

COSMOLOGICAL IMPLICATIONS OF THE SCUBA SOURCES

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- Main collaborators: Smail, Ivison, Kneib, Frayer

- What are the SCUBA(/MAMBO) sources?

Selection procedures

Results of follow-up observations

Are they mergers? Timescale, morphology and counts vs background

Are they powered by star formation or AGN?

Optical/radio/X-ray observations, SEDs

- Consequences for galaxy formation:

A significant fraction of Universe's energy was released in dust-enshrouded sources

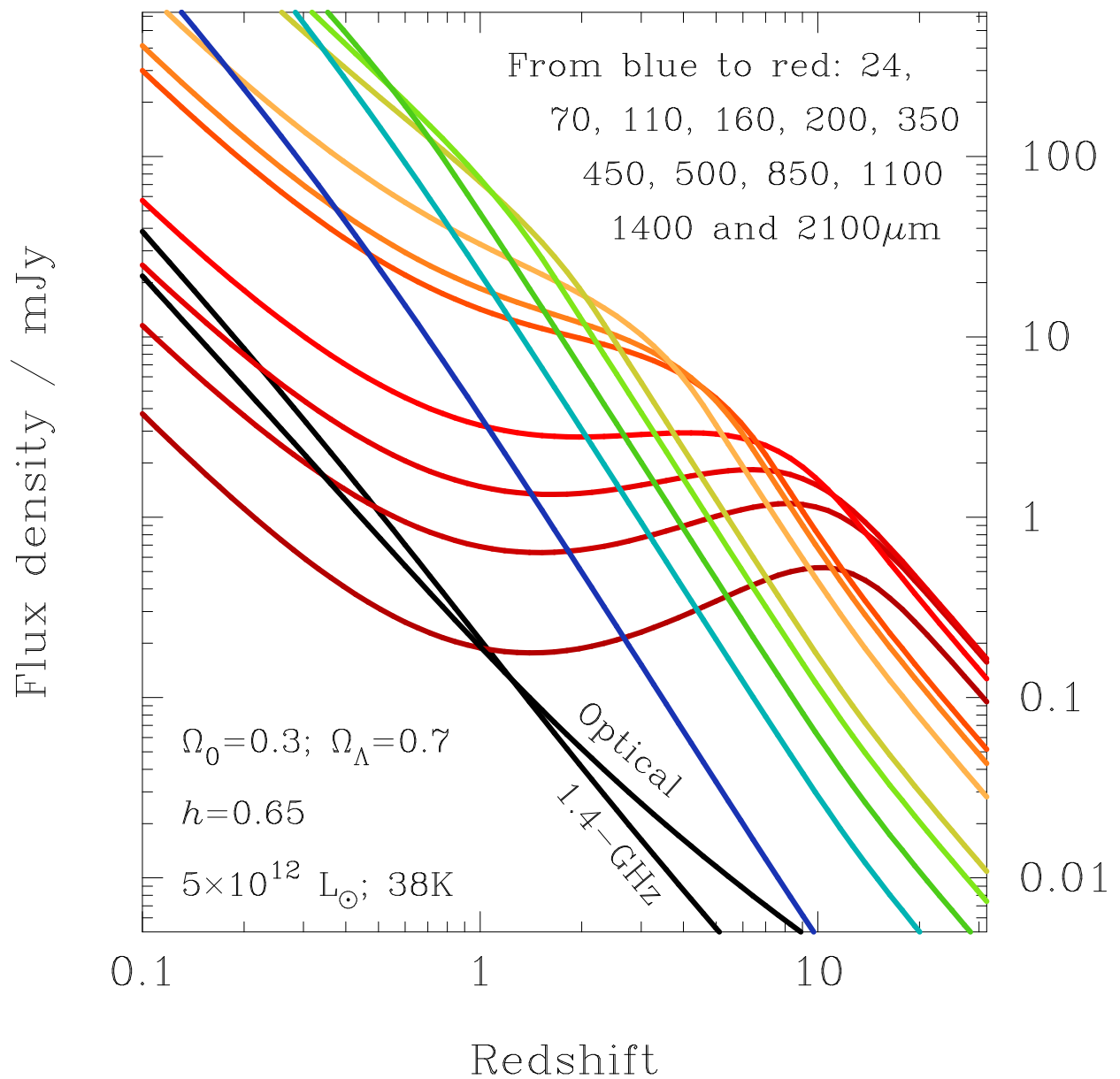
High-z luminosity function has $L^* > 10^{12} L_{\odot}$

The most extreme, active objects

Connection with low-z ultraluminous objects?

