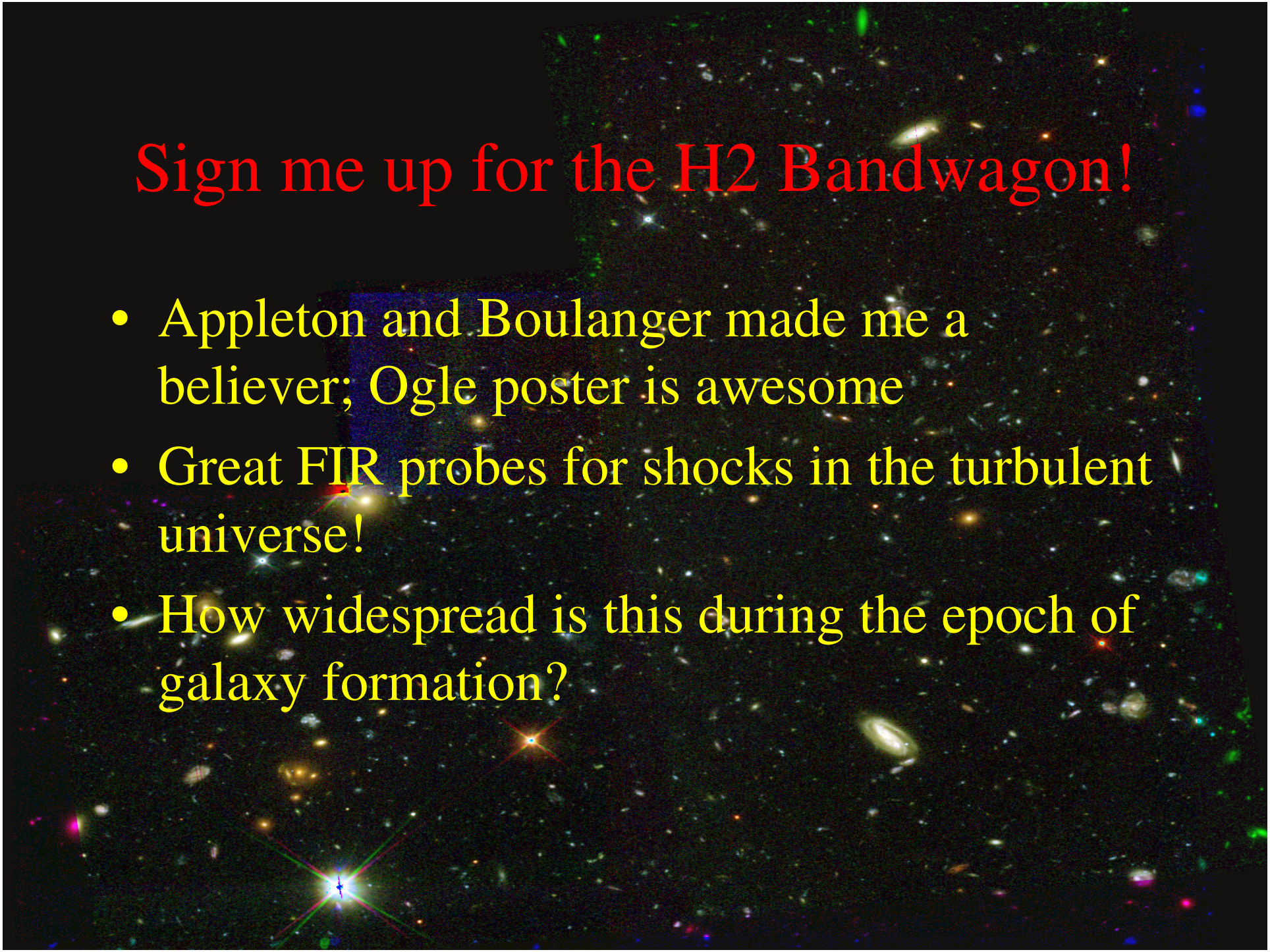
- Spinoglio, Malkan, Smith 2003

Line id.λ	Flux ($10^{-19} W cm^{-2}$) Observed	Modeled	Notes
34μm	$< .5$	-0.5	(absorption
48μm	...	0.12	
53μm	< 1.2	-0.4	(absorption
65μm	< 1.2	0.2	
79μm	0.80	1.10	
84μm	< 1.2	0.5	
96μm	...	0.3	
98μm	< 1.2	0.4	
115μm	...	.004	
119μm	1.20	1.31	
163μm	0.74	0.60	

Ultraluminous Infrared Galaxies May be Optically thick even in the mid-IR



- Some show FIR absorption lines, hardly any emission lines,
- But fortunately these show strong OH absorption
- (Fischer et al 2000, ISO LWS spectra)



Sign me up for the H2 Bandwagon!

