The SCUBA Local Universe Galaxy Survey

— Dust along the Hubble sequence —

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Overview

- What is SLUGS?
- Results from the survey
- Recent work using SLUGS results
  - the FIR-radio relation

Introduction: SLUGS

SLUGS – a submm survey of galaxies in the local Universe
– at 850μm and 450μm

Survey of ~200 nearby galaxies:

- 104 60μm-selected ("IRS")
(Dunne et al. 2000, Dunne & Eales 2001)
- 81 optically-selected ("OS")
  – drawn from right along the Hubble sequence
(Vlahakis, Dunne & Eales 2005)

"OS" sample: investigate the properties of dust along the whole length of the Hubble sequence, in particular the cool 20 K dust

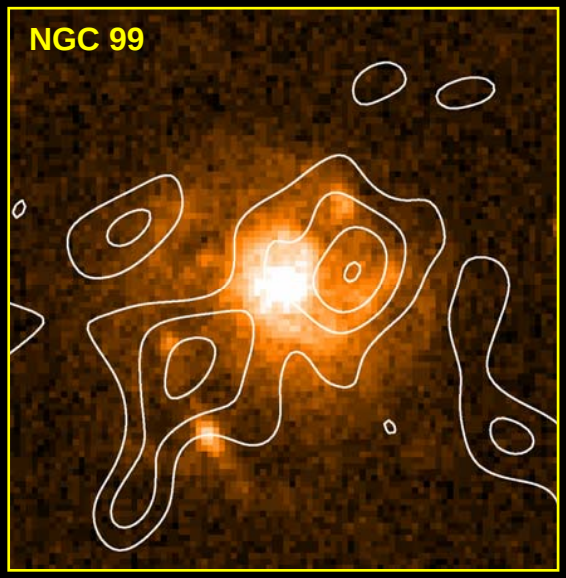
OS SLUGS results: submm morphology

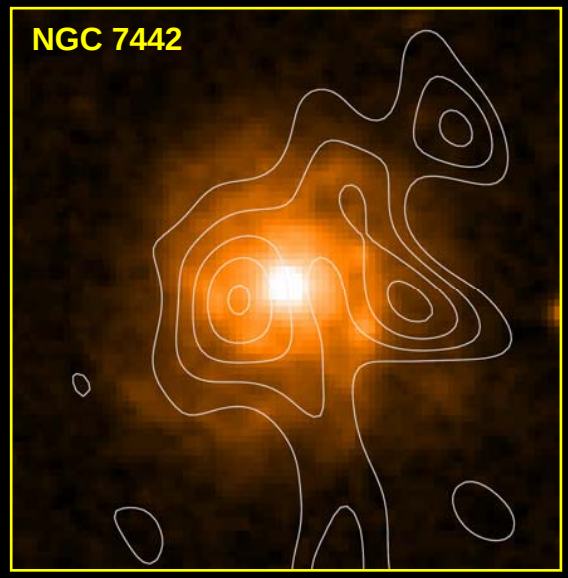
Detected 52 galaxies in the OS sample, 17 of which also detected at 450μm

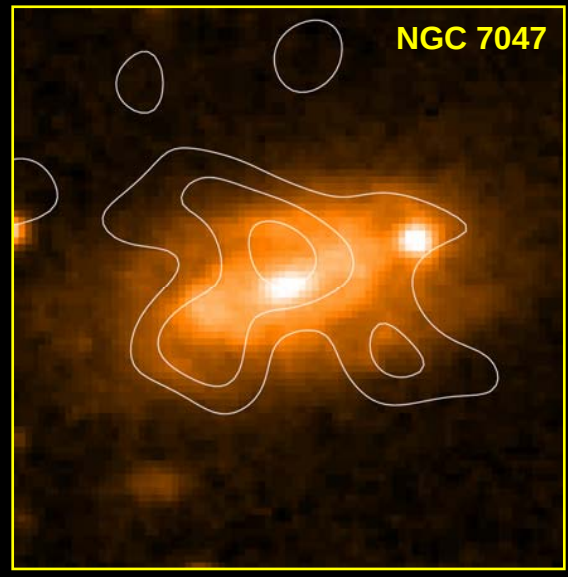
Several common features in the submm morphology of spirals:

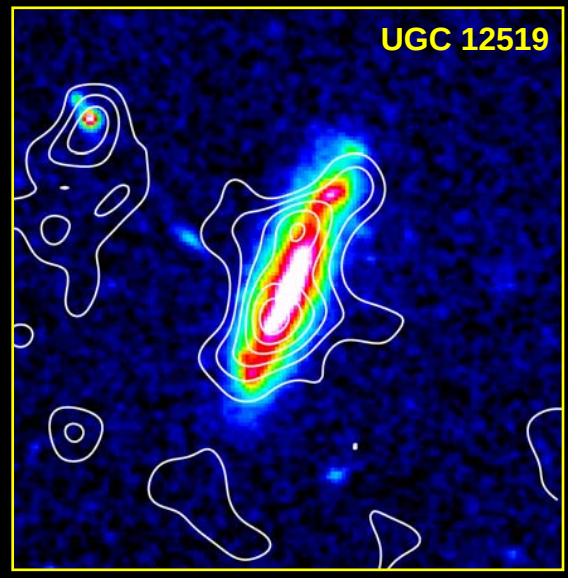
- many exhibit two peaks of 850-μm emission, seemingly coincident with spiral arms
- others are core dominated and exhibit a single central peak of submm emission
- many have a combination of these features or have irregular morphologies
- in a number of cases the submm emission clearly follows a prominent dust lane

