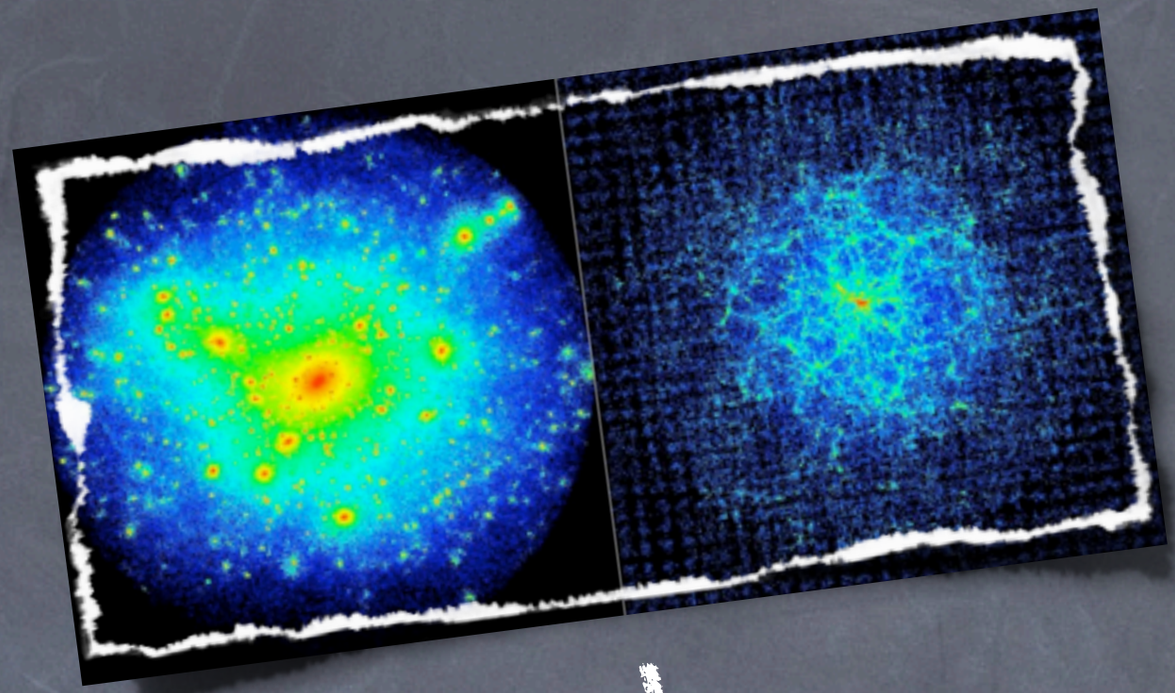
# SED modeling of galaxies in simulations

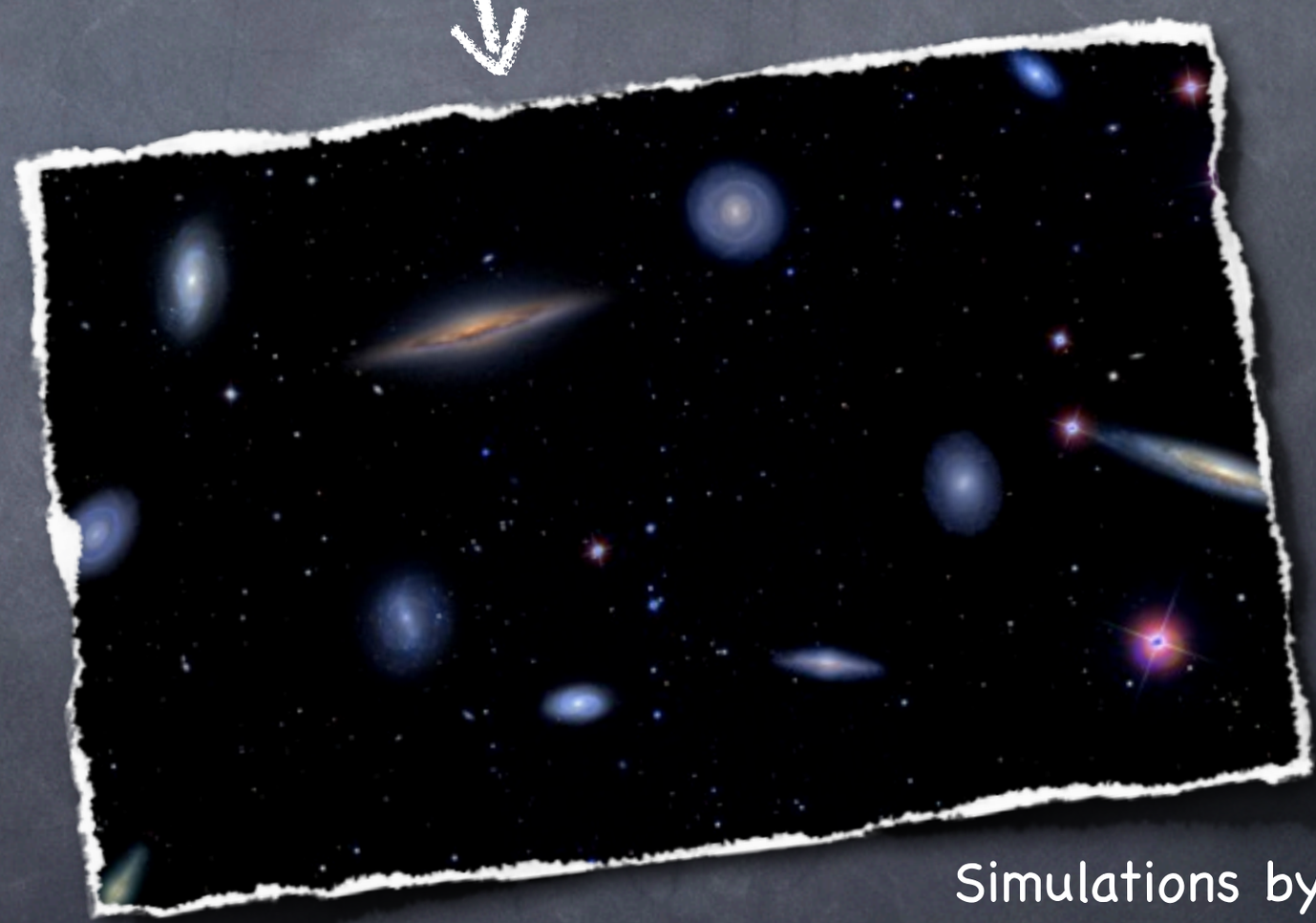

Patrik Jonsson

Harvard-Smithsonian Center for Astrophysics

+Chris Hayward, Brent Groves, TJ Cox, Greg Snyder, Lars Hernquist

What controls the SEDs of galaxies?