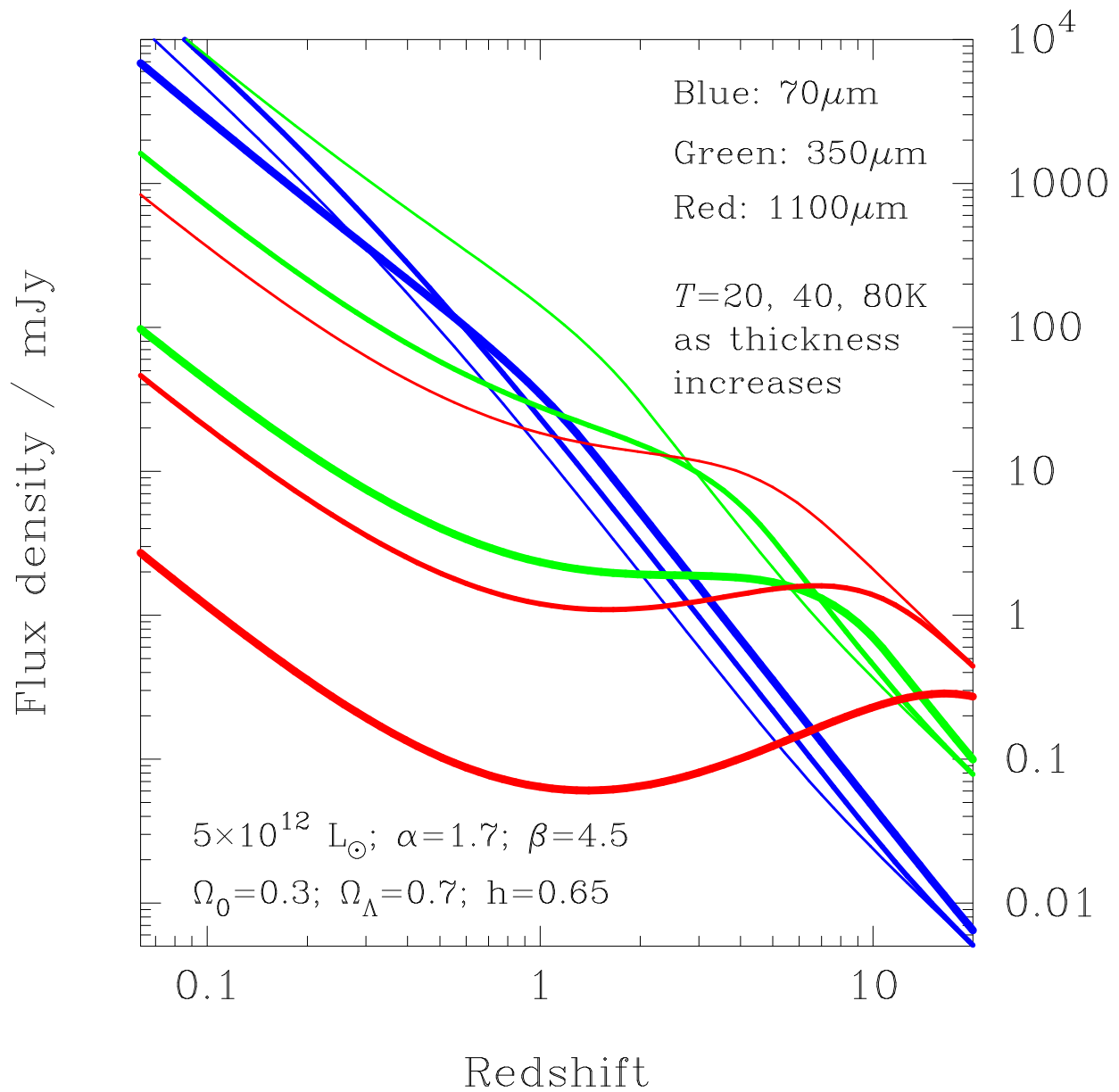
Important challenge to galaxy formation models

