HOW I WOULD USE CCAT

Solving the puzzles of extreme high-z star formation without confusion

Caitlin M. Casey
Institute for Astronomy, University of Hawaii
Hubble Fellow

Session Title:

“CHARACTERIZING THE **SMG POPULATION**”

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~~"CHARACTERIZING THE **SMG POPULATION**"~~

"CHARACTERIZING **EXTREME STARBURSTS**"

Thinking Physics, not "selection function."

No flux limitation in any single FIR band (e.g. 850um)

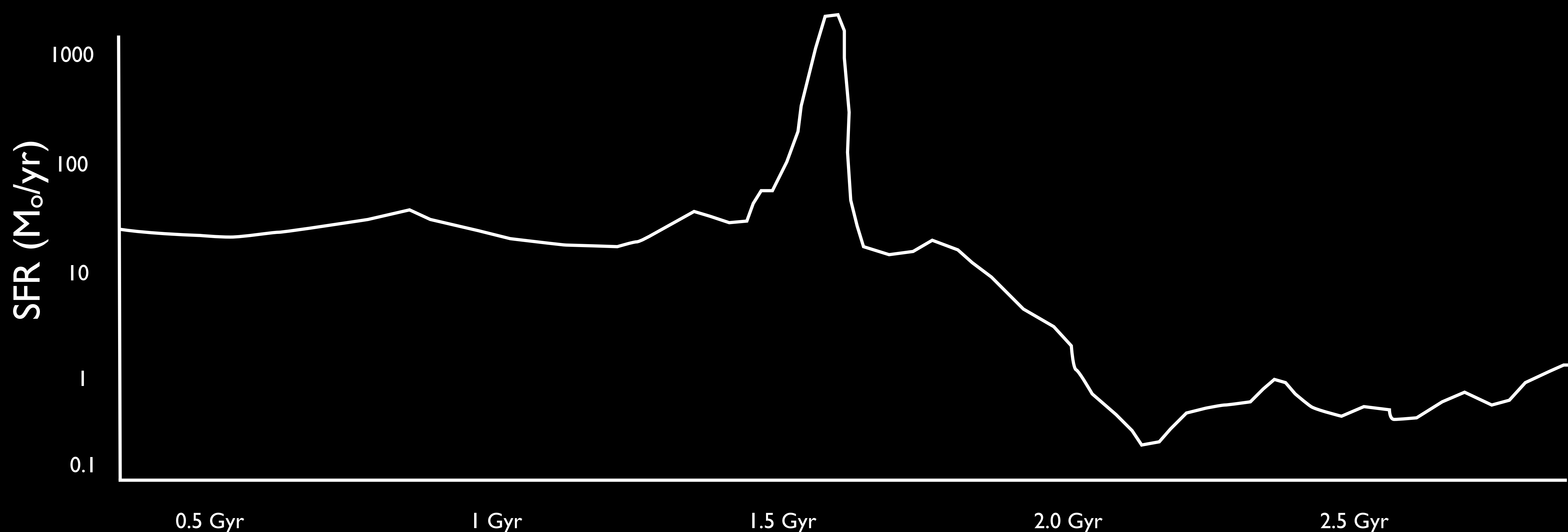
Not a strict luminosity cutoff at $10^{12}\ L_\odot$

major merger
or heavy bombardment

ULIRG

AGN

elliptical



e.g. Hopkins et al. 2009,
Narayanan et al. 2009

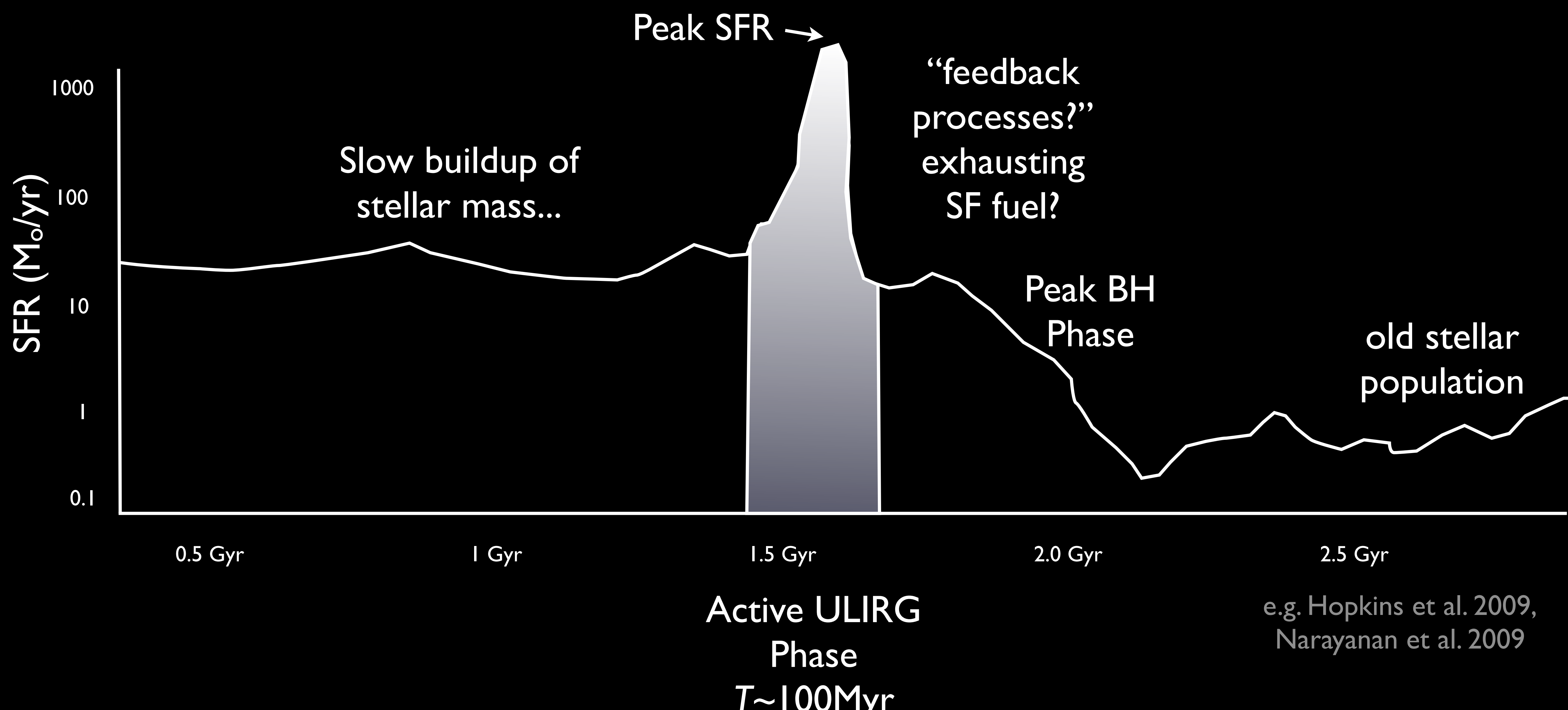
<u>Cartoon</u> for ULIRG evolution: e.g. Sanders et al. 1988a,b