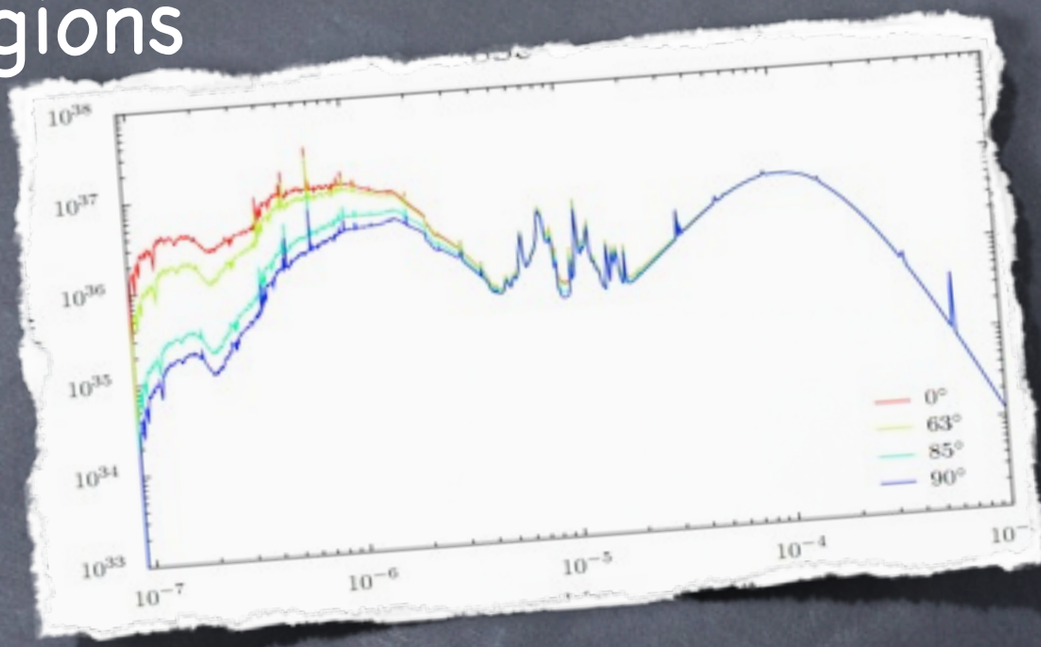


Use hydrodynamic simulations and radiation transfer to investigate

Simulations by the N-body Shop (U. Washington)

# What goes into a galaxy spectrum?

- Stellar (continuum) emission
- Emission lines from HII regions
- Dust & PAH emission
- AGN emission

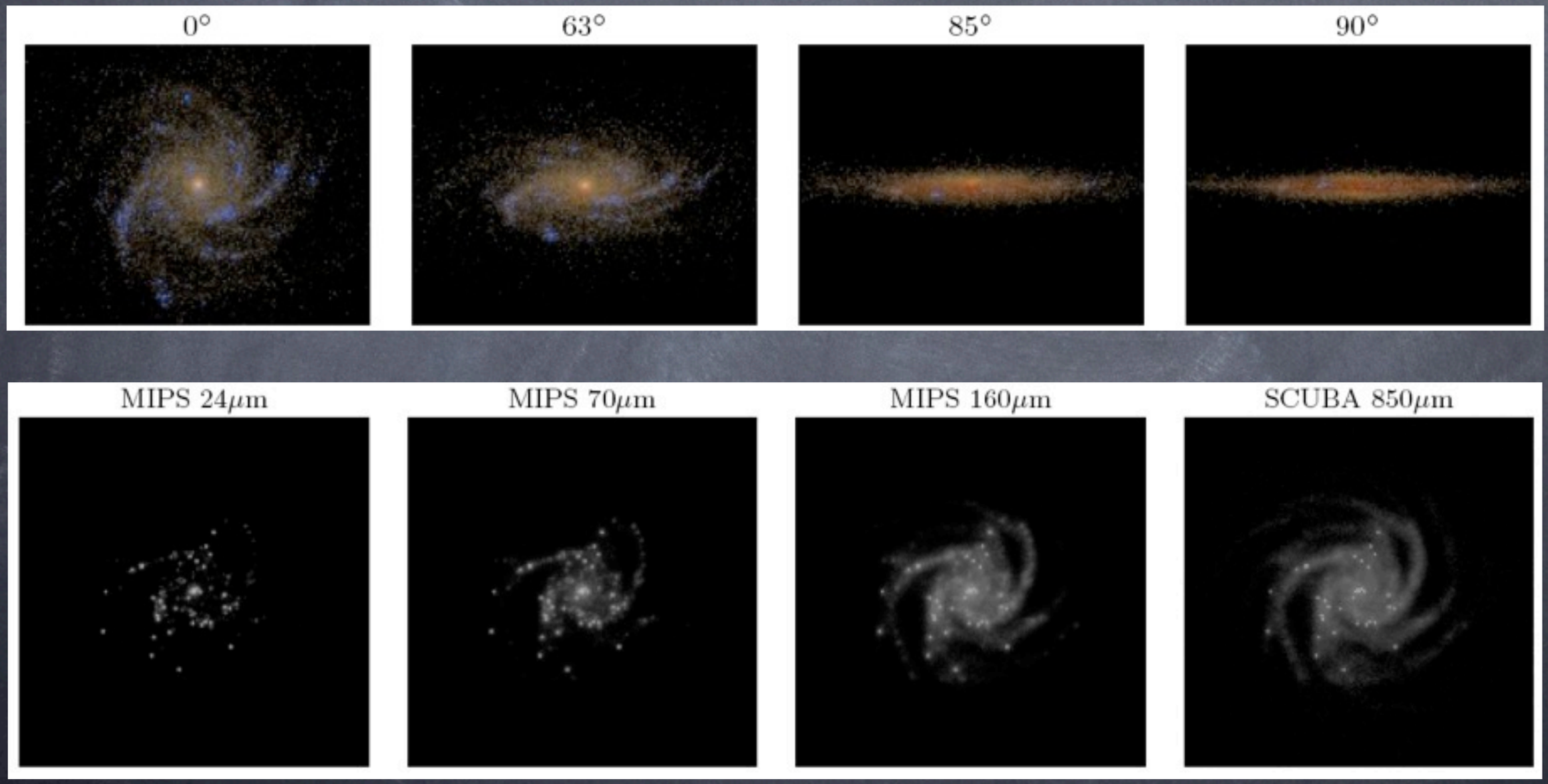



- Use radiation-transfer code **Sunrise** (PJ 06)

  Far-infrared emission is an interplay between dust emission and self-absorption, plus IR emission from AGN and SF regions