OS SLUGS results: submm morphology

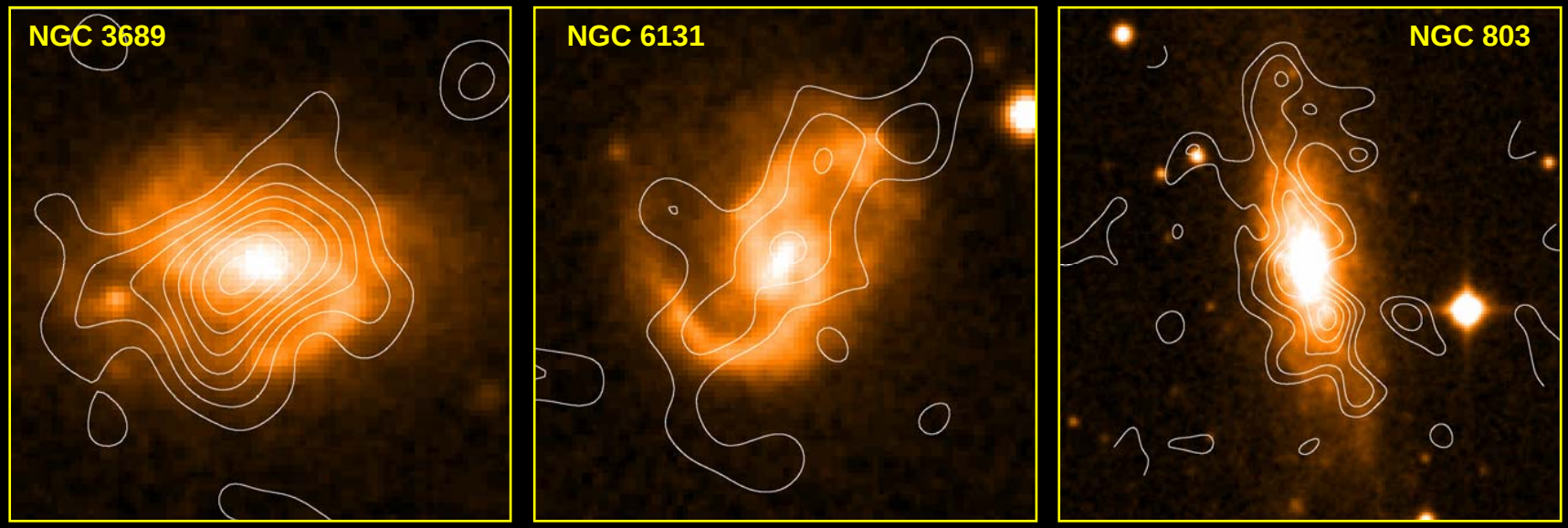








OS SLUGS results: submm morphology



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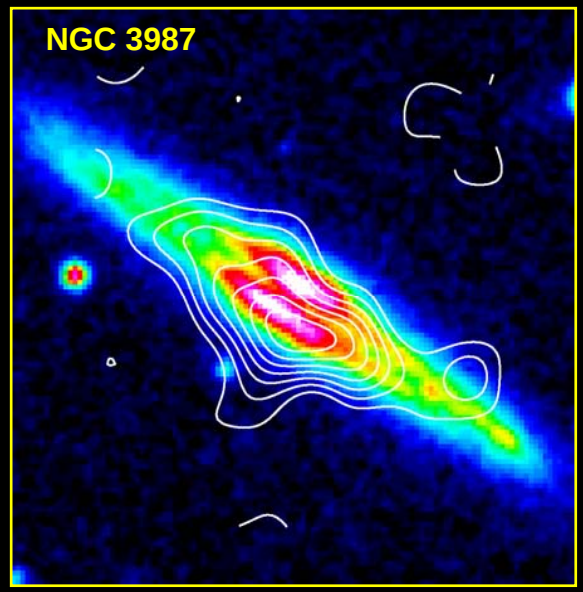
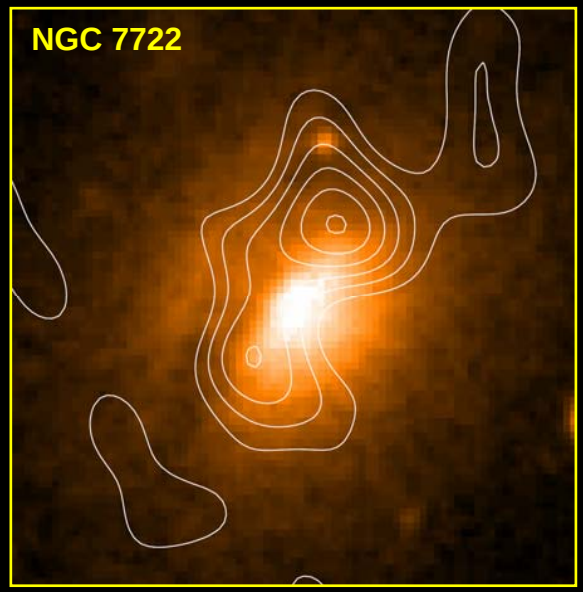
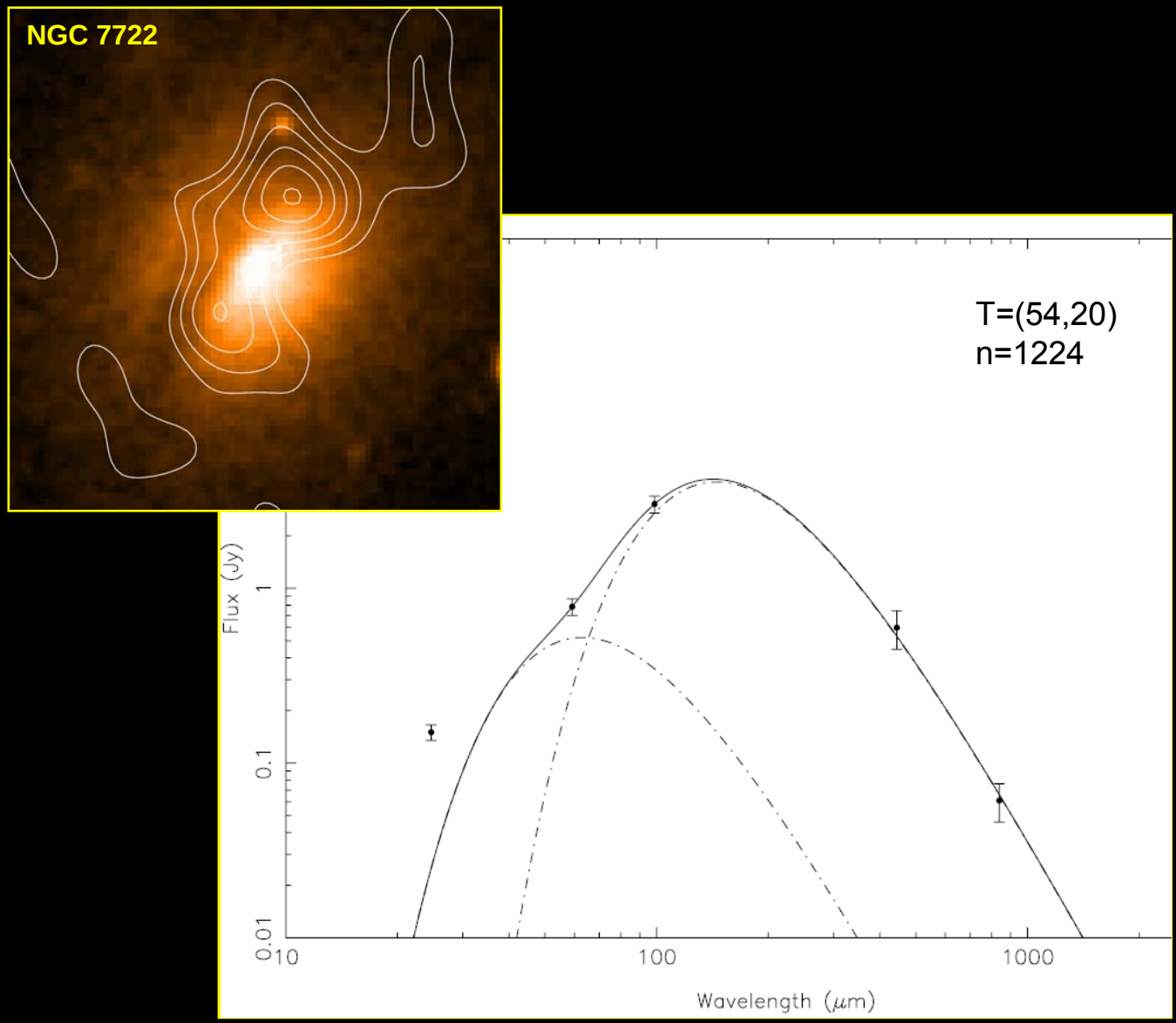