major merger
or heavy bombardment

ULIRG

AGN

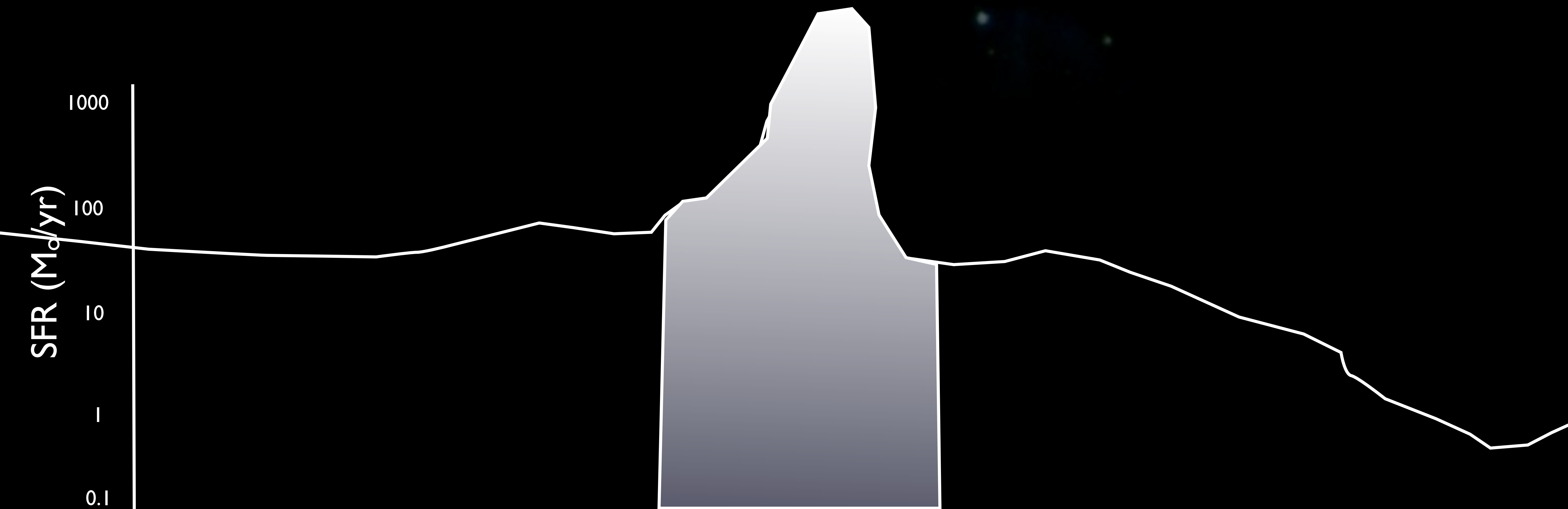
elliptical



e.g. Hopkins et al. 2009, Narayanan et al. 2009

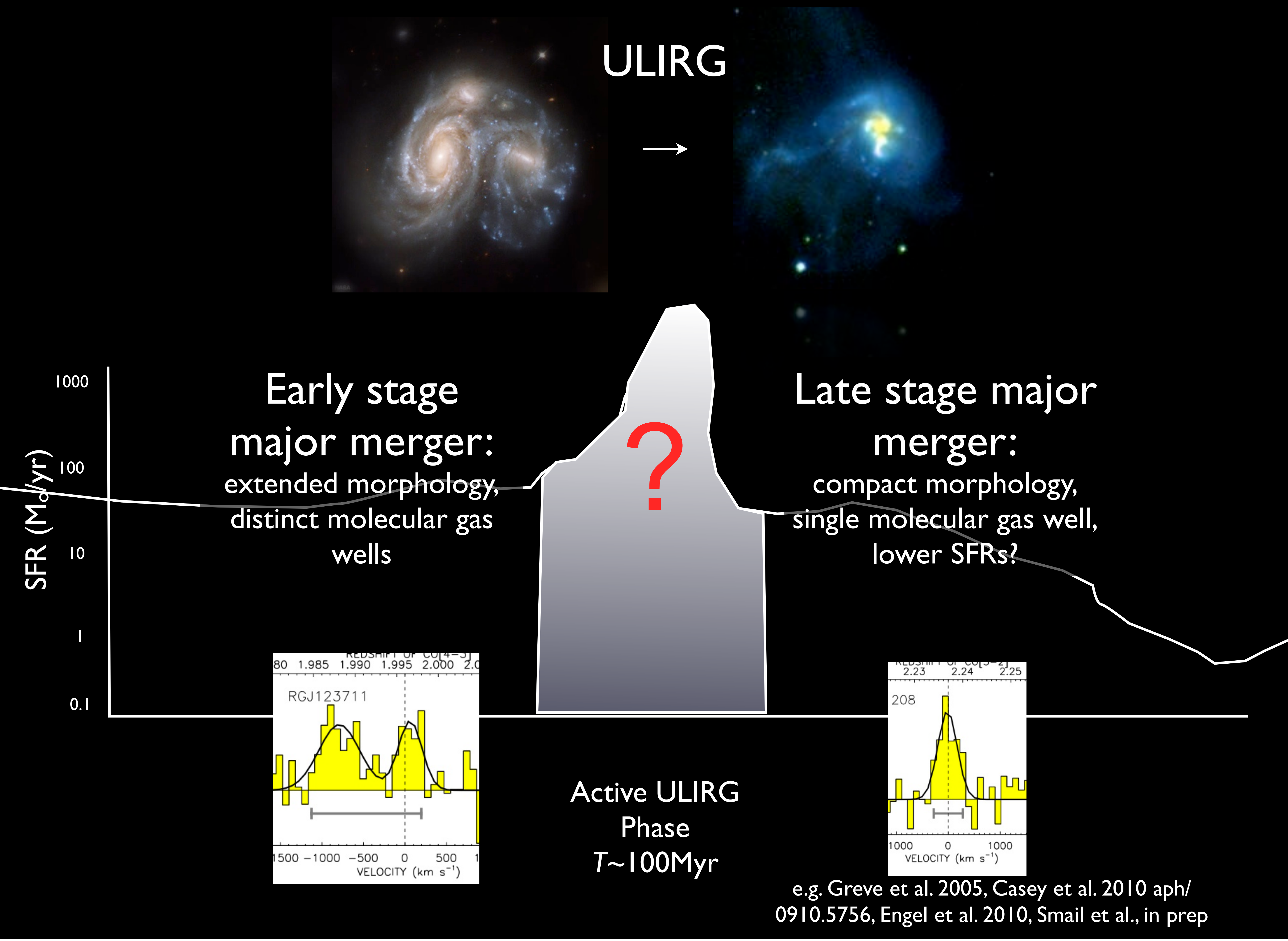
ULIRG

→



Active ULIRG
Phase
T~100Myr

e.g. Greve et al. 2005, Casey et al. 2010 aph/
0910.5756, Engel et al. 2010, Smail et al., in prep


ULIRG
→
1000
100
10
1
0.1
SFR (M☉/yr)
Early stage major merger:
extended morphology, distinct molecular gas wells
?
Late stage major merger:
compact morphology, single molecular gas well, lower SFRs?
RGJ123711
VELOCITY (km s⁻¹)
208
VELOCITY (km s⁻¹)
Active ULIRG Phase
T~100Myr
e.g. Greve et al. 2005, Casey et al. 2010 aph/0910.5756, Engel et al. 2010, Smail et al., in prep

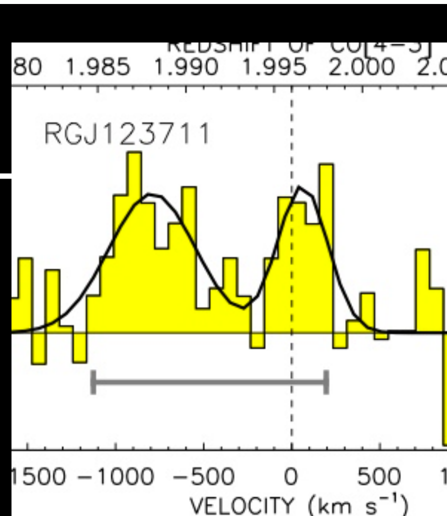
ULIRG →

What can CCAT do for FIR dust SED fits of z~1-3 ULIRGs?

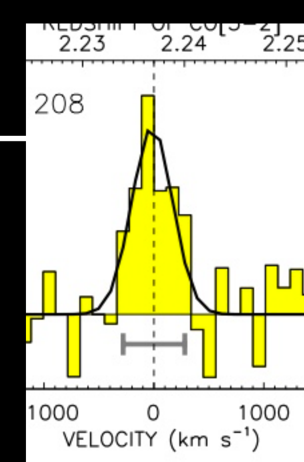
(discussed molecular line work)

SFR ($M_\odot$/yr)

1000
100
10
1
0.1



Active ULIRG
Phase
T~100Myr

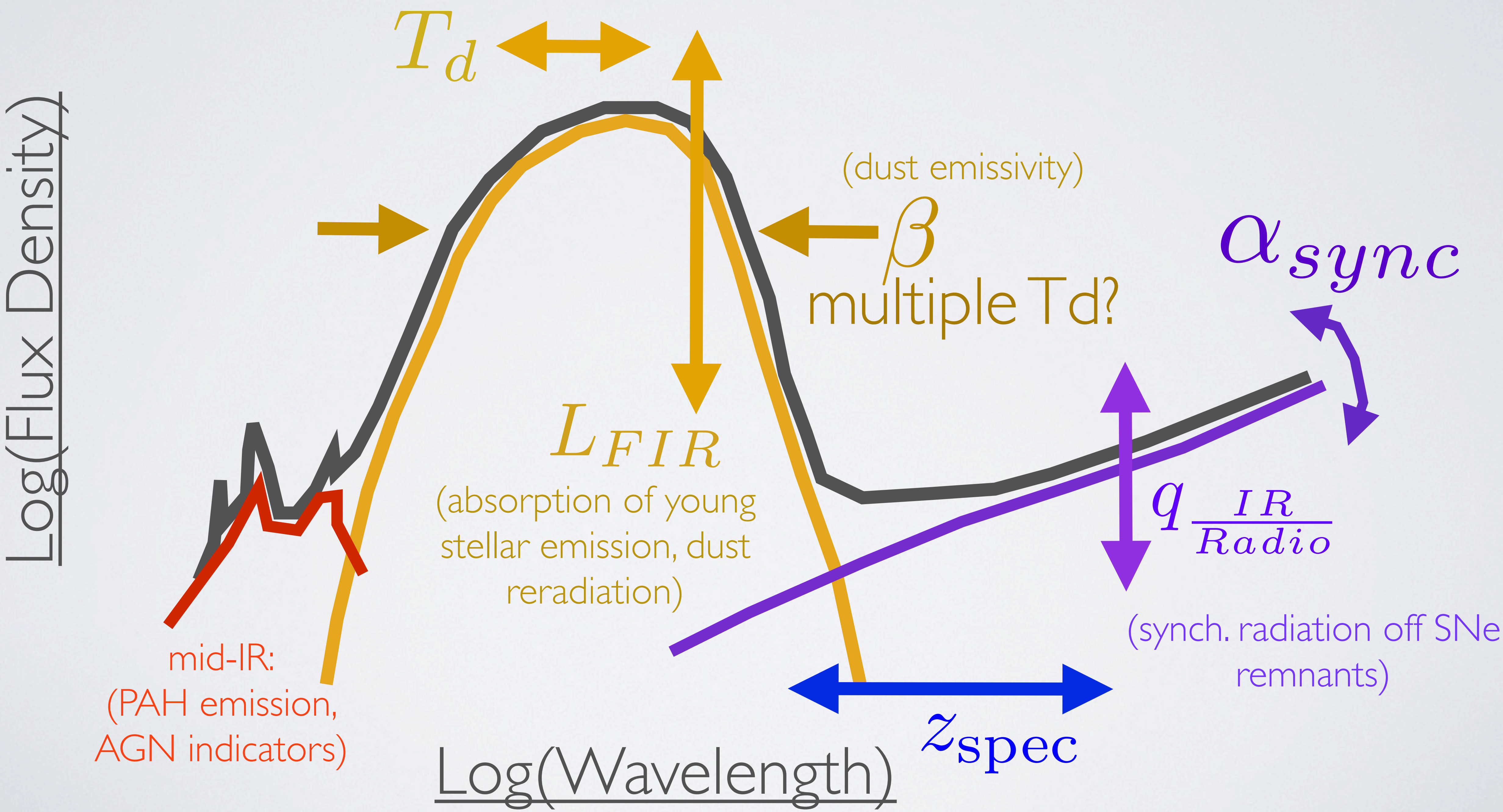


e.g. Greve et al. 2005, Casey et al. 2010 aph/0910.5756, Engel et al. 2010, Smail et al., in prep

ULIRG SED Manipulation.