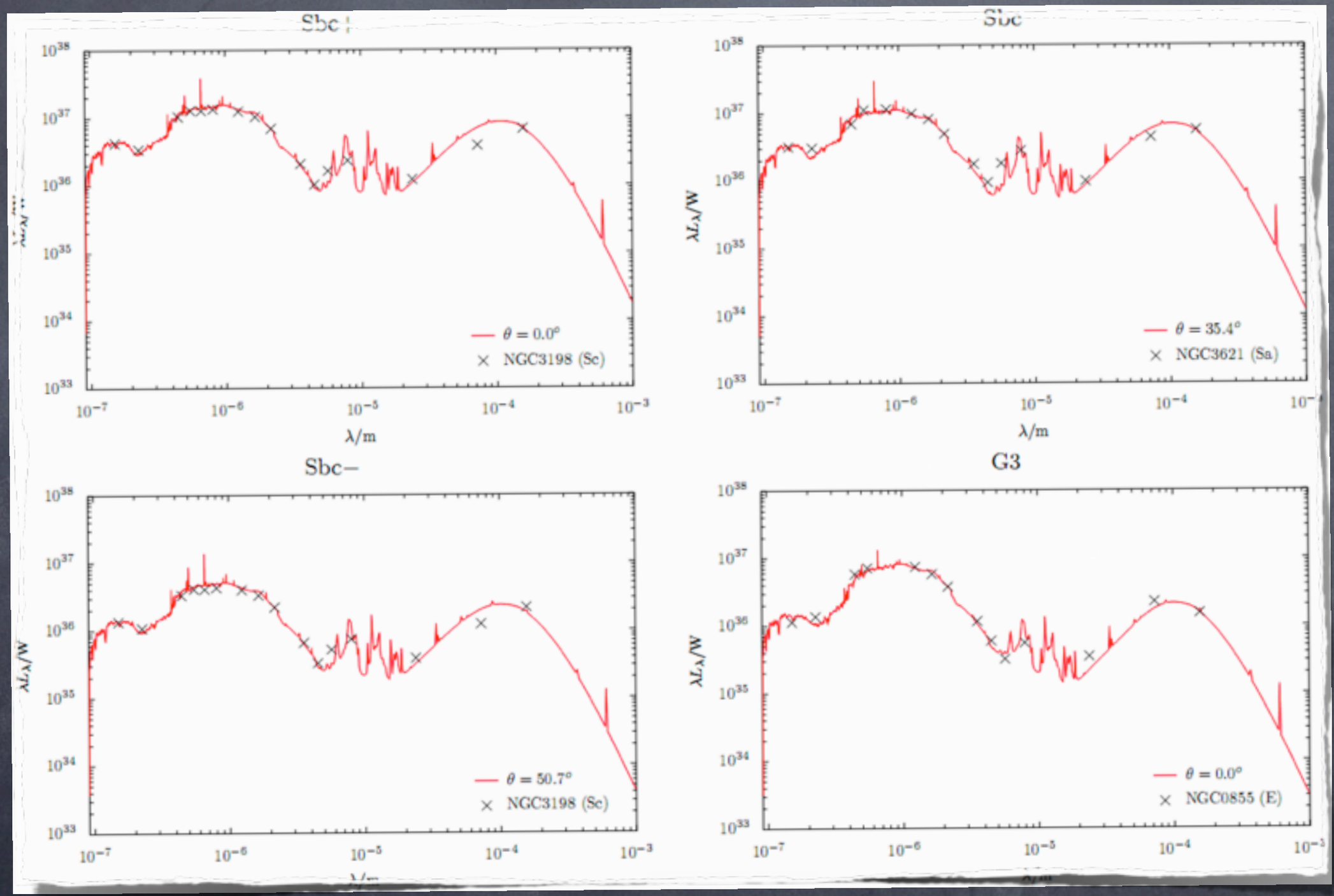
# Sunrise outputs

Broadband photometry & images



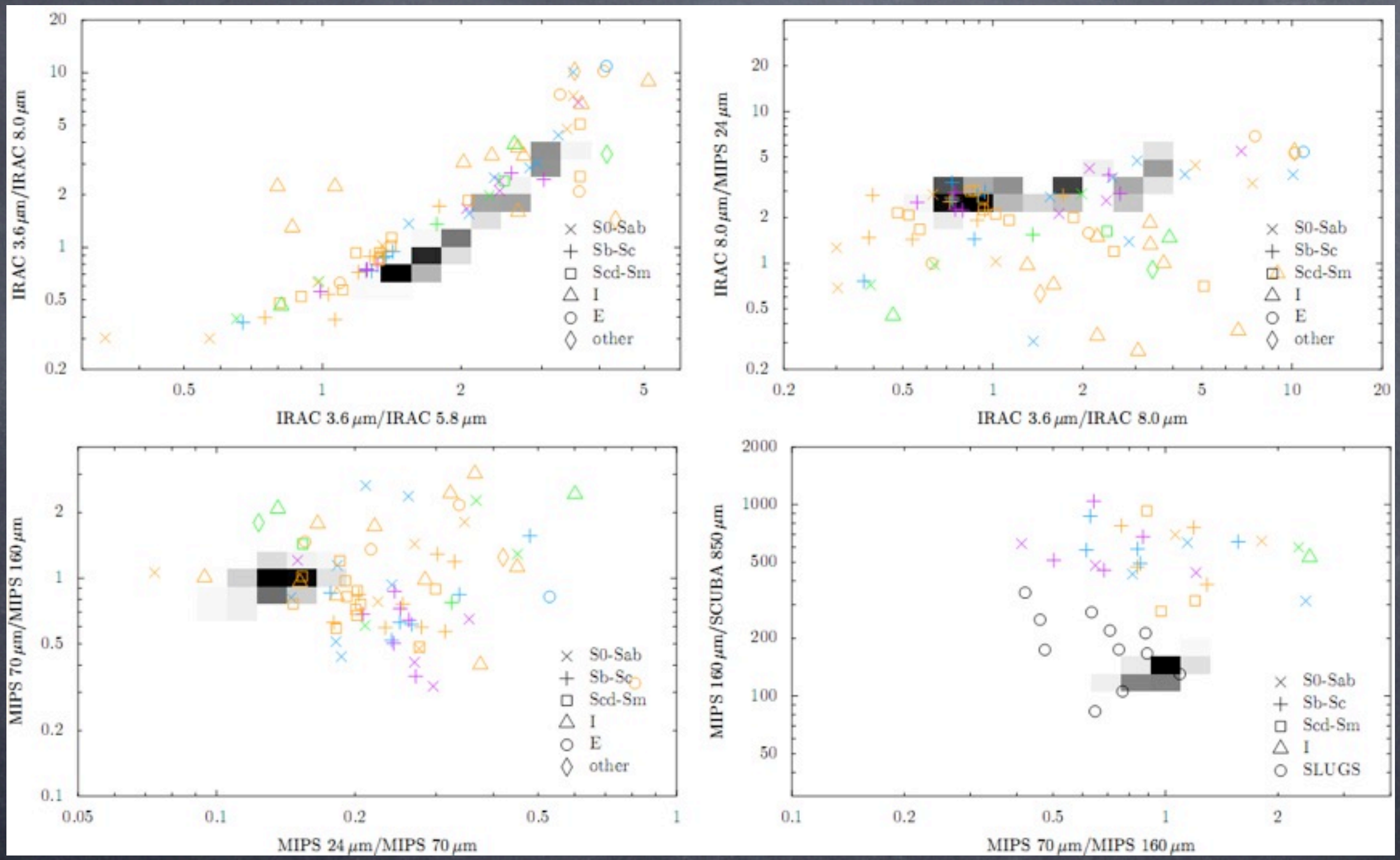

Jonsson, Groves, & Cox 10

# Comparing local disk sims to SINGS




See PJ, Groves & Cox 10. Samples: SINGS (Dale et al. 07)