- Appleton and Boulanger made me a believer; Ogle poster is awesome
- Great FIR probes for shocks in the turbulent universe!
- How widespread is this during the epoch of galaxy formation?

Many key parameters are not as well determined as you might think

- See Samir poster!
- Don't count on having photometric redshifts for everything (many filters needed at long wavelengths, and don't forget the DOGs, hot dust in AGN/starbursts kills the 1.6um bump)
- Currently tremendous uncertainty in numbers of UV-selected galaxies at z=6+
- 4—5x "correction" for dust extinction (from UV slope) Extinction corrections (and reddening "laws") are very rough guestimates, expect lots of cosmic variance

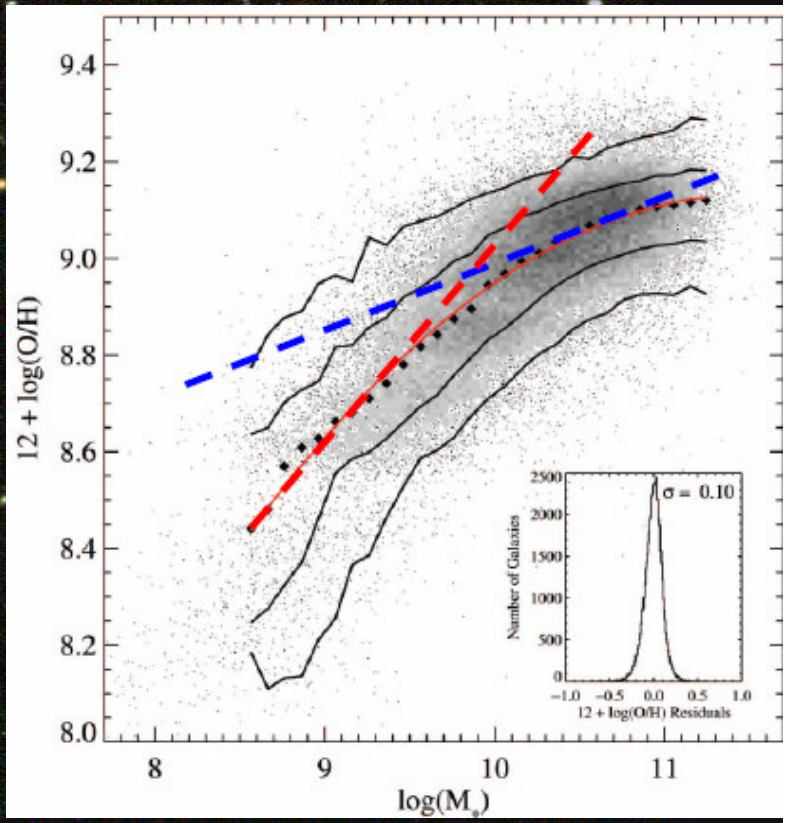
- Star formation rates from UV continuum, emission lines, dust continuum
- Can we reconcile SFR(z) with Stellar Mass(z)?

How much energy in the Universe came from fusion versus accretion?

- Locally difficult to answer because of:
  - Extinction (absorbs shorter wavelengths)
  - Reprocessing (original continuum re-emitted by dust and gas)
- All difficulties become much worse as z>1 (where most of the action is)