Key parameters:

$$L_{\rm FIR}, T_d, \beta$$



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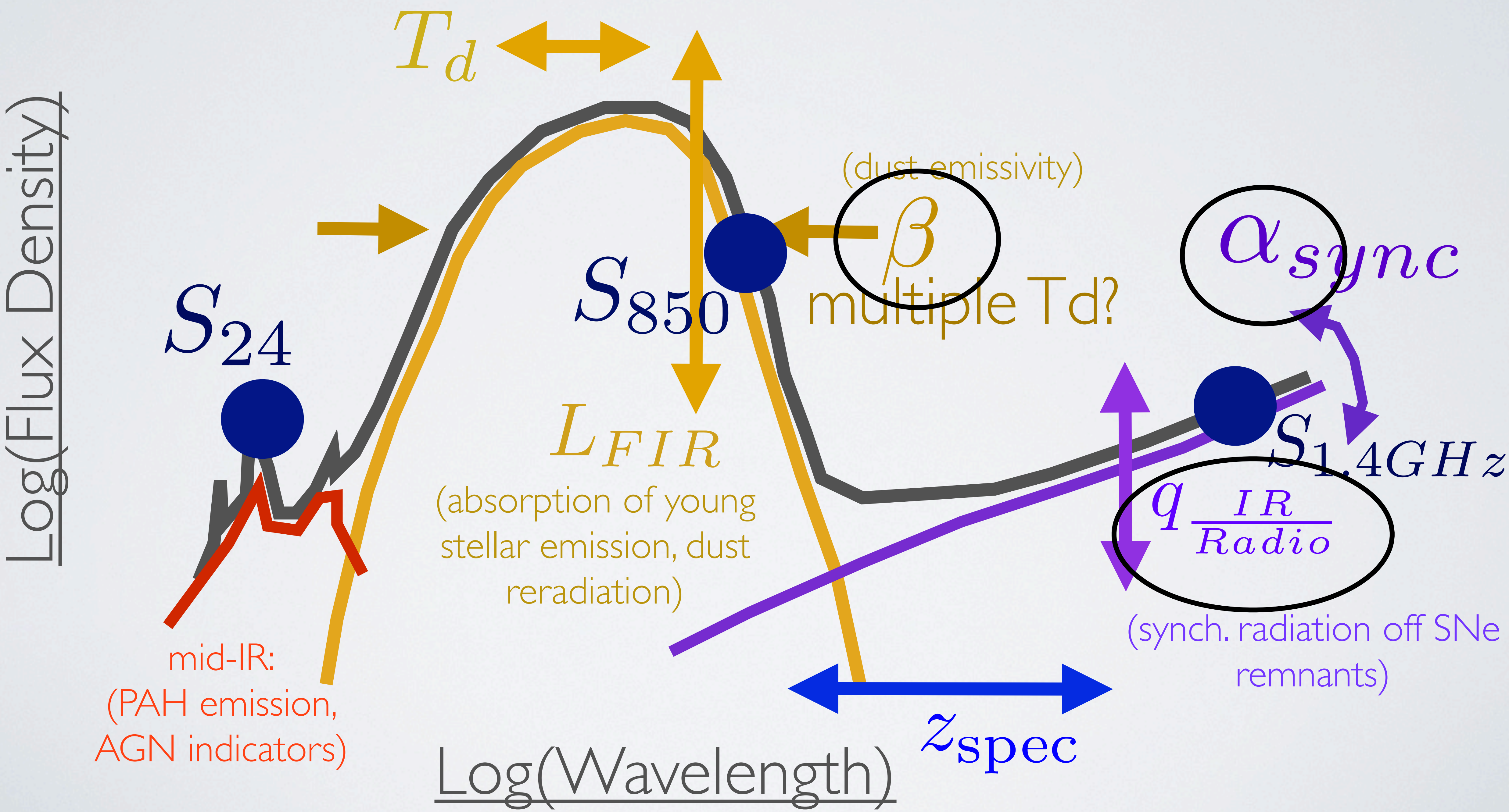


ULIRG SED Manipulation.

(Luminosity Variation)

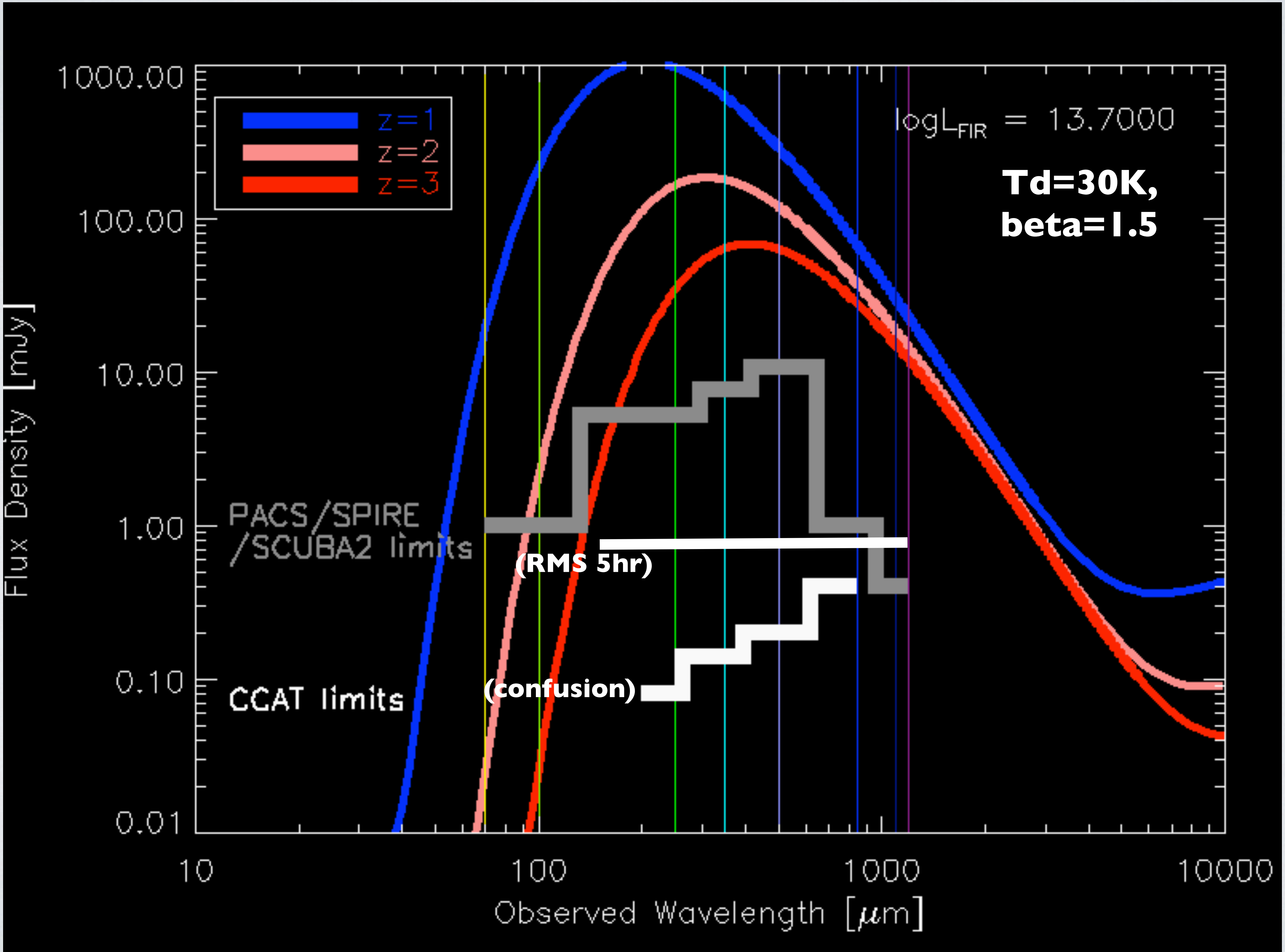
Td=30K, beta=1.5

(RMS 5hr)

(confusion)