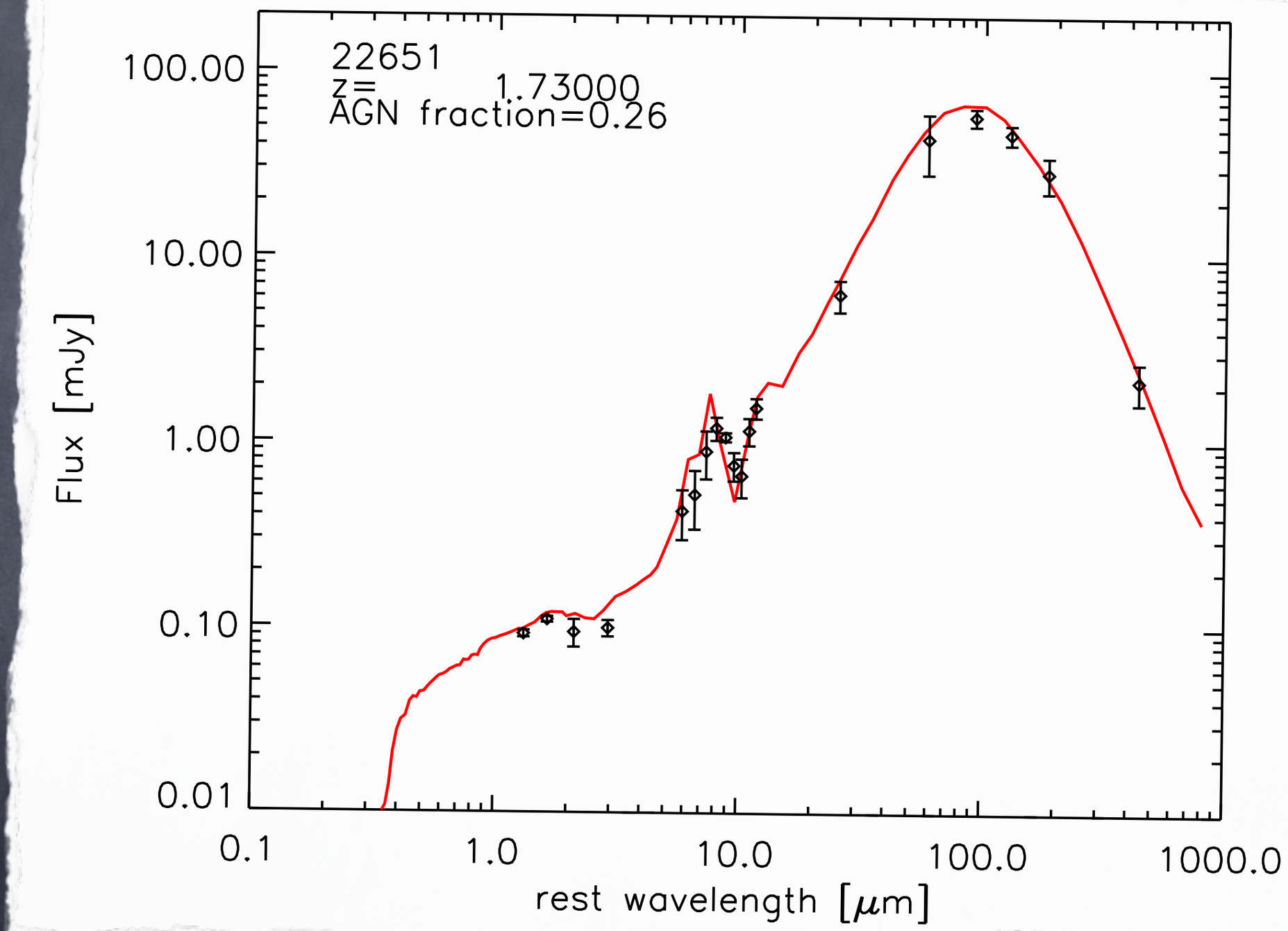
# Comparing local disk sims to SINGS




See PJ, Groves & Cox 10. Samples: SINGS (Dale et al. 07), SLUGS (Willmer et al. 09)

# In progress: Testing hi-z models against observations

(+ testing AGN indicators)




w/Anna Sajina, Lin Yan (Spitzer FLS sample)