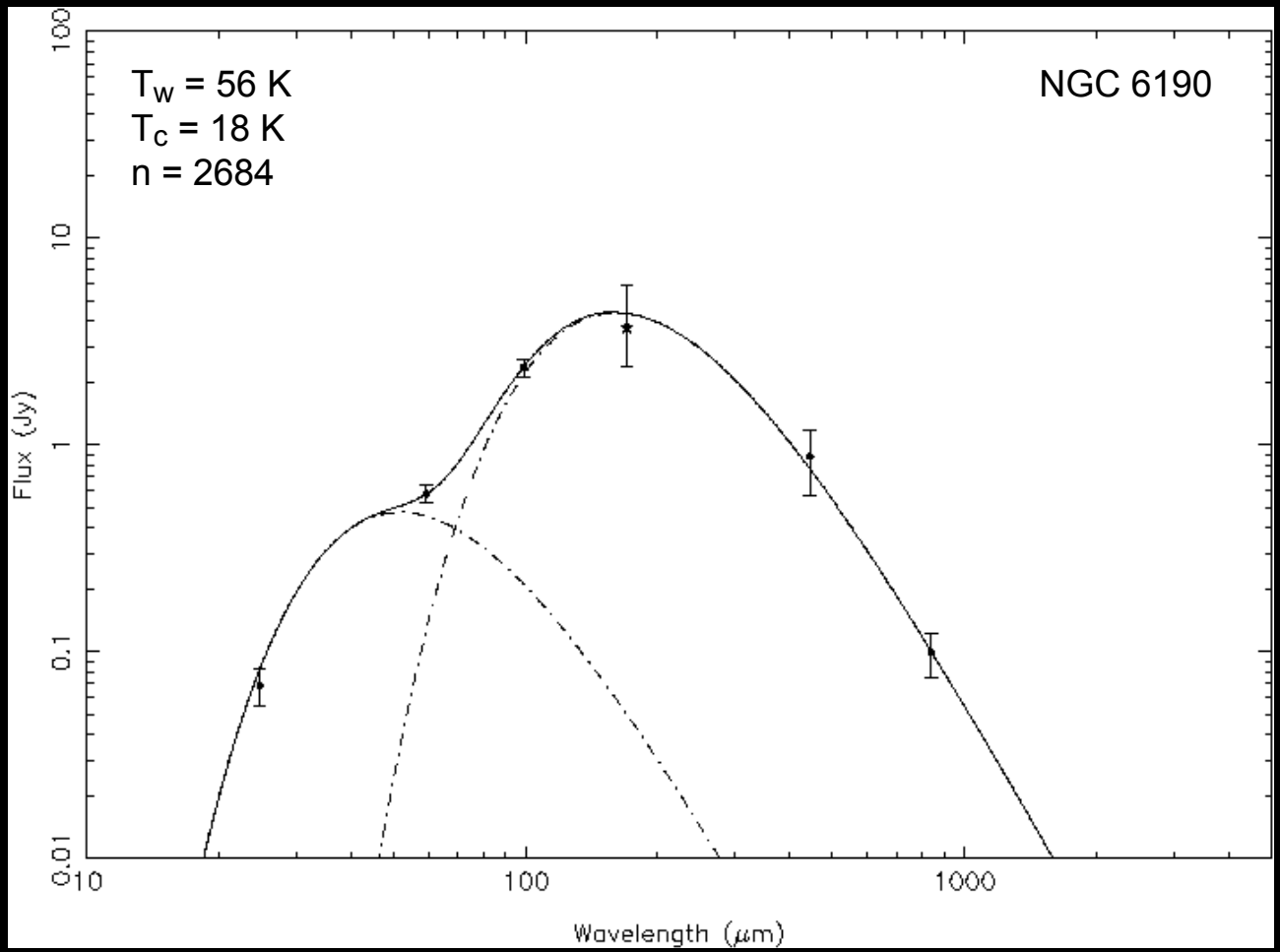


Any correlation between Hubble type and submm morphology?