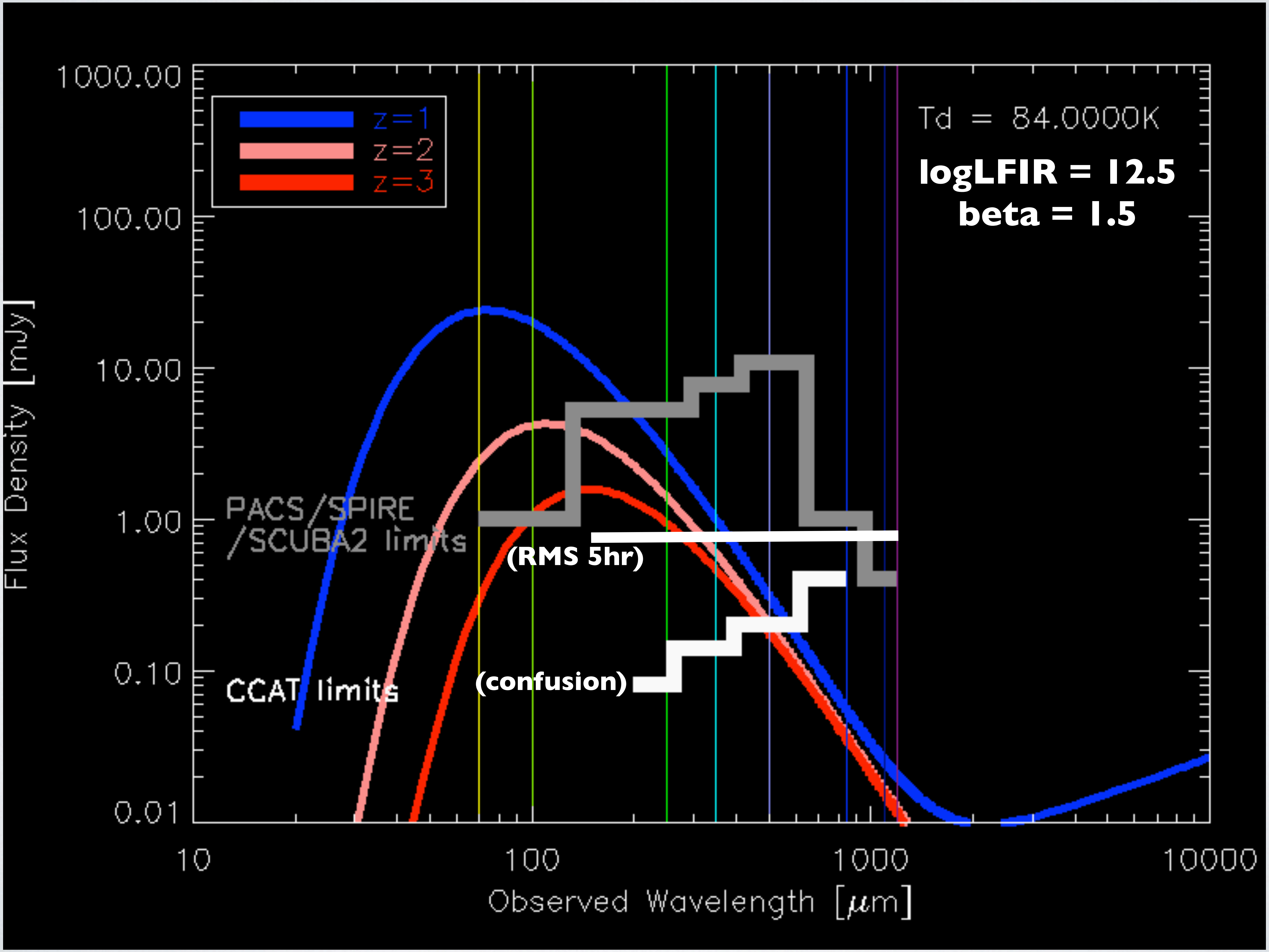
ULIRG SED Manipulation.

(Luminosity Variation)



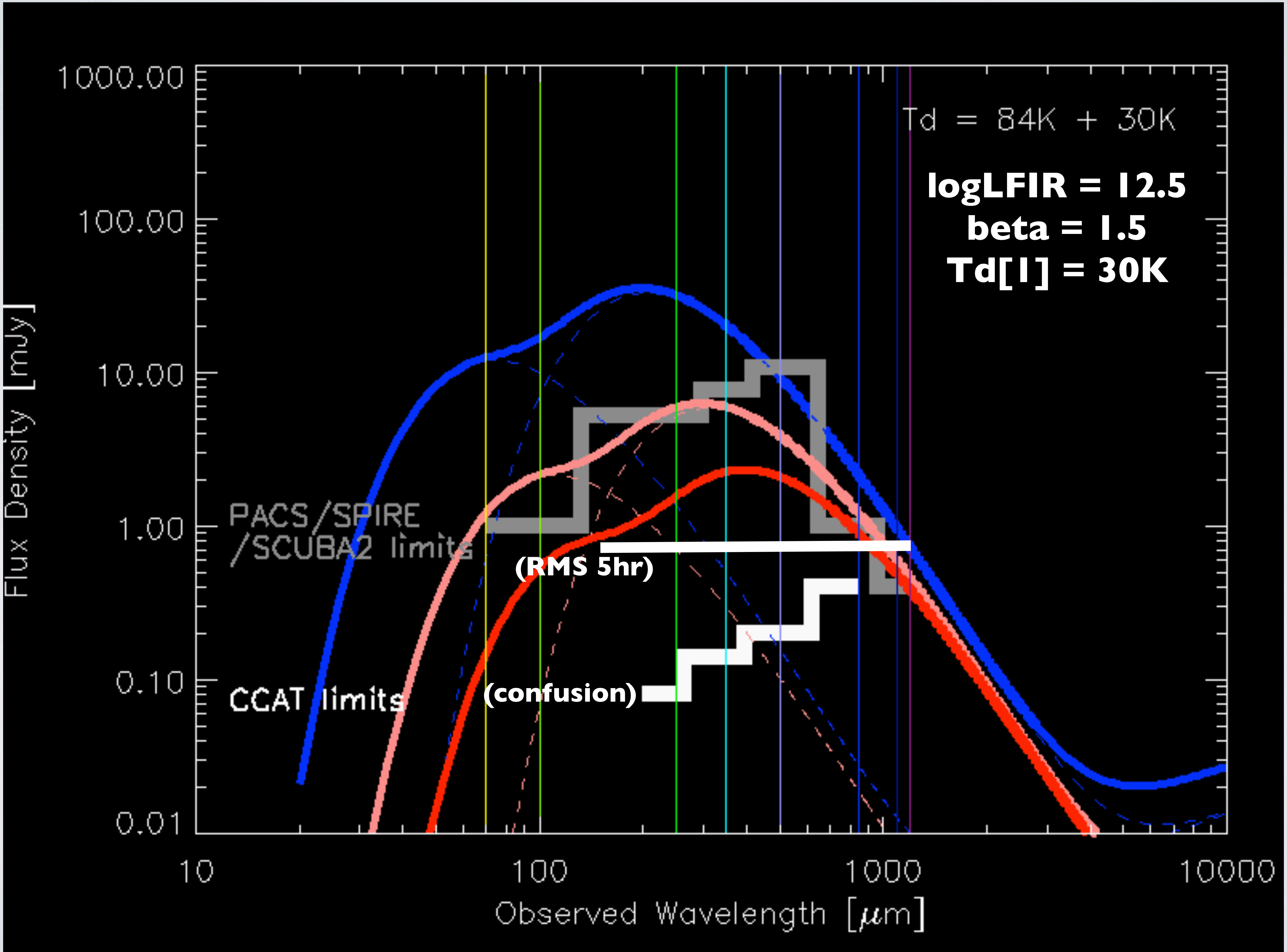
ULIRG SED Manipulation.

(Dust Temperature Variation)



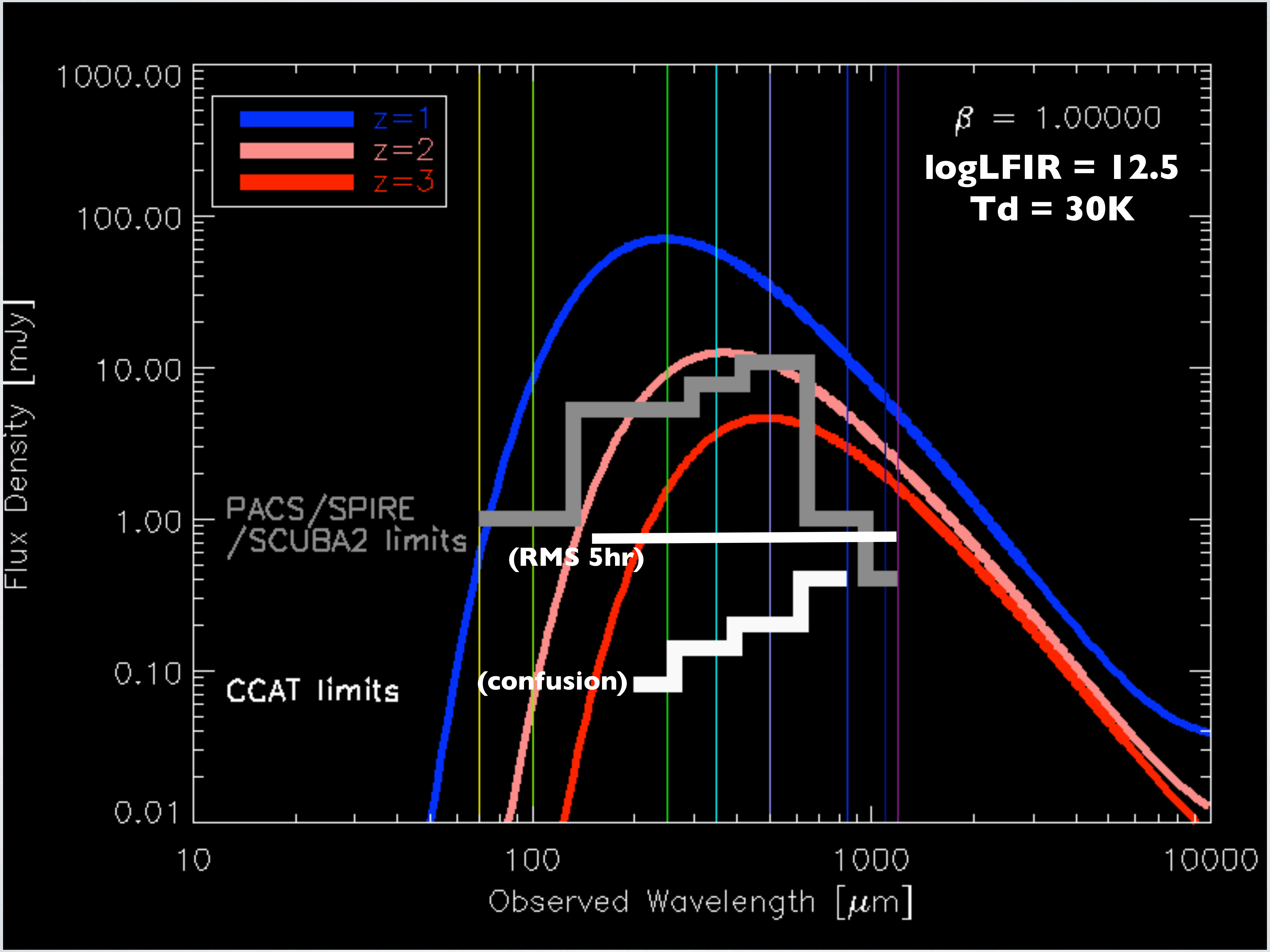
ULIRG SED Manipulation.