Gas Phase Abundances at High Z

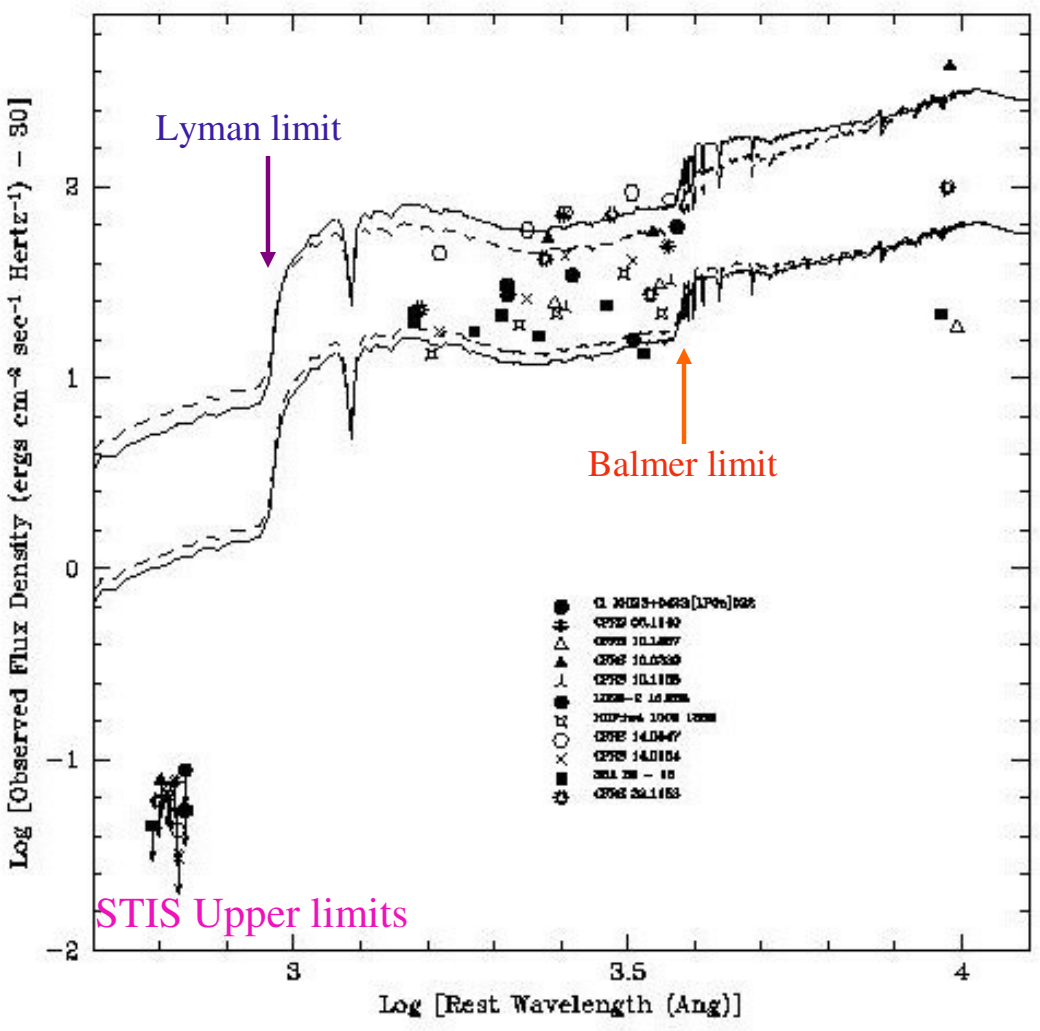
- Cannot use strong Far-UV ISM absorption lines: since they are totally saturated their strength depends mostly on velocity range
- Curve-of-growth analysis of Equivalent Widths in Damped Lyα Absorbers (in front of background quasars) {these are *not* "*galaxies*"}