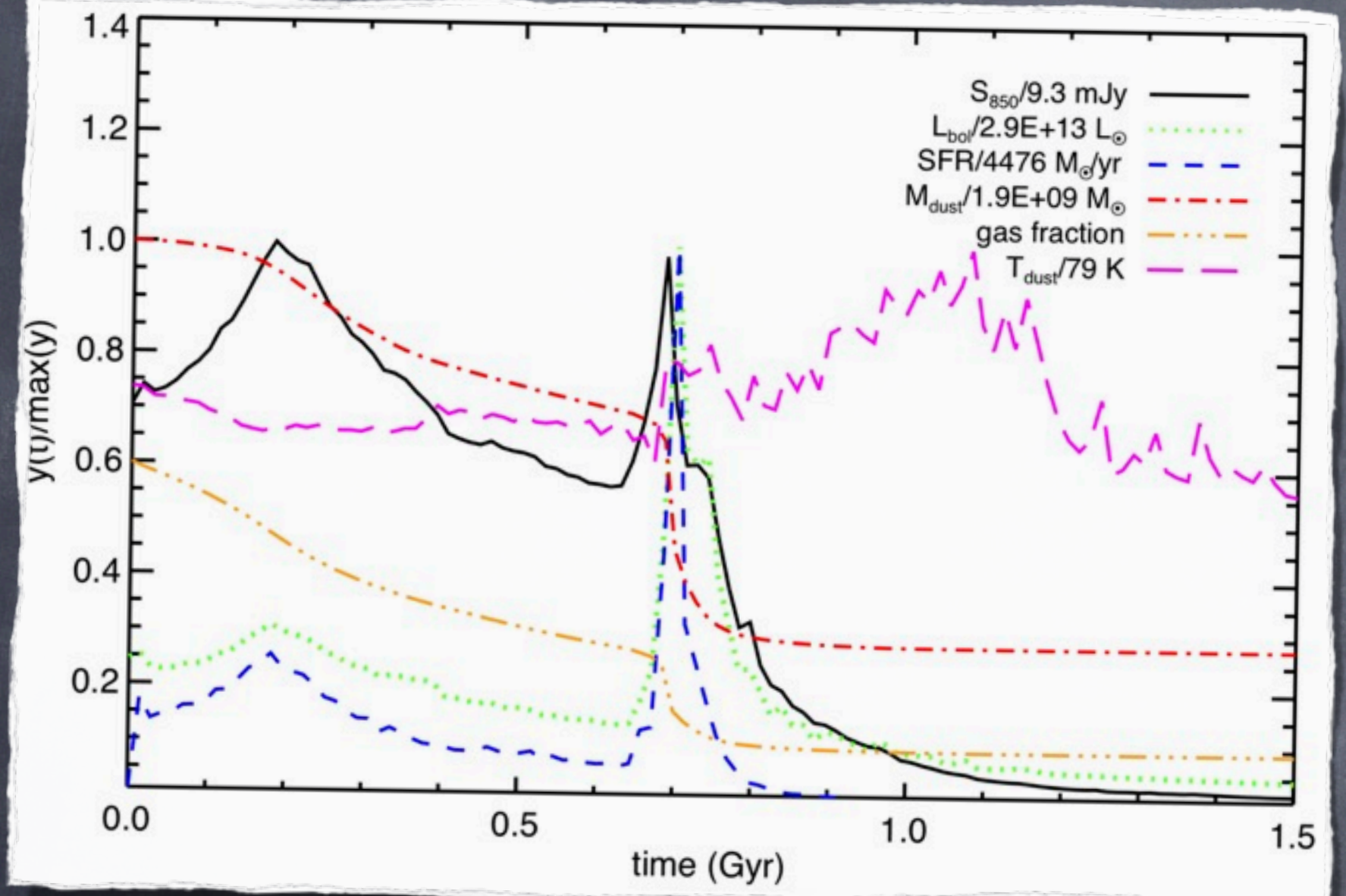
# Sub-millimeter galaxies (SMGs)

Chris Hayward et al. (11)

- Population of optically faint sources detected in sub-mm (fiducial cut $S_{850}$ > ~5 mJy)
- 99% of L is emitted in IR
- Powered by SF rather than AGN
- $L_{IR}$ ~ $10^{12}$ - few x $10^{13}$ $L_{sun}$ ⇒

  SFR ~ few x$10^2$-$10^4$ $M_{sun}$/yr
- Median z ~ 2.2, σ ~ 1.2 ⇒ sub-mm traces ~ 200-400 μm emission (longward of peak)

# Merger evolution




Merger of two $z \sim 2$ disks:

$M_{halo}$ = 9e12

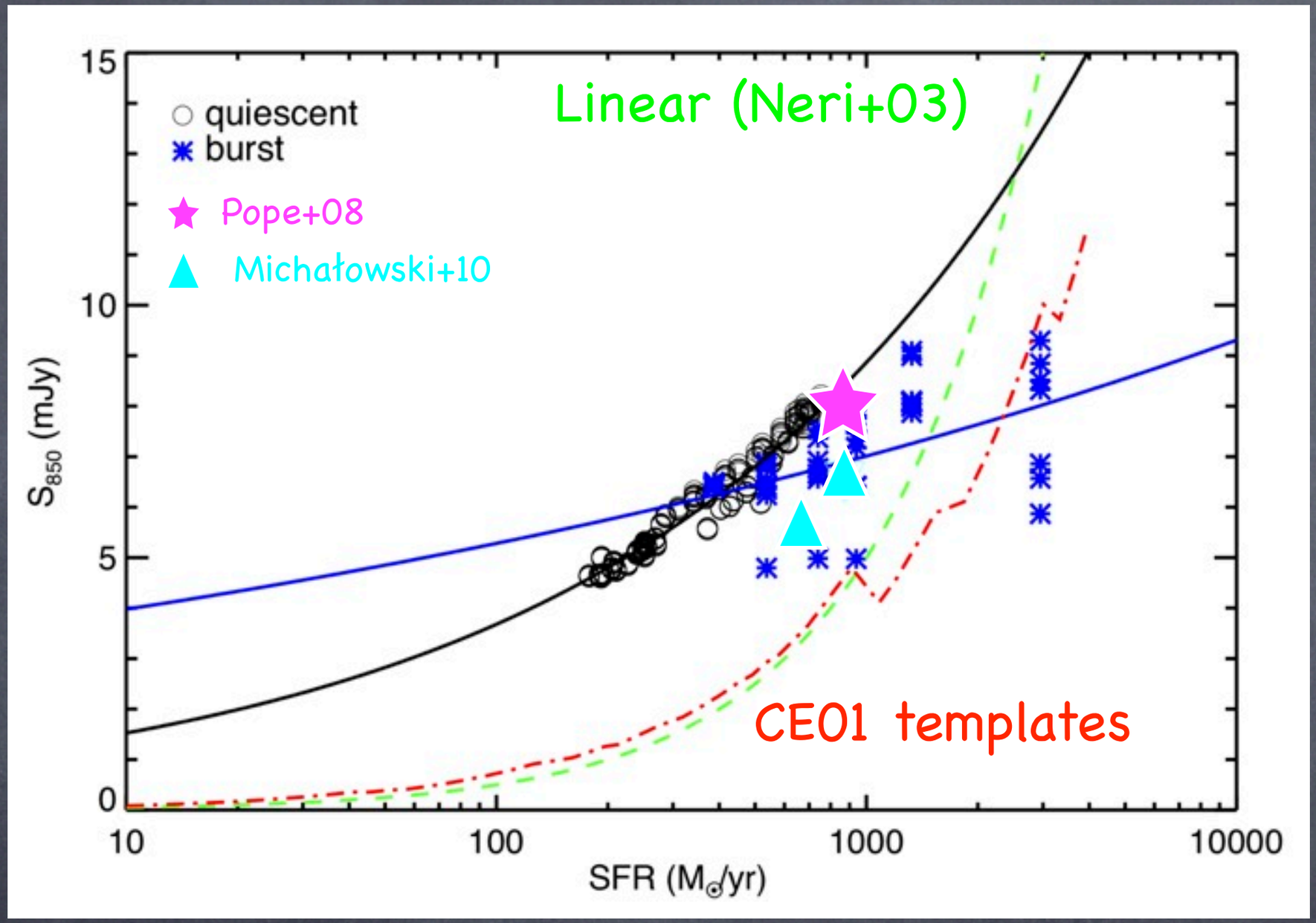
$M_b$ = 4e11

initially 60% gas

Burst consumes gas, lowers dust mass, increases dust T

→ **Inefficient** at boosting submm flux (~15x in SFR but <2x in $S_{850}$)