OS SLUGS results: two-component SED



OS SLUGS results: two-component SED



OS SLUGS results: two-component SED

We find that the 60-, 100- (*IRAS*), 450- and 850-μm (SCUBA) data are well fitted by a two-component dust model with dust emissivity index β=2

The temperatures of the warm component range from 28 to 59 K

The cold component temperatures range from 17 to 24 K

Ratio of mass of cold dust to mass of warm dust (N_c/N_w) much higher for our OS galaxies than for *IRAS*-selected galaxies

- *can reach values of ~1000*

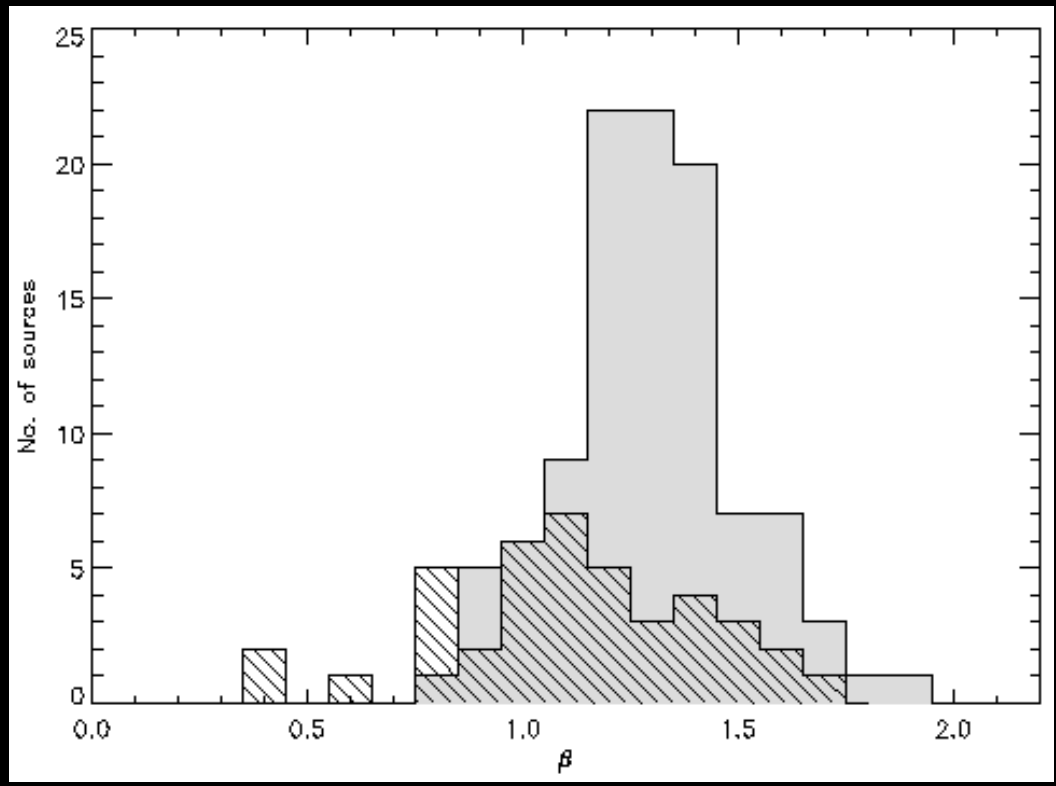
OS SLUGS results: single-component SED

Mean dust emissivity index β=1.1