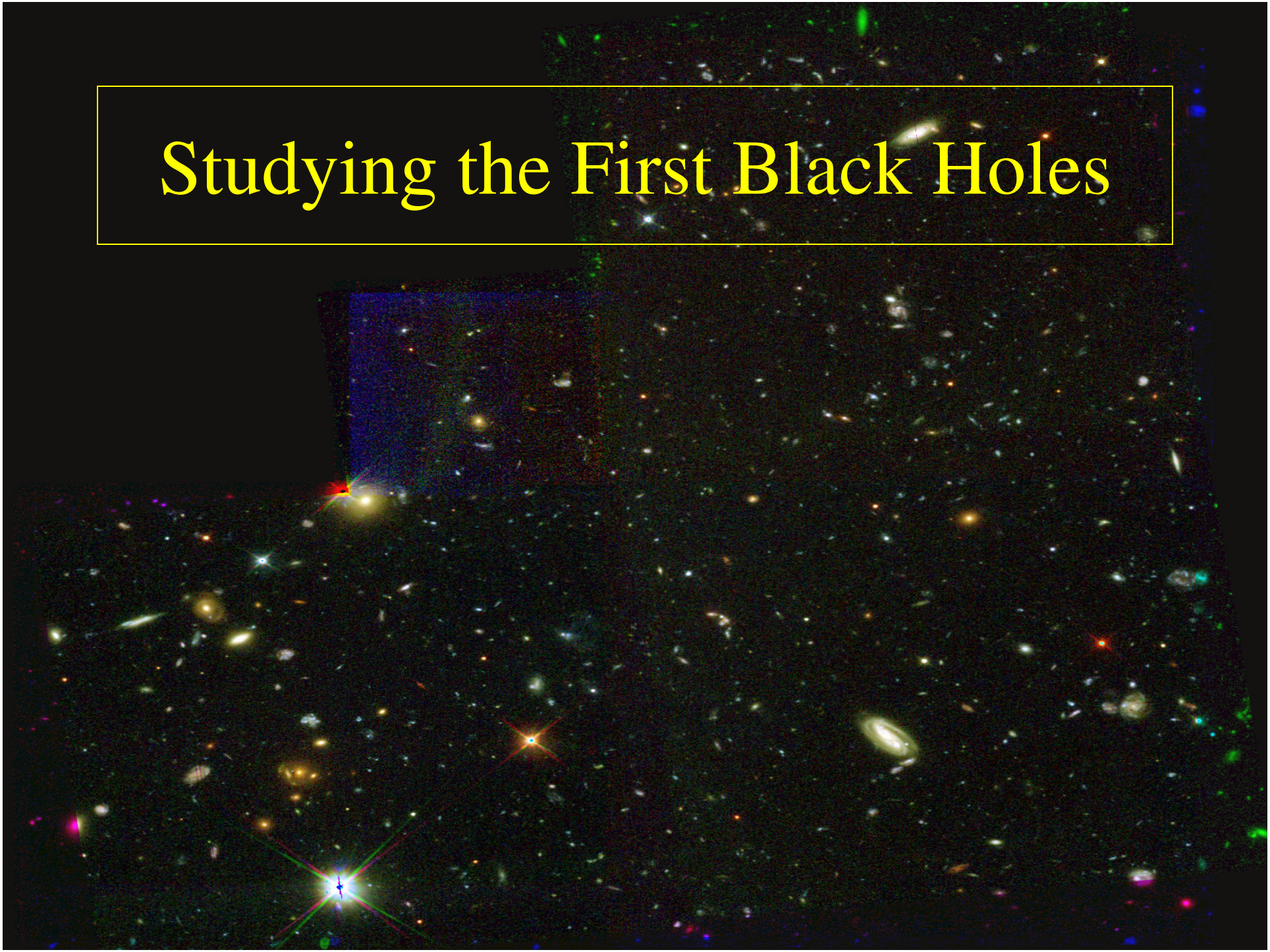
What ionizes the Universe, at all redshifts?

- AGN completely *dominate the ionization of the IGM*, now and at all epochs (STIS FUV MAMA deep imaging of 11 z=1.5 starburst galaxies:

Malkan, Webb & Konopacky (2003)