(Multiple Dust Temperature Fits)

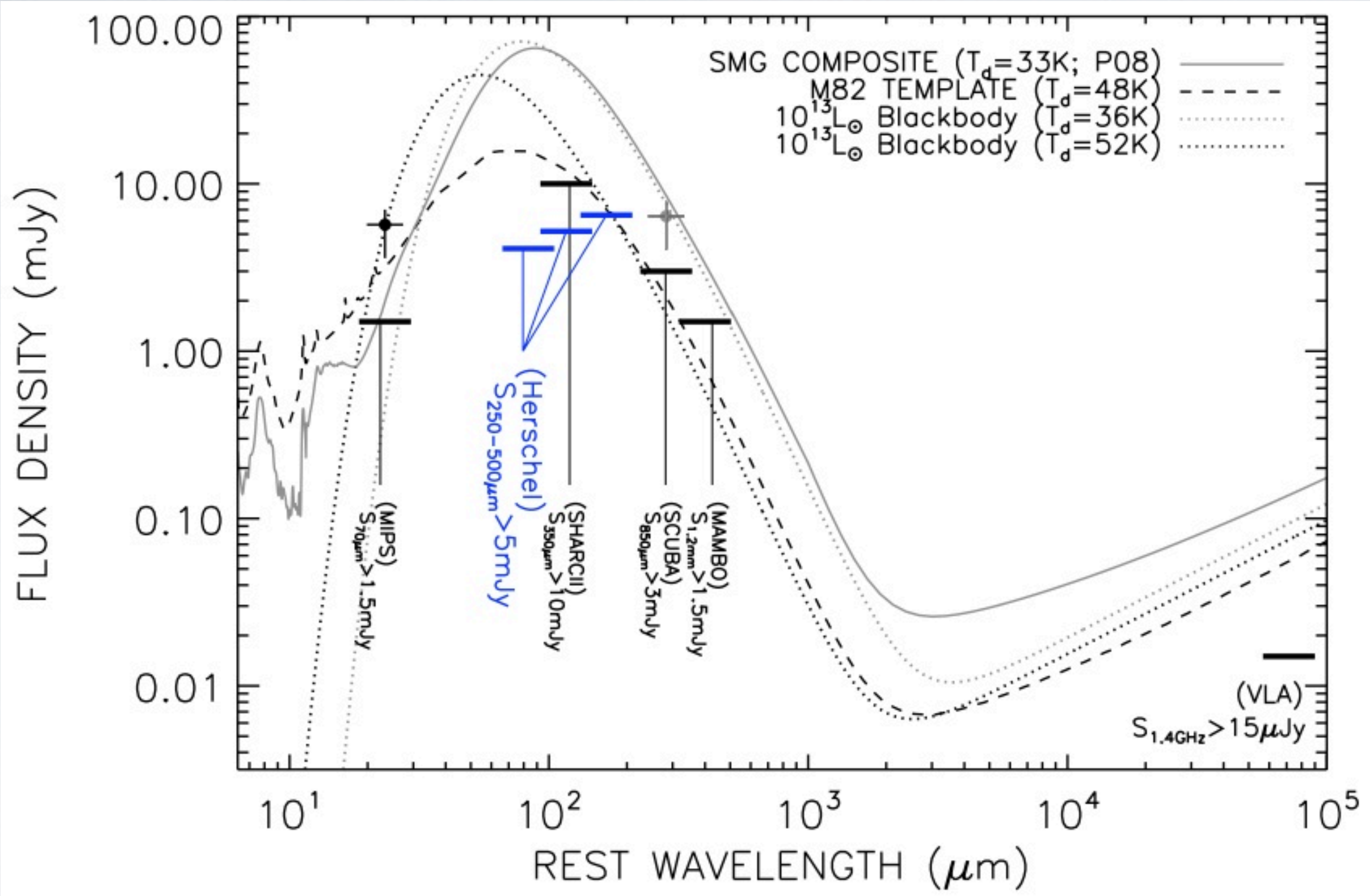


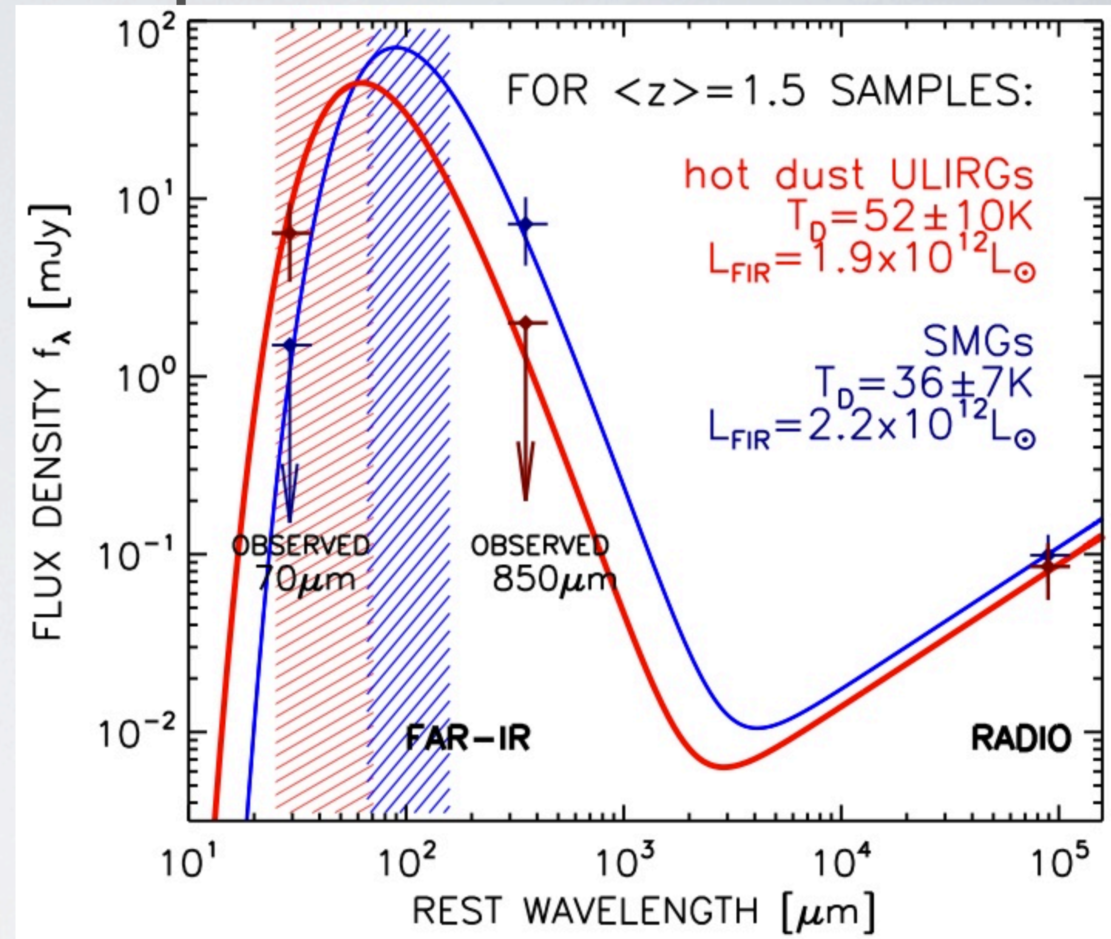
ULIRG SED Manipulation.

(Emissivity Variation)



ULIRG SED Manipulation.