CONTINUUM FLUX DENSITY vs REDSHIFT



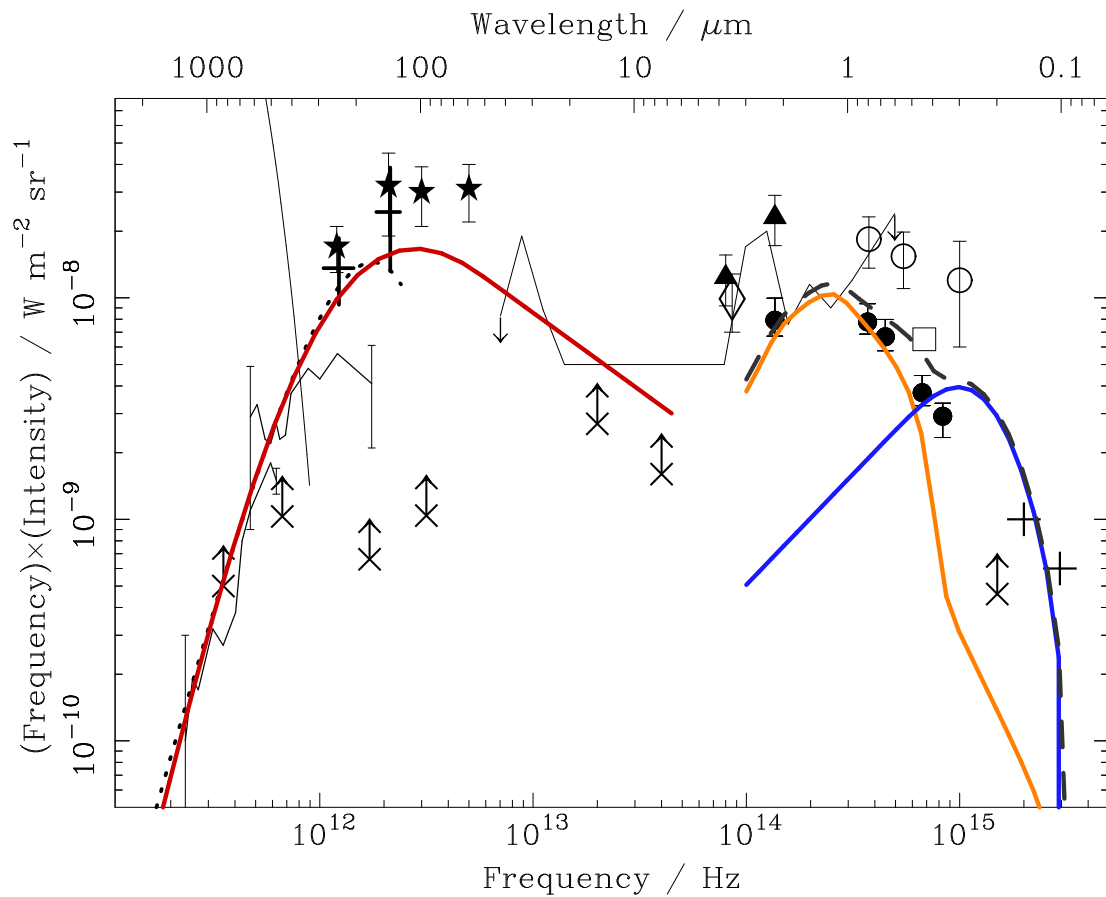
- Counter-intuitive flat relation in sub-mm
- Sufficiently sensitive instruments see 'forever'
- No problems with intervening absorbers
- Redshift information available when lines cross

EFFECTS OF DUST TEMPERATURE



- Dust temperature matters for interpretation
- Strong (sub-)mm K-correction at all T
- Sub-mm (not far-IR) selects against hot things