Studying the First Black Holes



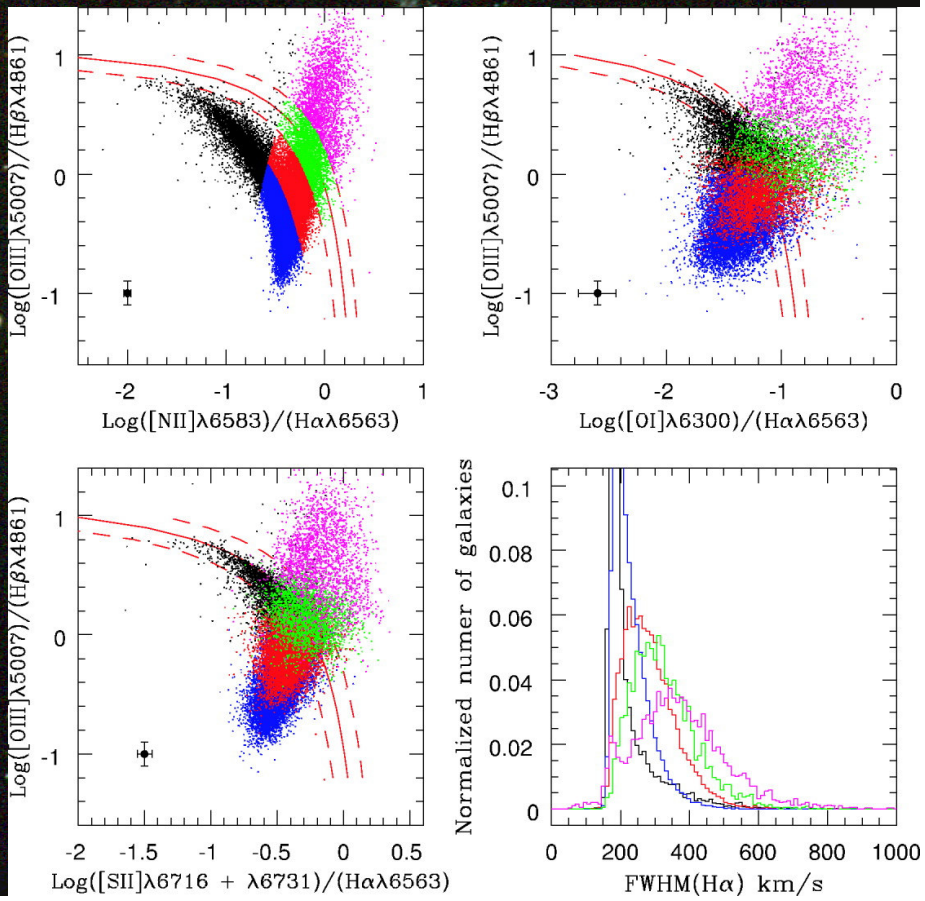
"No bickering rule", but…

How to find/ determine energy output of "Obscured" AGN?

- Can't rely on Hard X-rays for very Compton-thick (10^{25} cm^{-2}) nuclei (buried Sy1's, most Sy2's not generally detectable, except maybe via Fe Ka 6keV line, or scattering)
- Even when detected, HX cannot (in general) predict the rest of the spectrum to better than a factor of 10 (because in some quasars, X-rays are <few% of bolometric luminosity)
- So we're going to the DOGs [Desai Poster]

Best developed Accretion indicators are "narrow" forbidden lines

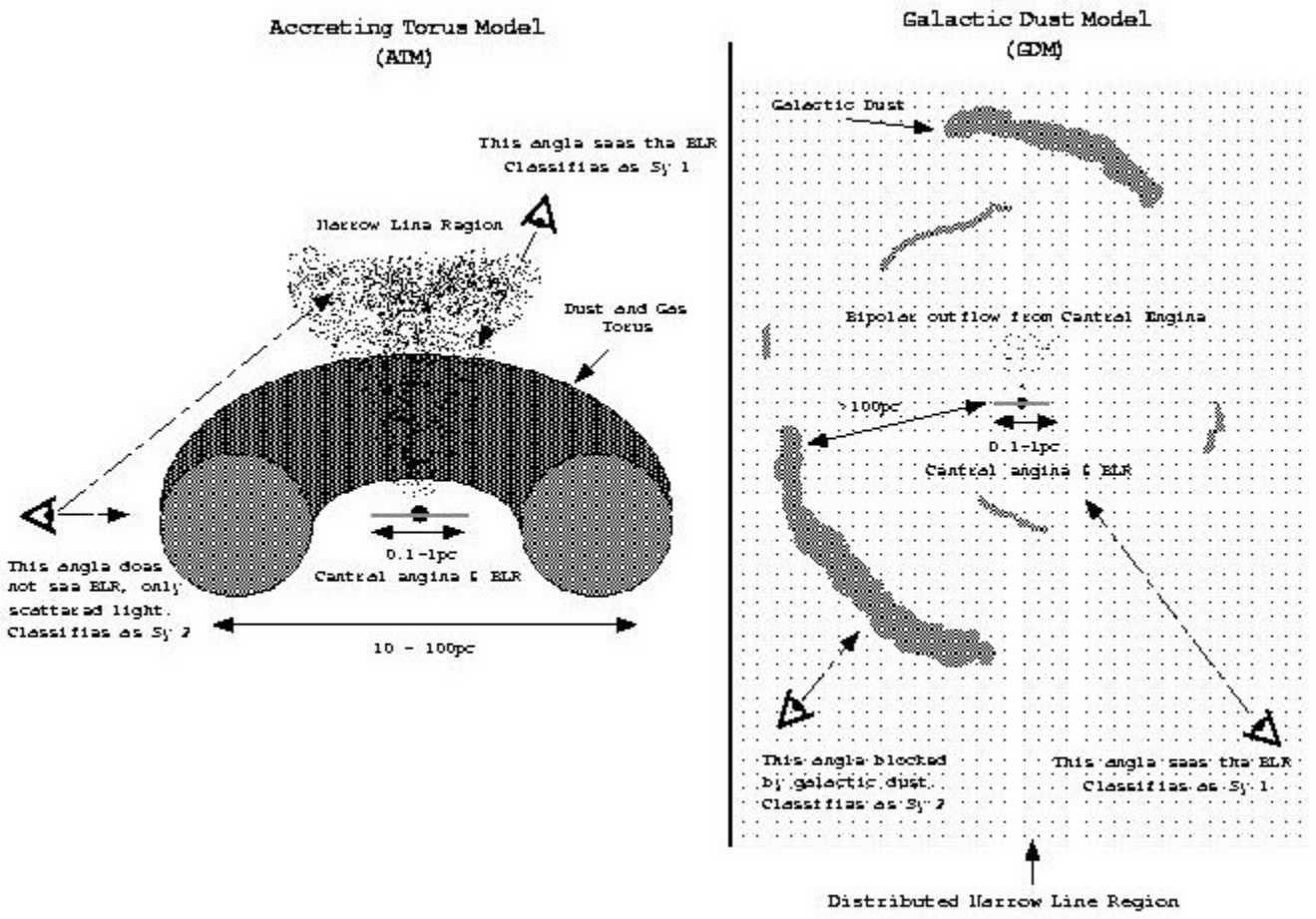
- Since they arise 100's of parsecs from the nucleus, but are photoionized by its high-energy spectrum, they are good tracers in obscured Sefyert 1's and Sey 2's
- Mid to Far-IR EFS lines are producing equivalent extinction-independent "BPT" classification diagrams
- Petric ULIRG spectra poster shows how we are heading to an IR BPT diagram, with FeII 26um as a shock diagnostic
- Warning: not all AGN have much of an NLR (extreme Eigenvector 1