# Merger evolution




Two SF regimes:

1. Quiescent disk (during infall)
2. Merger-driven burst

→ SMGs are not just the high-SFR tail of galaxy population

# SMG bimodality

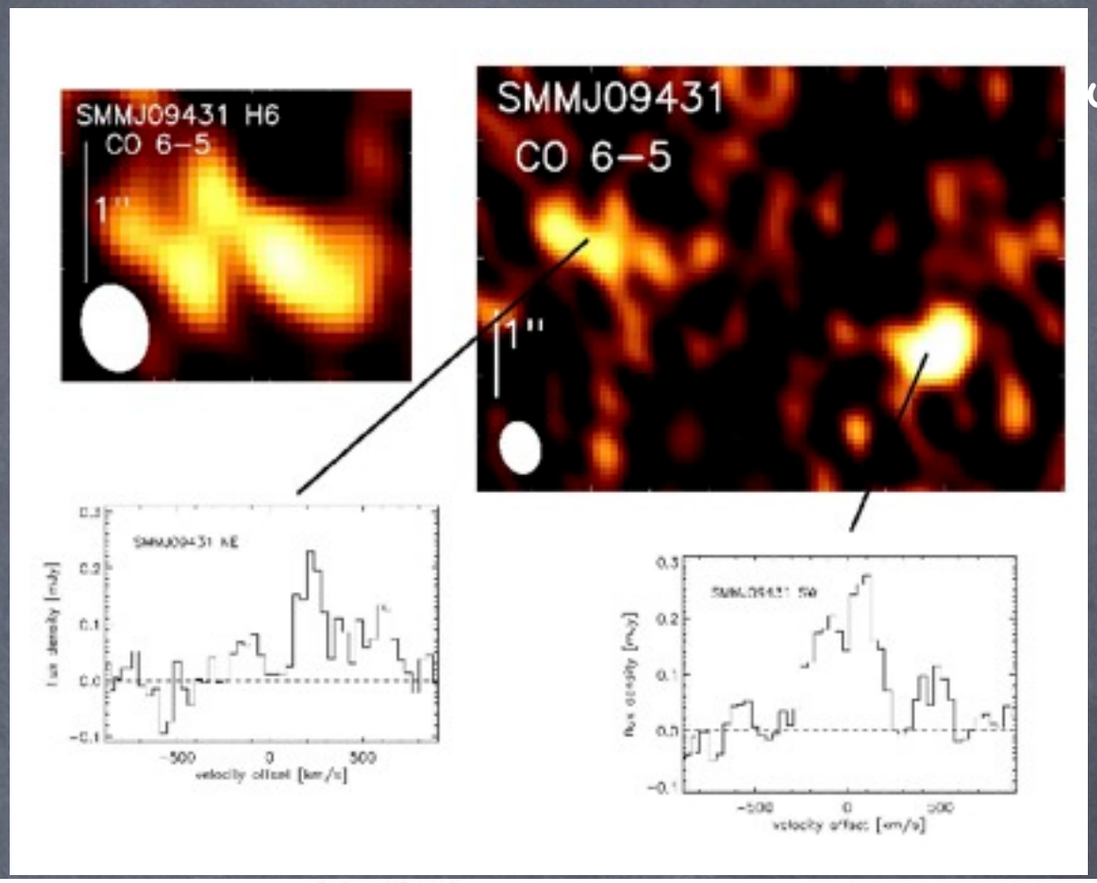
- SCUBA/AzTEC beams ~15" (~130 kpc at z = 2) ⇒

  easy to fit two disks in beam

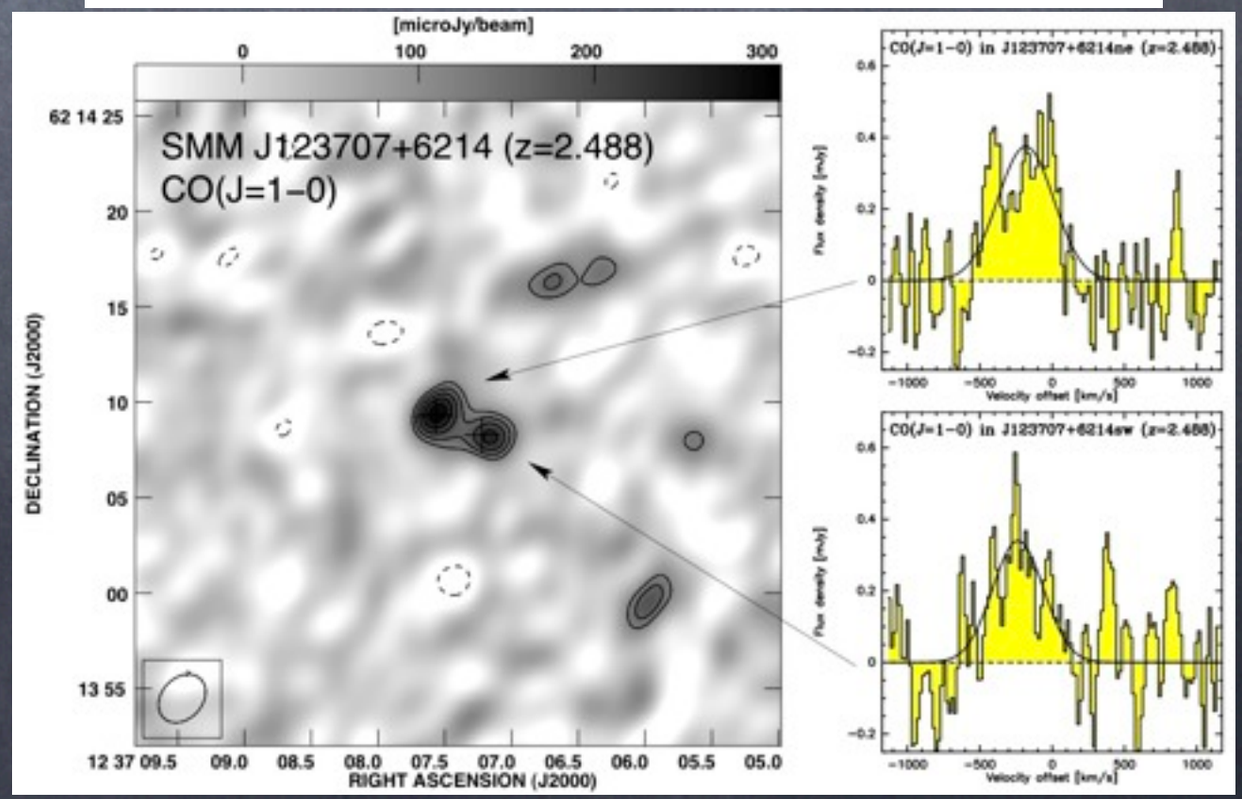
- Very efficient way to boost submm flux