Casey et al. 2009b

Template FIR SEDs often used:

Dale et al. 2005, Pope et al. 2008 "SMG Composite"

$$\beta = 1.5 \ T_d = 30\,K \quad \alpha_{sync} = 0.75$$

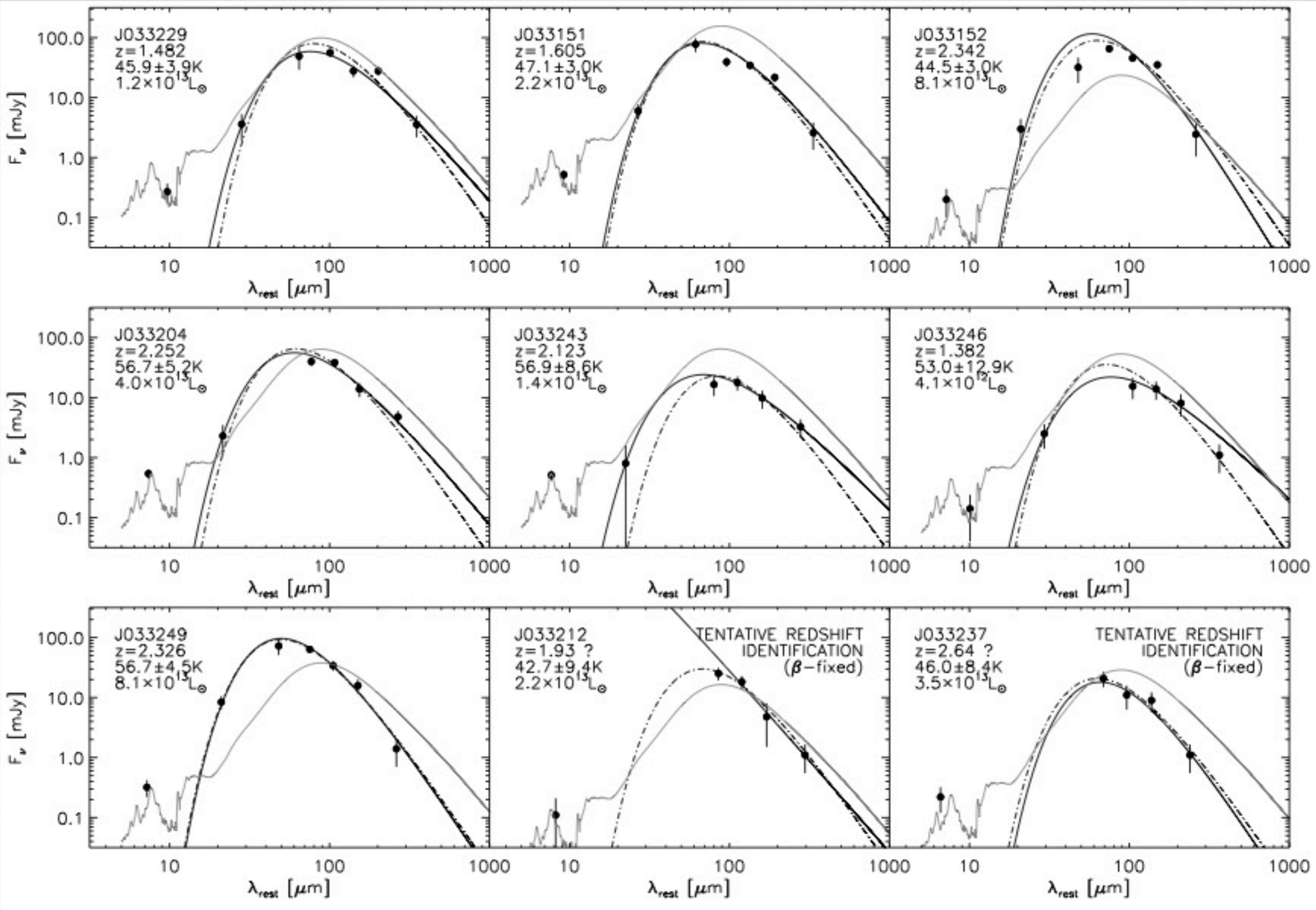
$$L_{FIR} \propto L_{1.4GHz} (\propto L_{24\mu m})$$

Wide variation seen locally:

e.g. Arp 220, Mrk 231 have $T_d \geq 50\,K$, and average 10K warmer than SMGs, beta varies ~1.0-2.0, radio/FIR holds?

BLAST z~2 250um HLIRGs

(Casey et al. 2010a)



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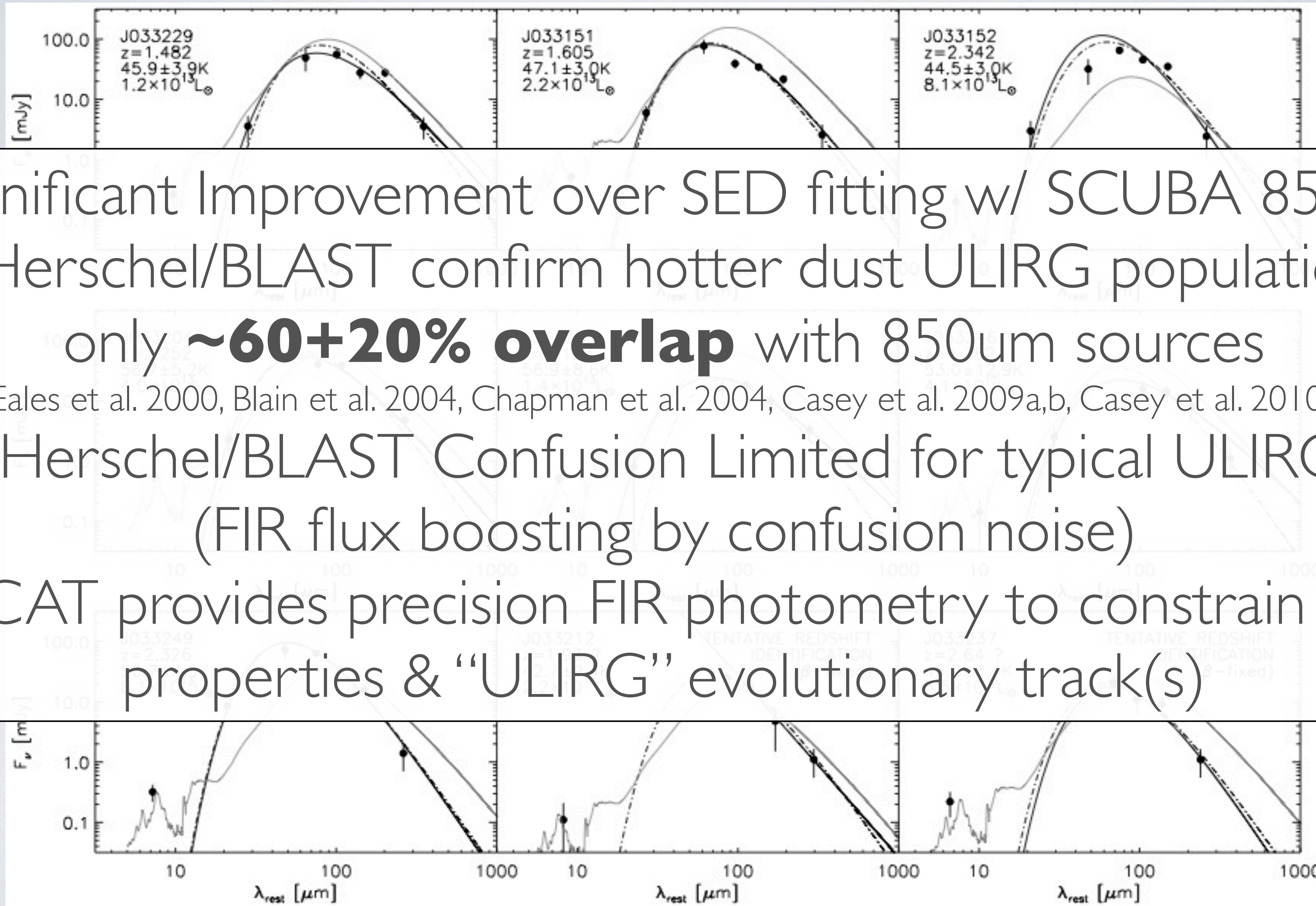

- Significant Improvement over SED fitting w/ SCUBA 850um
- Herschel/BLAST confirm hotter dust ULIRG population, only **~60+20% overlap** with 850um sources

(Eales et al. 2000, Blain et al. 2004, Chapman et al. 2004, Casey et al. 2009a,b, Casey et al. 2010a)

- Herschel/BLAST Confusion Limited for typical ULIRGs (FIR flux boosting by confusion noise)
- CCAT provides precision FIR photometry to constrain dust properties & "ULIRG" evolutionary track(s)

What we "know" about SMGs in 2010:

1. $\langle z \rangle \sim 2 \; SFR > 500 \, M_{\odot} yr^{-1} \;\; L_{\rm FIR} > 3 \times 10^{12} \, L_{\odot}$

Chapman et al. 2005...

2. Extremely dusty, very high UV extinction

Chapman et al. 2004a

3. Dust temperature increases with luminosity

Blain, Chapman, et al. 2004, Casey et al. 2009b,10a

4. Starburst dominated, AGN only ~25% contribution

Alexander et al. 2005

5. Huge $> 10^{10} \, M_{\odot}$ gas masses, efficient star formers, most are in major mergers

Greve et al. 2005, Tacconi et al. 2006,08

6. Volume density: $\sim 5 \times 10^{-5} h^3 Mpc^{-3}$

e.g. Barger, Cowie et al,, Chapman et al, Pope et al

7. Significant contribution to the cosmic SFRD at high-z (increasing with z) e.g. Goto et al. 2010

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Rest UV/optical spec-z's difficult/biased against complete obscuration

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850um strongly biased against hot-dust SEDs

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AGN contribution to radio? Obscured AGN?

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Only very bright SMGs surveyed in CO $>10^{13} L_{\odot}$: major mergers at $\sim 10^{12} L_{\odot}$?