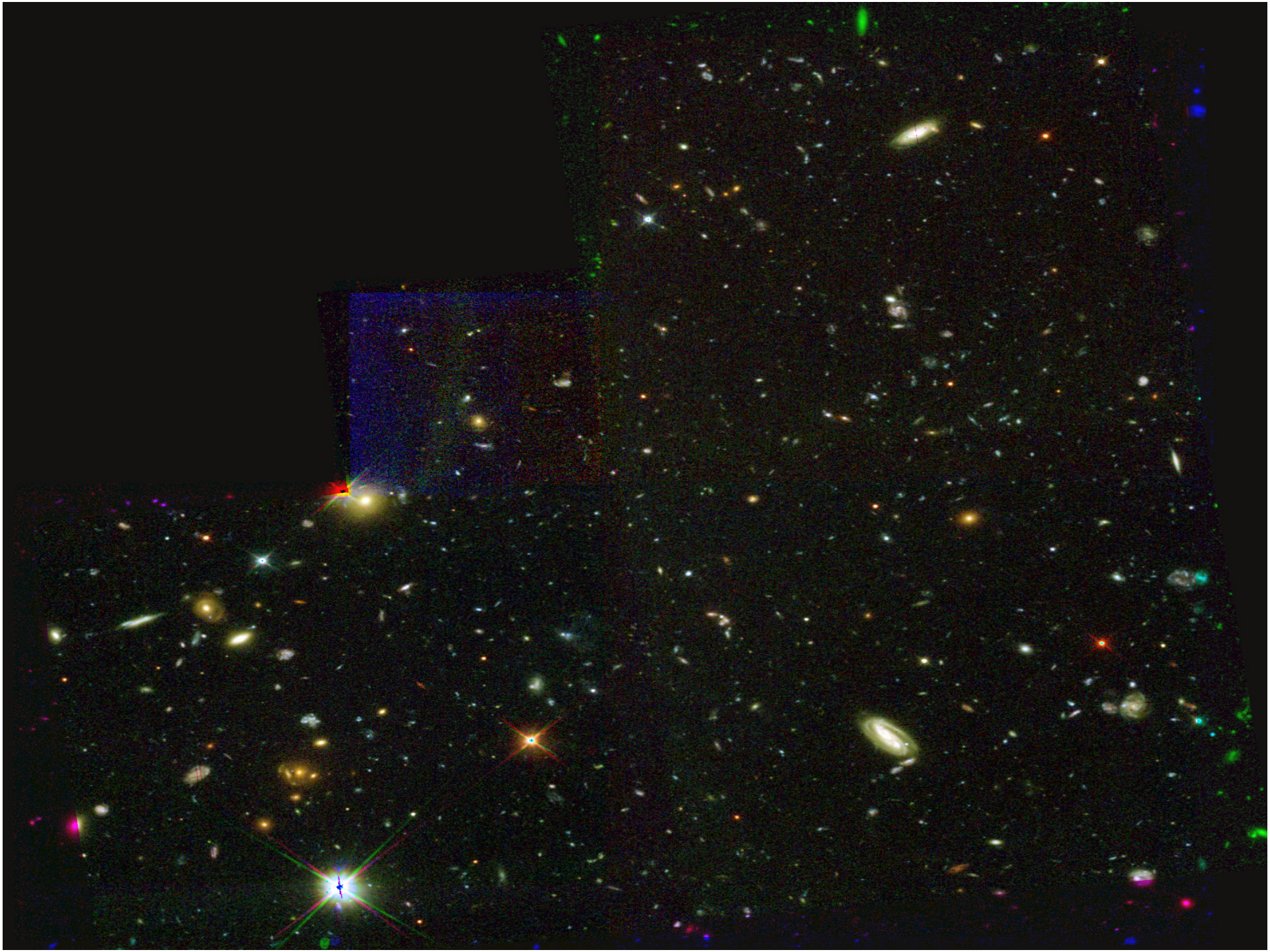
Will we ever detect a "torus"?