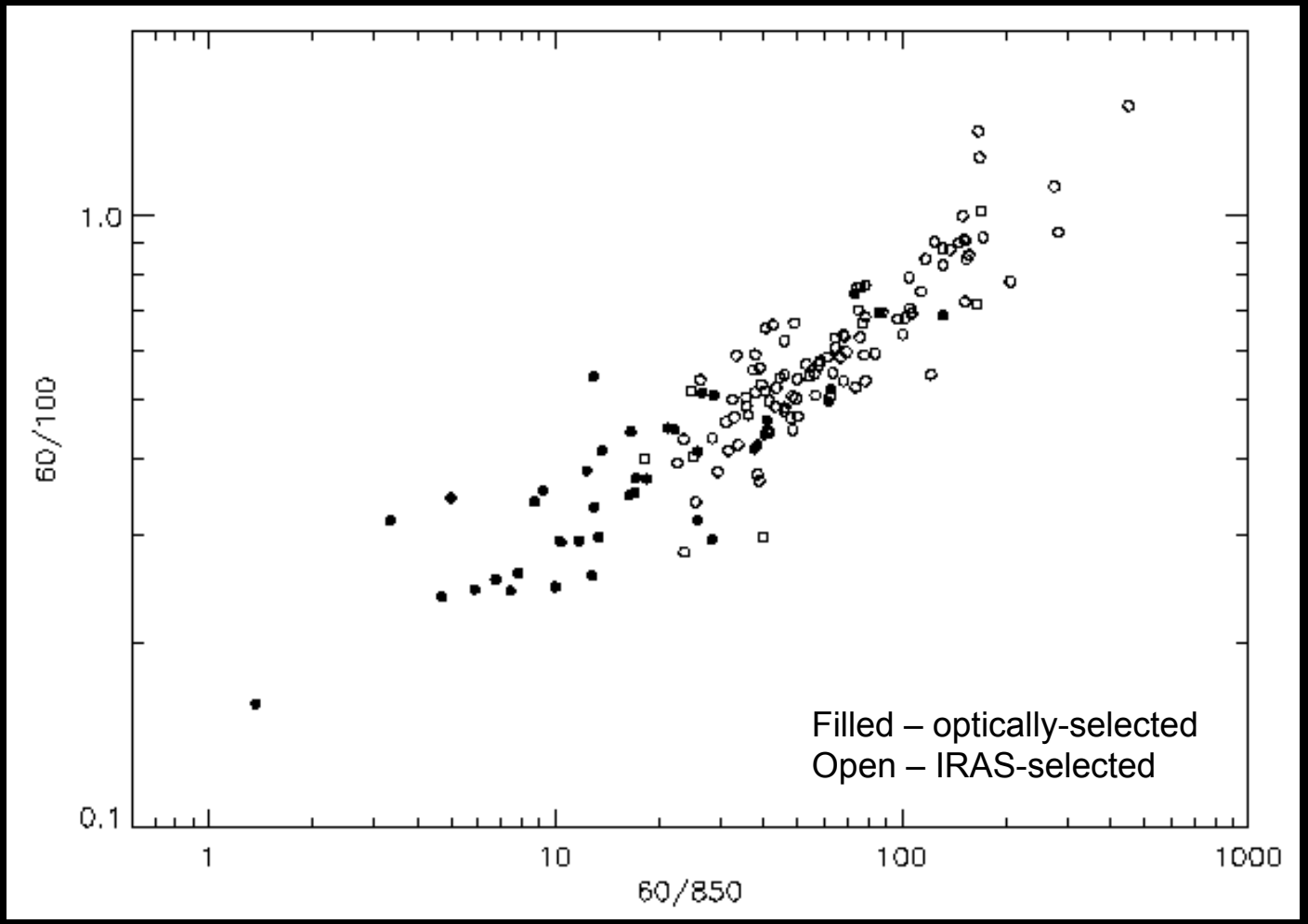
Significantly lower than the *IRAS* selected sample

Rather than a physical difference in the emissivity behaviour of the grains (β) we believe that it is due to a difference in the ratios of cold to warm dust

Distribution of β values



SLUGS results: Colour-colour plot



Population of galaxies containing a large proportion of cold dust - unrepresented in the *IRAS* sample

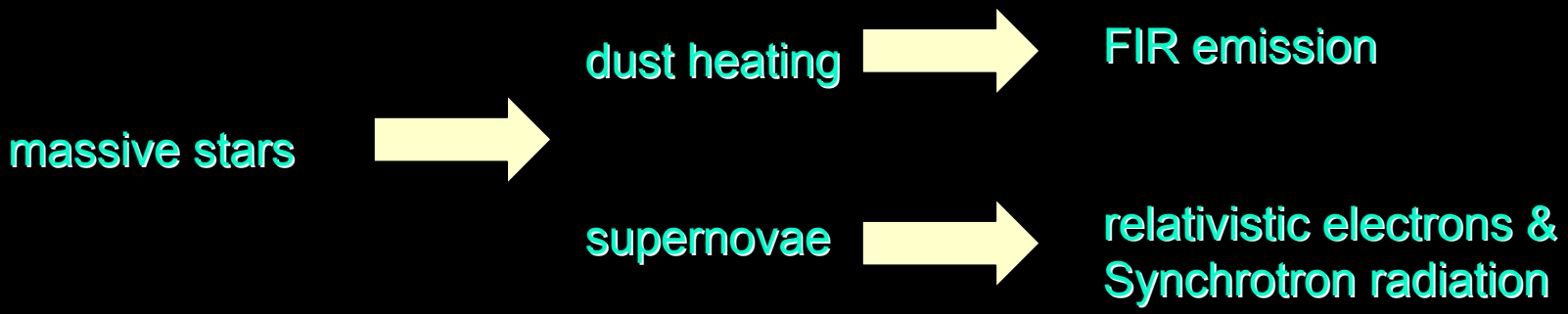
FIR-radio relation

Relation between non-thermal radio and FIR emission from galaxies

- *One of strongest correlations in astronomy*
- *Tight correlation over 5 decades of luminosity*