- Early-stage merger; no strong interactions yet

- SMGs are a mix of merger-driven starbursts (near coalescence) and blended galaxy pairs (early-stage)




Engel+10




Riechers+11

# Summary

- Simulations of local disks replicate local SEDs well, but real galaxies are a more diverse population
- (U)LIRG samples at low and high z are now beginning to cover FIR - will be able to test predictions of mergers
- Intense starbursts are an inefficient way of boosting submm flux
- Merger SMGs fall into two classes:

  1. Late-stage merger: starburst induced at coalescence
  2. Early-stage merger: two progenitor disks blended into one submm source

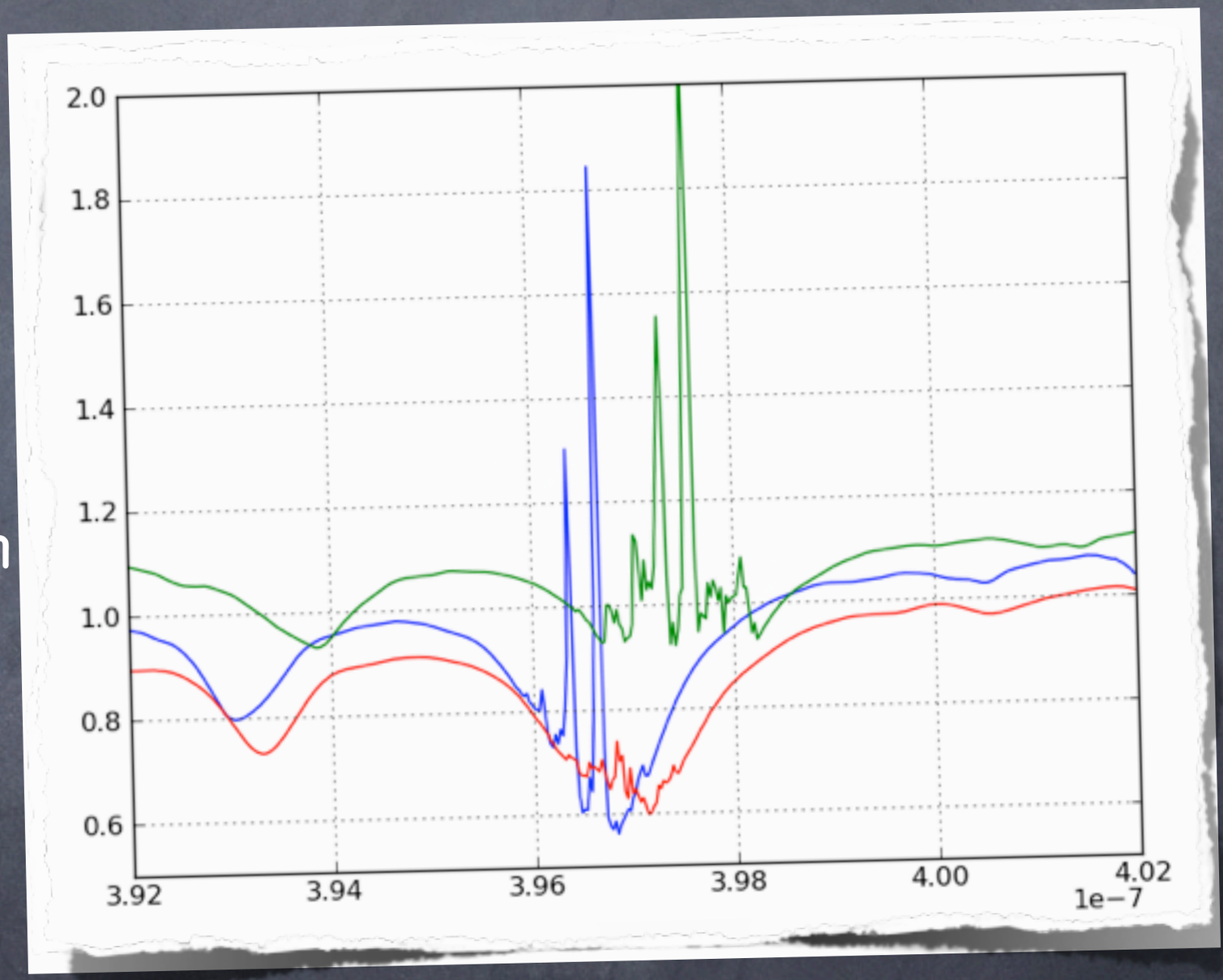
- Unlike local ULIRGs, SMGs are a mix of quiescent and bursting sources -- clear observational tests of this

# Summary

- Intense starbursts are an inefficient way of boosting submm flux
- Merger SMGs fall into two classes:
  1. Late-stage merger: starburst induced at coalescence
  2. Early-stage merger: two progenitor disks blended into one submm source ("galaxy pair SMGs")
- Unlike local ULIRGs, SMGs are a mix of quiescent and bursting sources -- clear observational tests of this