BACKGROUND RADIATION



Compare optical/UV and far-IR/sub-mm bands
Star/AGN light reprocessed by dust

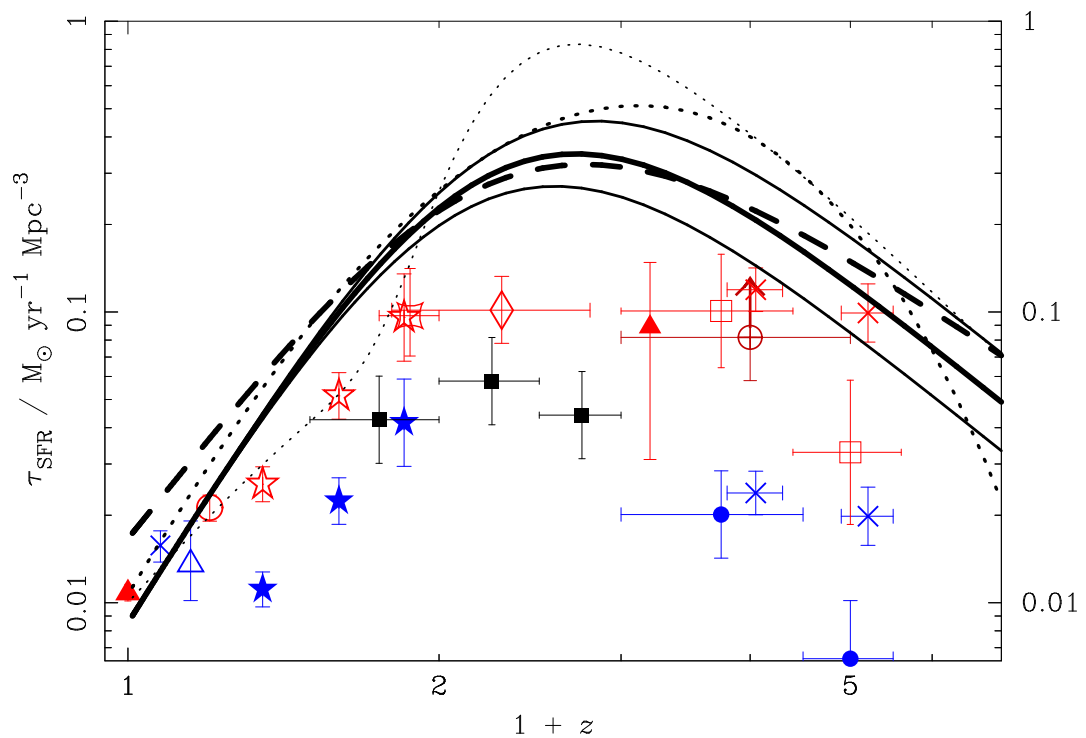
Dramatic progress in last 3 years:

- COBE-FIRAS/DIRBE in sub-mm & far-IR
- Agreement on optical/near-IR spectral shape
- SCUBA & ISO lower limits
- Uncertain 5-200 μm region (SIRTF/SOFIA)