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Blain, Chapman, et al. 200… Casey et al. 2009b,10a

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850um strongly biased against hot-dust SEDs

Blain, Chapman, et al. 200 Casey et al. 2009b,10a

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AGN contribution to radio? Obscured AGN?

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Only very bright SMGs surveyed in CO $>10^{13}L_\odot$: major mergers at $\sim 10^{12}L_\odot$?

Greve et al. 2005, Tacconi et al. 2006,08

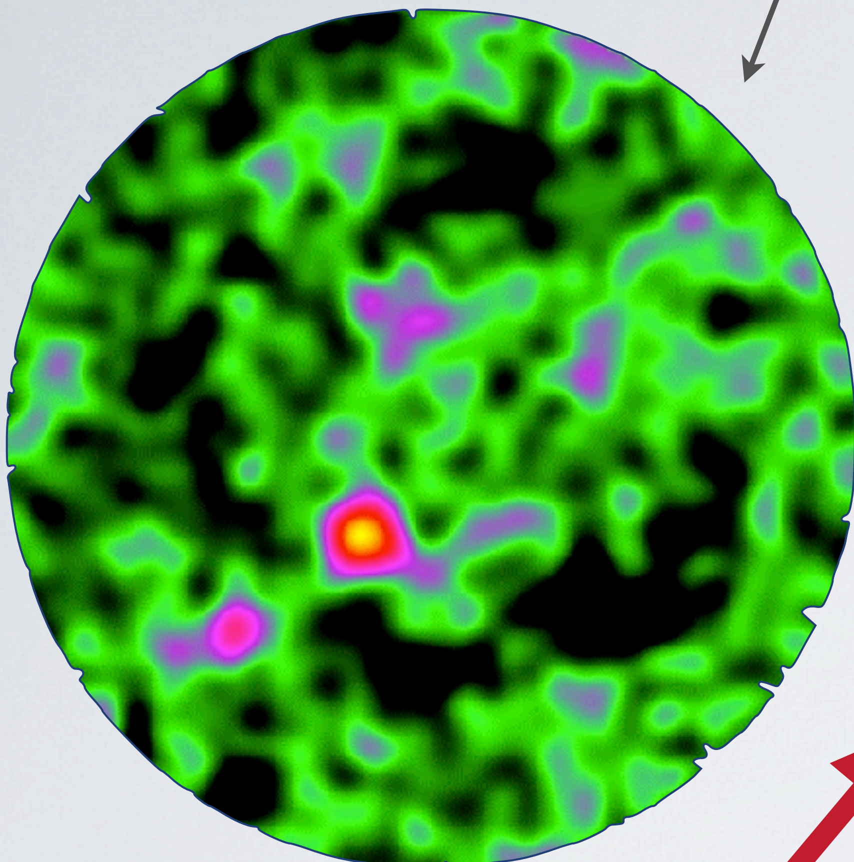
6. Volume density: $\sim 5\times10^{-5}h^{3}Mpc^{-3}$

7. Significant ... high-z (increasing with z) e.g. Goto et al. 2010

SIGNIFICANT FRACTION of z>1 ULIRG ACTIVITY POORLY CONSTRAINED

2000-2009

(misses hot-dust systems)



(misses high-z)

(misses v. obscured sources)

SCUBA: ~1000 sources from multiple legacy fields

Radio ID → Spec Obs. → ~75 sources: Confirmed UV/optical redshifts

ULIRG characterization!

~35 SMGs Detected in CO

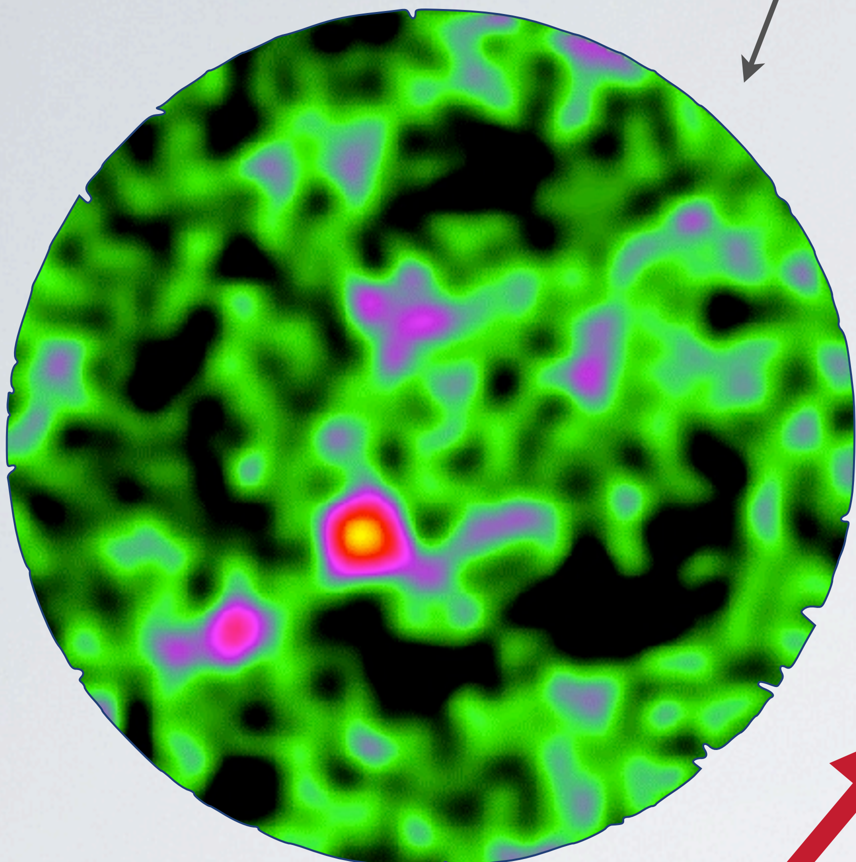
Neri et al. 2003, Greve et al. 2005, Tacconi et al. 200608

2000-2009

(misses hot-dust systems)

(misses high-z)

(misses v. obscured sources)



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SCUBA:
~1000 sources from
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Submm-Faint Radio sources with starburst spectra →

ULIRG characterization!

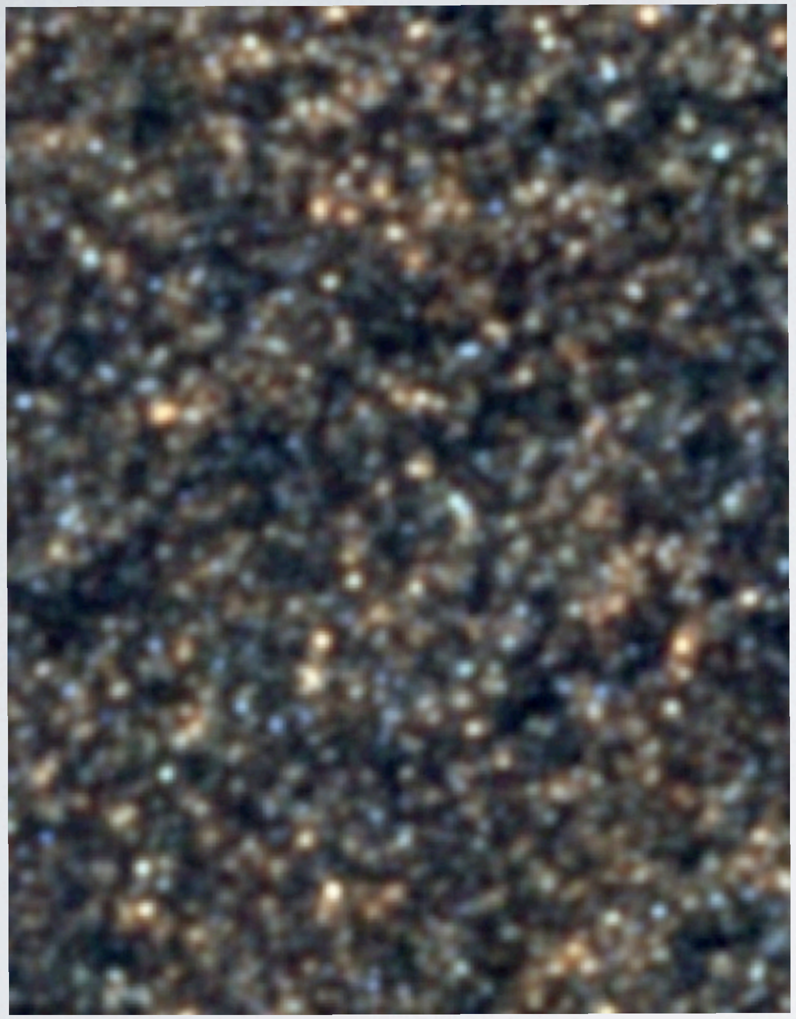
~35 SMGs Detected in CO

Neri et al. 2003, Greve et al. 2005, Tacconi et al. 200608

~10 SFRGs Detected in CO

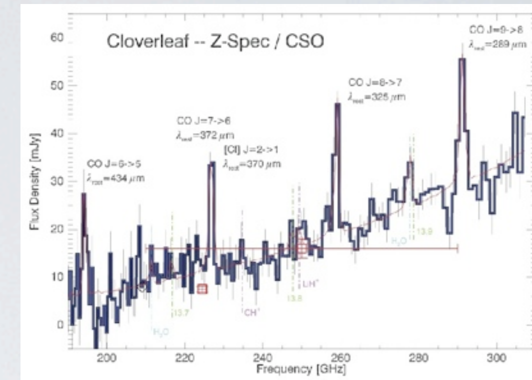
Casey et al. 2010 aph/0910.5756

2010-2013/4



(misses high-z, EVLA deeper)

(see Nikola, Aguirre, Bradford talks)



(ZSpec limited to $10^{13}\,L_\odot$ systems)

Radio ID, (24um ID)

Blind CO redshifts

rest UV/optical Spec Obs.