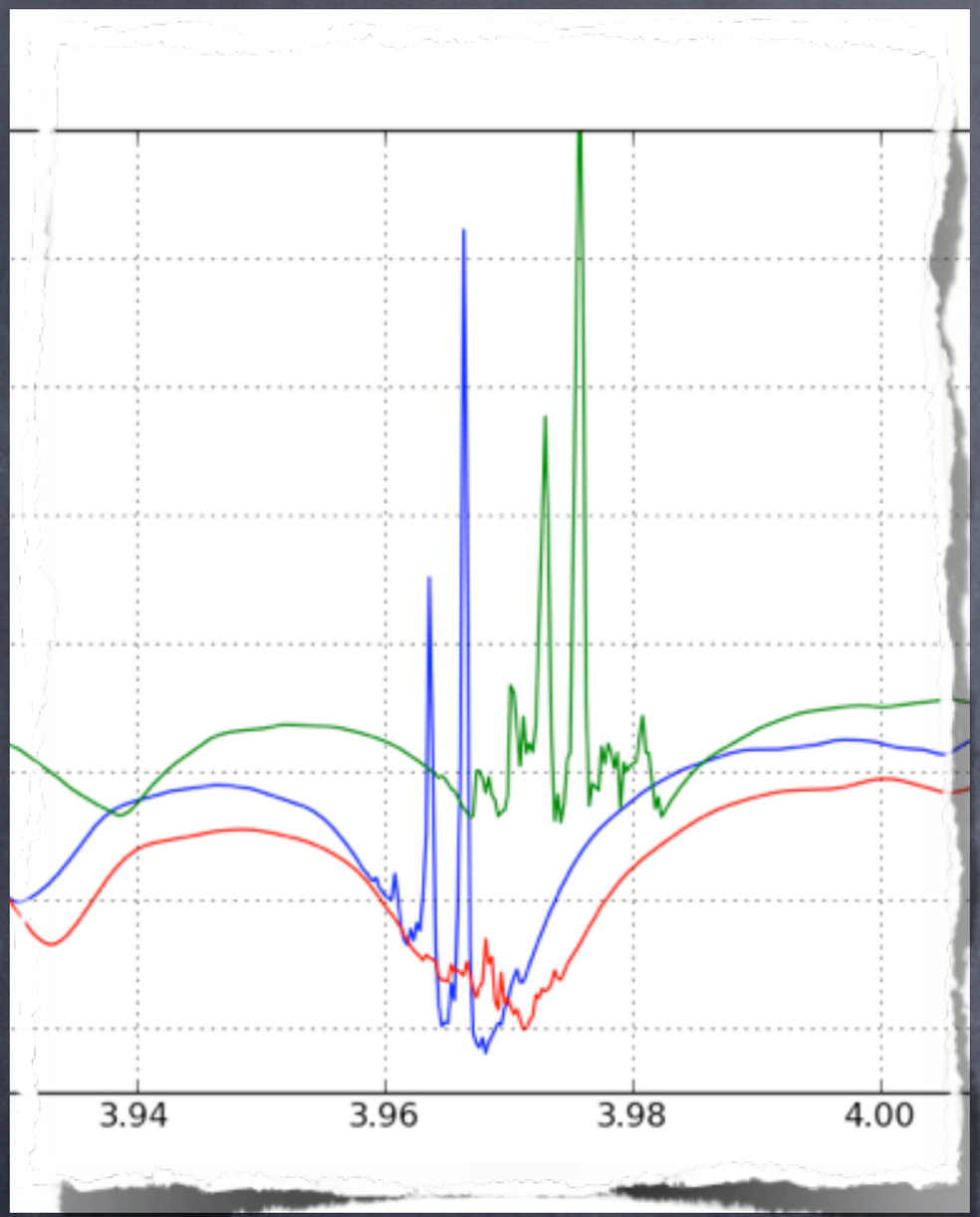
# New: Kinematics

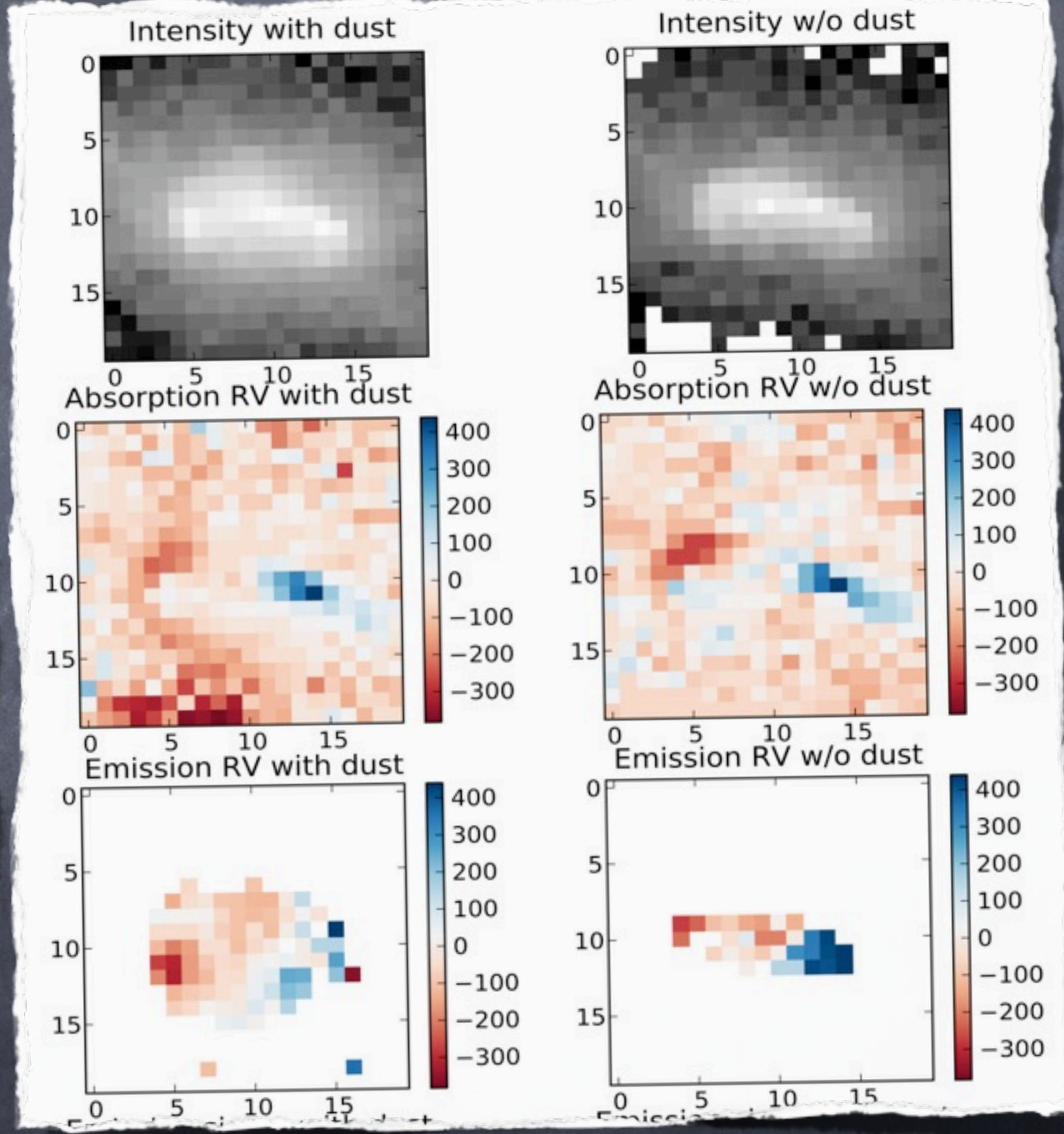
- Taking into account velocities of sources and scatterers
- Can generate emission and absorption line profiles at high resolution (R~16000)




(requires high-res SEDs; in the works...)

# IFU-style outputs



# Spectral Energy Distributions