TO DERIVE A STAR FORMATION HISTORY

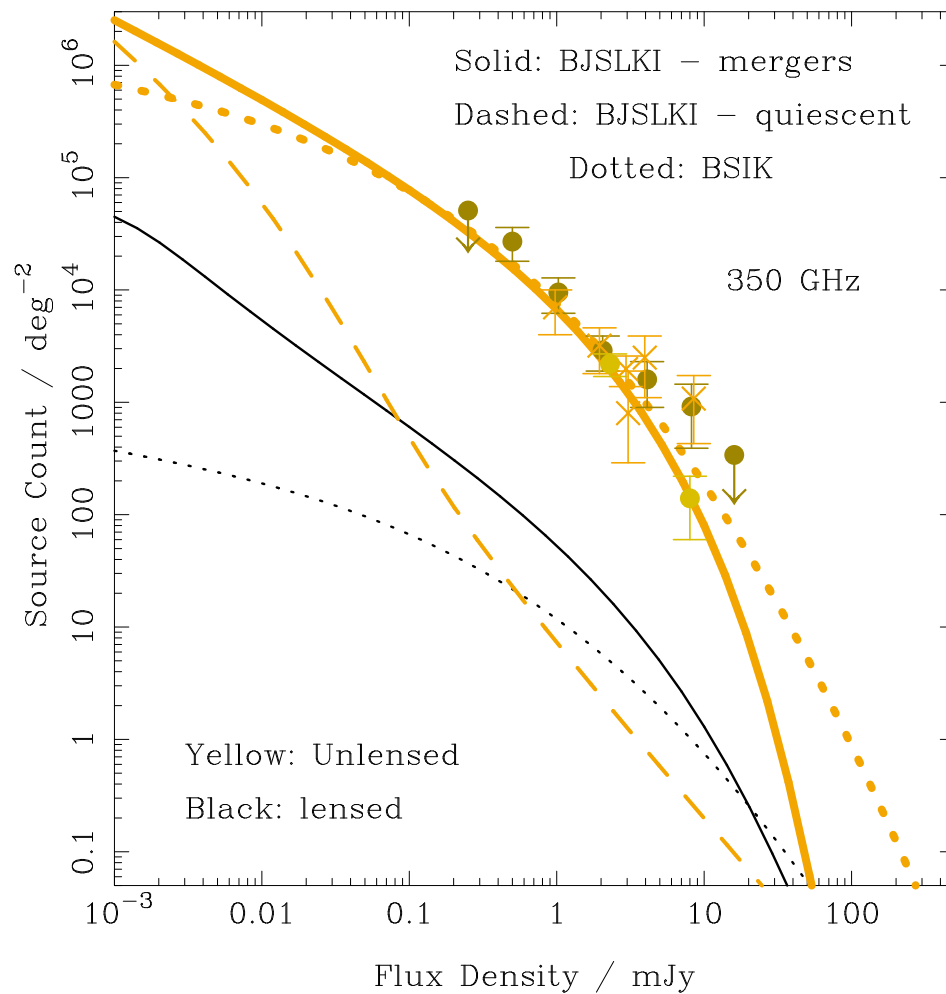
- Galaxy population well known at $z=0$ (IRAS)
 - We know the luminosity density
 - We know that it evolves as $(1+z)^{\sim 3-4}$
- Evolution confirmed at $175\ \mu\text{m}$ by ISO
 - Extends our knowledge to $z \sim 1$
 - Provides a temperature for dust
 - Accounts for 10% of background
- Finally, COBE background and SCUBA
 - Sensitive to $z \geq 1$
 - SCUBA provides the tightest constraint
 - However, no unique solution
 - Trade off rapid evolution vs. early cutoff
- To break this degeneracy need:
 - Observations at other sub-mm wavelengths
 - Redshift distribution of SCUBA galaxies
 - This is not easy – see next

GLOBAL STAR FORMATION HISTORY



- Local H α /UV surveys + radio
- Multi-waveband CFRS
- Near-IR detections at $z \simeq 1$
- Hubble Deep Field / dust corrections
 - Recently more at high-redshift?
- Submm surveys (lines + dark red point)

VERY DEEP SURVEYS AT 350 GHz



- Data from all published SCUBA surveys
- Continuum models again, plus lensed galaxies
- The quiescent galaxies could steepen faint counts
- In 160 hrs ALMA can reach 20 μ Jy (5σ)
in a 2×10^{-5} deg² area

CURRENT UNDERSTANDING OF EVOLUTION?

- Up to 80% of energy from galaxies in the Universe was emitted in the far-IR
- Could be from either massive stars or accretion: however, Chandra implies not from Type-I AGN
- Strong evolution at $z \lesssim 1$ in most bands/data
- Most optical/near-IR work implies luminosity density is flat from $z \simeq 1$ to $z \gtrsim 5$
 - Moderate/high- z $H\alpha$, restframe UV continuum
- Submm results indicate that luminosity density probably peaked (higher) at $2 \lesssim z \lesssim 3$
 - Submm background implies decline at high z
 - As does the submm-selected z distribution
 - But, weak-ish limit & incomplete distribution
- In submm almost all background comes from super- L^* ($>10^{11} L_{\odot}$) high-redshift objects

SUMMARY

- Sub-mm selection, using SCUBA and MAMBO, has revealed a new population of high- z galaxies
- Difficult to select in other wavebands – certainly true in optical, but note K-faint/ μ Jy-radio galaxy observations (Barger, Cowie & Richards)
- Some are certainly involved in mergers
- AGN and star-formation power well-studied cases
- Only 3 sub-mm-selected galaxies have certain redshifts: $z = 1.06, 2.55, 2.80$. Additional $z = 1.61$ and 2.80 candidates. Searches continue
- A significant fraction of high- z luminosity comes from SCUBA galaxies and their fainter cousins
- Provide signposts to high-activity sites at high- z ?