Malkan and Spinoglio 1989; 1992 found similar Luminosity Functions for Sy 1 and Sy 2 in our 12um Sample

If the difference is simply obscuration, we still do not know where it occurs!



Malkan et al 1998 WFPC2 imaging survey



What Spectral Resolution will we need?

- R(effective) of 50 (NICMOS Grism) was useable for surveying strong lines (mainly Hα)
- R~ few hundred (WFC3) is a minimum for measuring lines redshifts and ratios
- R~1000 is good for galaxy-wide properties, clusters and interactings
- R~2000-4000 for dynamics inside galaxies

Don’t forget the broad continuum features!

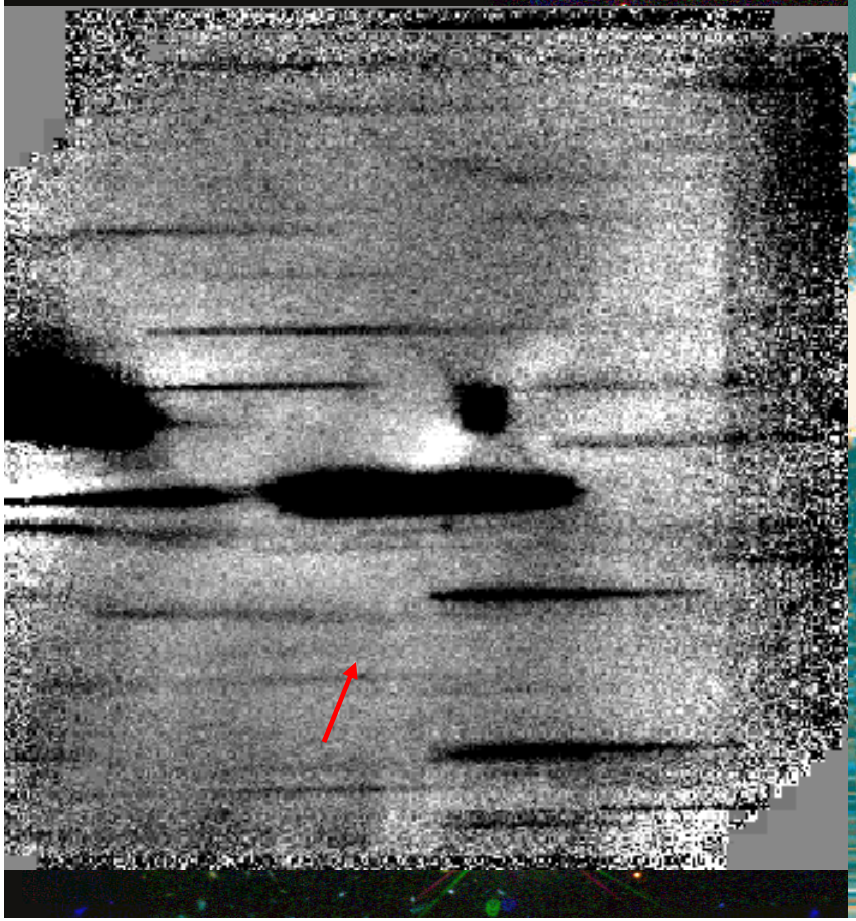
- PAHs are powerful, also Silicate (emission or absorption, see Gorjian poster!) and ICE absorption [see Petric poster!],