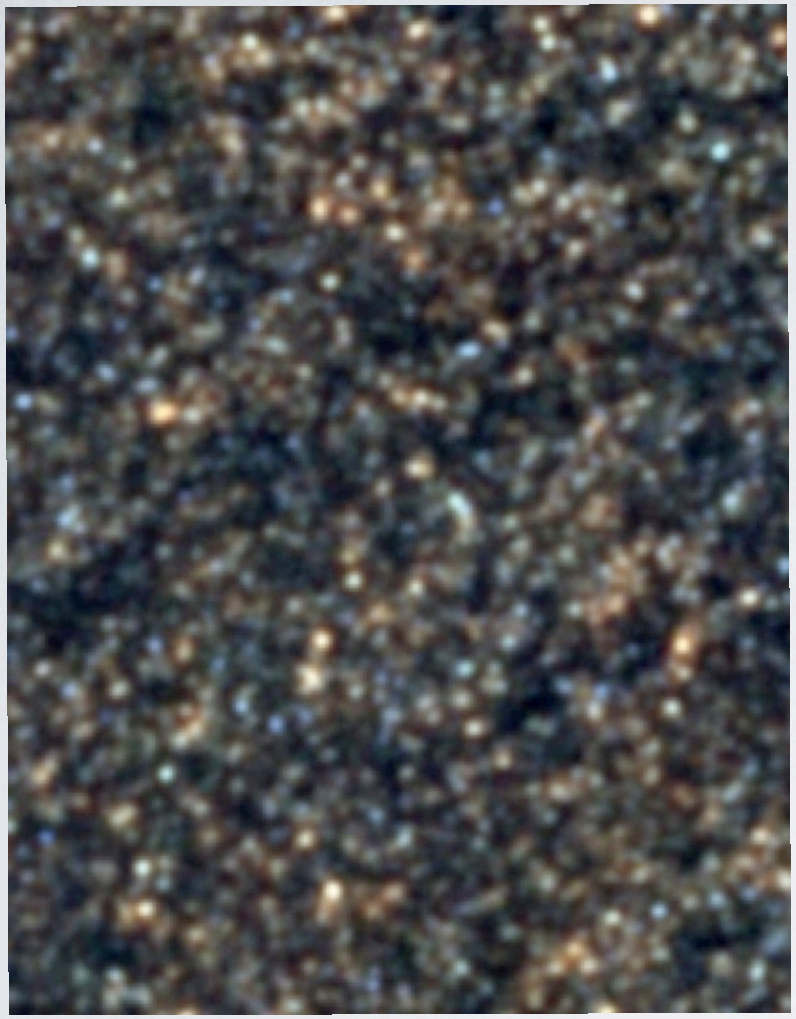
Spec-z's for deep *Hermes* samples

Herschel: ~1000s sources from multiple legacy fields

Saturday, November 13, 2010

>2014

Bottleneck opens when not so limited by confusion.



Blind CO redshifts

(backup: rest UV/optical Spec Obs.)

Not loosing radio faint, high-z (or optically obscured) samples

CCAT:
~10000s sources

How to probe evolutionary sequence of extreme starbursts with CCAT...

1. FIR continuum, star formation & dust probe

SEDs of high-z ULIRGs probe full range of dust distributions/temperatures: potentially more widely varied than range of local ULIRGs.

CONFUSION, CONFUSION, CONFUSION

2. Molecular Gas Emission in CO, [CII], etc. probes star forming gas

Gas masses, CO gas excitation, "XCO" factor, gas fractions, star formation efficiency, gas dynamics (disturbed vs. rotating disk)

CCAT SPECTROSCOPY

ALMA follow up:

best focused on high-resolution, CO latter, not necessarily efficient for blind CO IDs.

CCAT has potential to

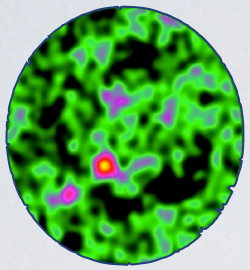
(a) follow up 100s of sources quickly, "dusty starburst" luminosity function (MOS:10 sources per 0.5 sq deg)

Zspect →

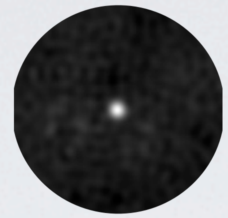
(b) ..??.. kilo-pixel heterodyne arrays/ refractive FP: take spectral slices of wide sky area at low spectral resolution & dither (cluster measurements/ CO "narrow band filter")

Photometry. → Spectroscopy.

Then. 2000-2008

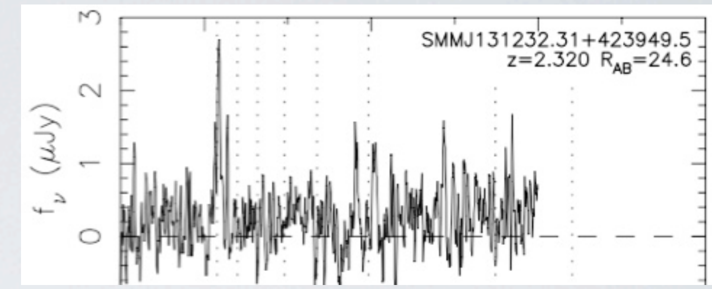


SCUBA
LABOCA
MAMBO
AzTEC



~60% have radio astrometry ID

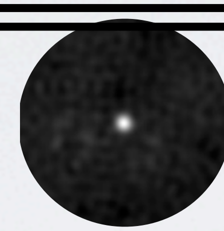
find optical/near-IR counterpart:



~60% rest-UV/optical spectroscopic completeness: Keck LRIS/DEIMOS

CO used to confirm.

Now. 2009-2014



~70% have radio astrometry ID AND/OR 24um ID

rest UV/optical spectroscopy with CO confirmation: ongoing spec-z survey at IfA Hawaii

Blind CO redshifts (e.g. ZSpec, ALMA)

Future. 2014-

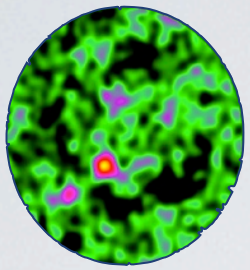
CCAT

Bypass reliance on radio/mid-IR IDs

Blind redshifts with ALMA, make *more efficient* with CCAT:
10 sources in 0.5 sq deg simultaneously

Photometry. → Spectroscopy.

Then.
2000-
2008



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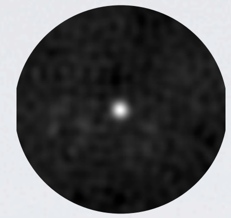

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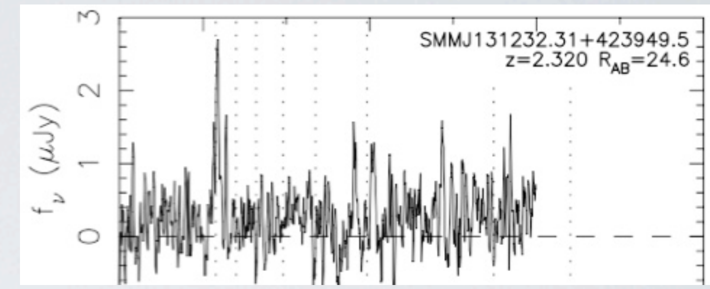
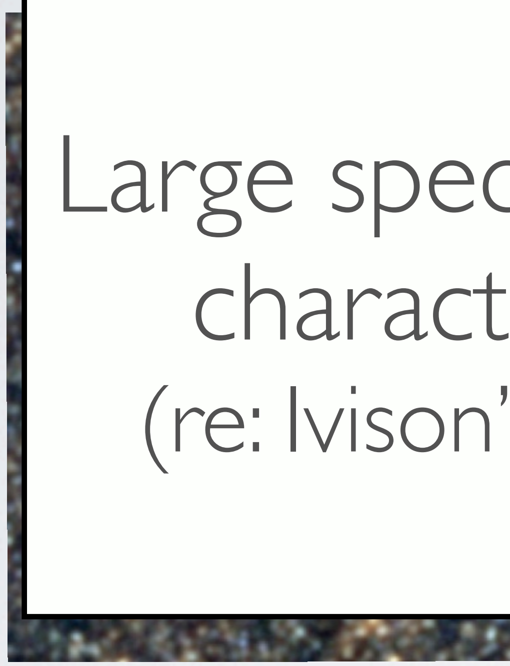


oscopic
EIMOS
firm.



Large spectroscopic samples enable detailed characterization of starbursts at high-z
(re: Ivison's comment: "are spec-z's necessary?")

Now.
2009-
2014

with CO
survey at

ALMA)

Future.
2014-

CCAT → Bypass reliance on radio/mid-IR IDs → Blind redshifts with ALMA, make *more efficient* with CCAT:
10 sources in 0.5 sq deg simultaneously

Pre-CCAT GOAL:

High-z (U)LIRG "Completeness"

Translating number counts into a bolometric/FIR luminosity function → ULIRG contribution to cosmic SFRD

Good handle from Herschel PACS/SPIRE samples (UV/optical counterpart matching is a bottleneck)

SCUBA2 450um maps

CCAT GOAL:

ULIRG Completeness revisited, remove counterpart ID bottleneck, Precise dust characterization + gas observations providing snapshot into evolutionary conditions