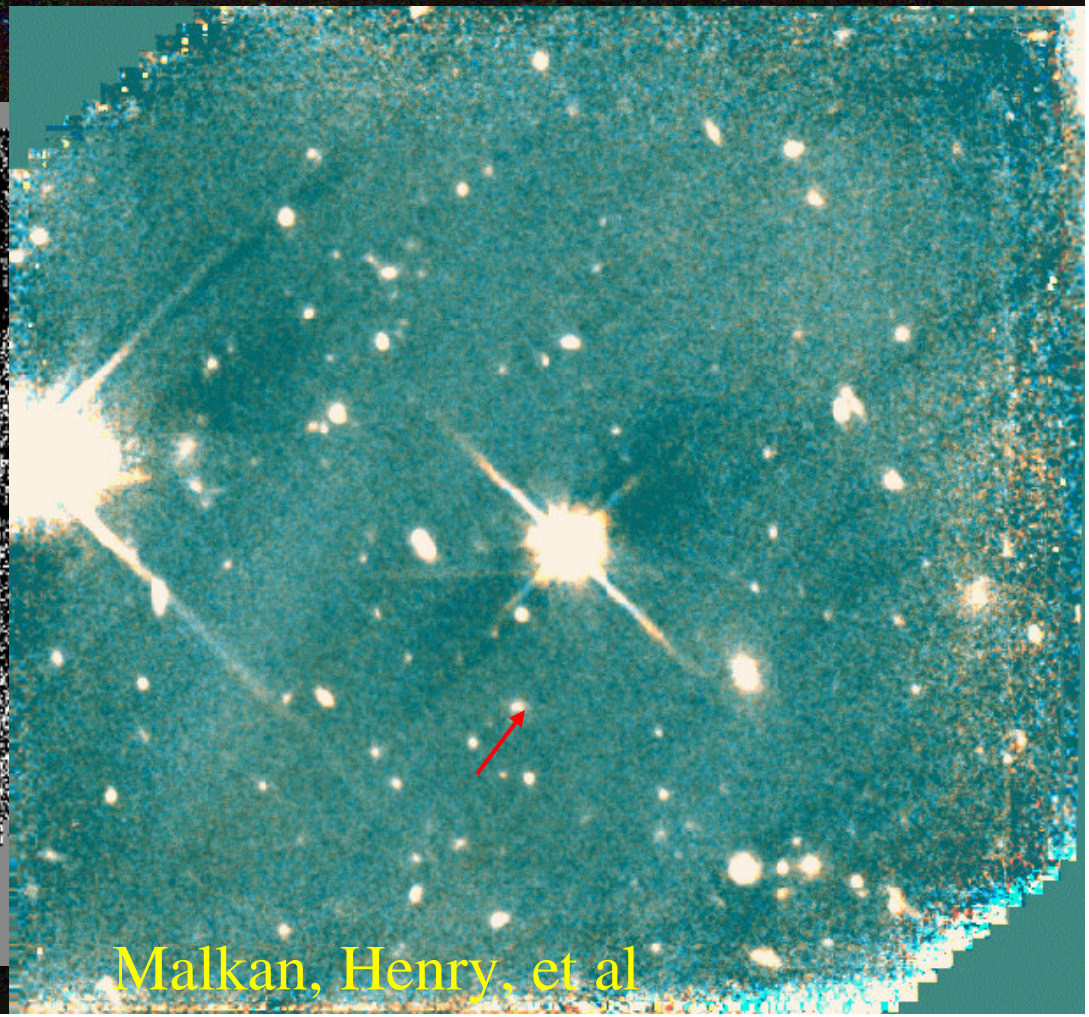
all shifted to FIR at reionization z’s

NICMOS Grism Parallel Survey

- Showed R~50 was "good enough" to find ~100 line emitting galaxies, mostly Ha in the "redshift desert"

Need to resolve confusion limit
Emission lines solve this problem





Malkan, Henry, et al

Need R>1500 for resolving lines

- See Dasyra poster, using [NeV] and [OIV] line widths to guestimate Mbh, since they probe the galactic bulge potential
- We'll know how this works in next 5 years…

What Can we Expect in 2010—2020?

- Acronyms will have gotten COOCy
  (Completely Out Of Control)
- We'll need to add more shocks and turbulence in our grad courses (even though they'll complain)
- We'll search for the first frosted mini-haloes
- ~One Third of the most exciting work will still be getting done by GR