Cause of relationship still unclear

"Standard" explanation: both FIR and radio emission caused by high-mass stars



FIR-radio relation

Optically-selected SLUGS submm measurements allow us to **test a basic prediction of the standard theory**

Standard model prediction:

- FIR-radio correlation will be tighter than the submm-radio

Reason:

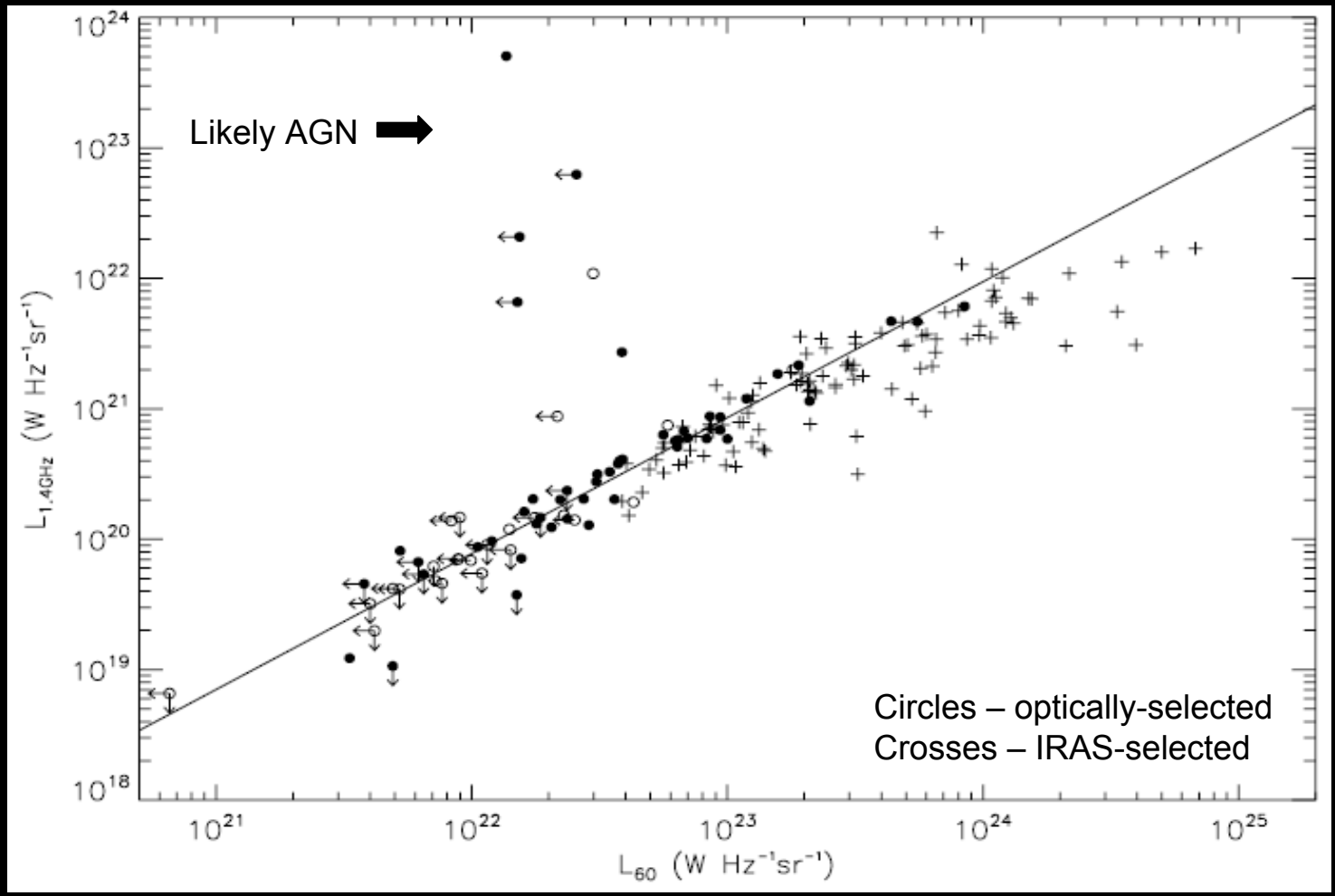
Regions with large no. of OB stars :

- ISRF more intense
- dust hotter than in general ISM
- gives rise to 60μm emission

850μm emission:

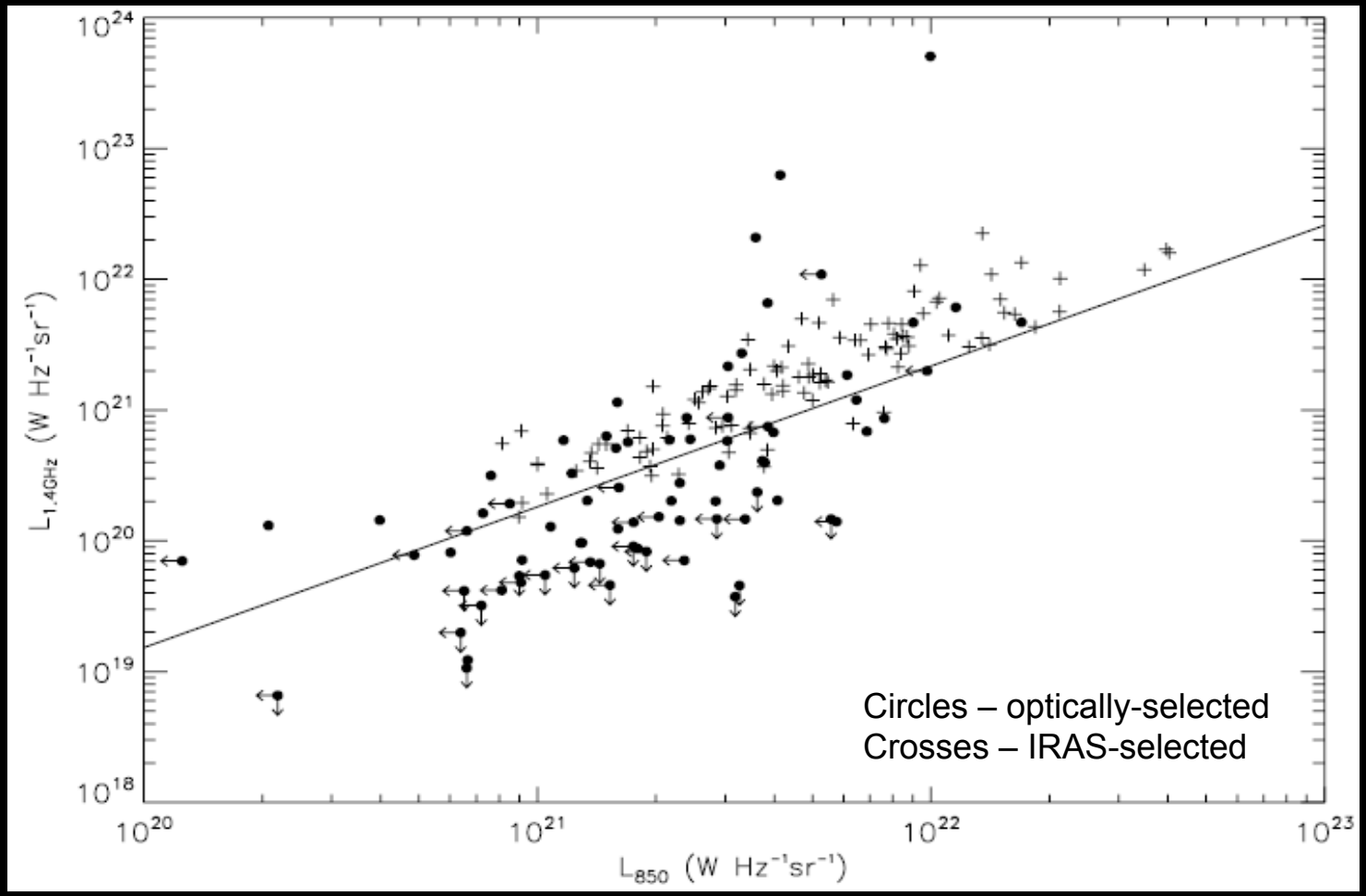
- traces colder dust heated by ISRF
- includes component from older stellar populations

SLUGS FIR-radio relation



Tight correlation between FIR and radio for OS sample

SLUGS submm-radio relation



Much larger scatter of submm-radio relation for OS sample

→ Exactly the behaviour we would expect if standard model is correct

High-z Universe: α-redshift relation

Carilli & Yun method:– Use redshift-sensitive nature of submm-radio flux density ratio as redshift estimator

$$\alpha_{1.4}^{850} \propto \log\left(\frac{S_{850}}{S_{1.4}}\right)$$

Based on assumption that the FIR-radio relation is the same at low-z and high-z

We use fitted SEDs for 17 OS SLUGS galaxies to

– Predict how α depends on redshift, for "normal" low-z galaxies

– Compare with deep SCUBA sources with spectroscopic redshifts (Chapman et al. 2005)

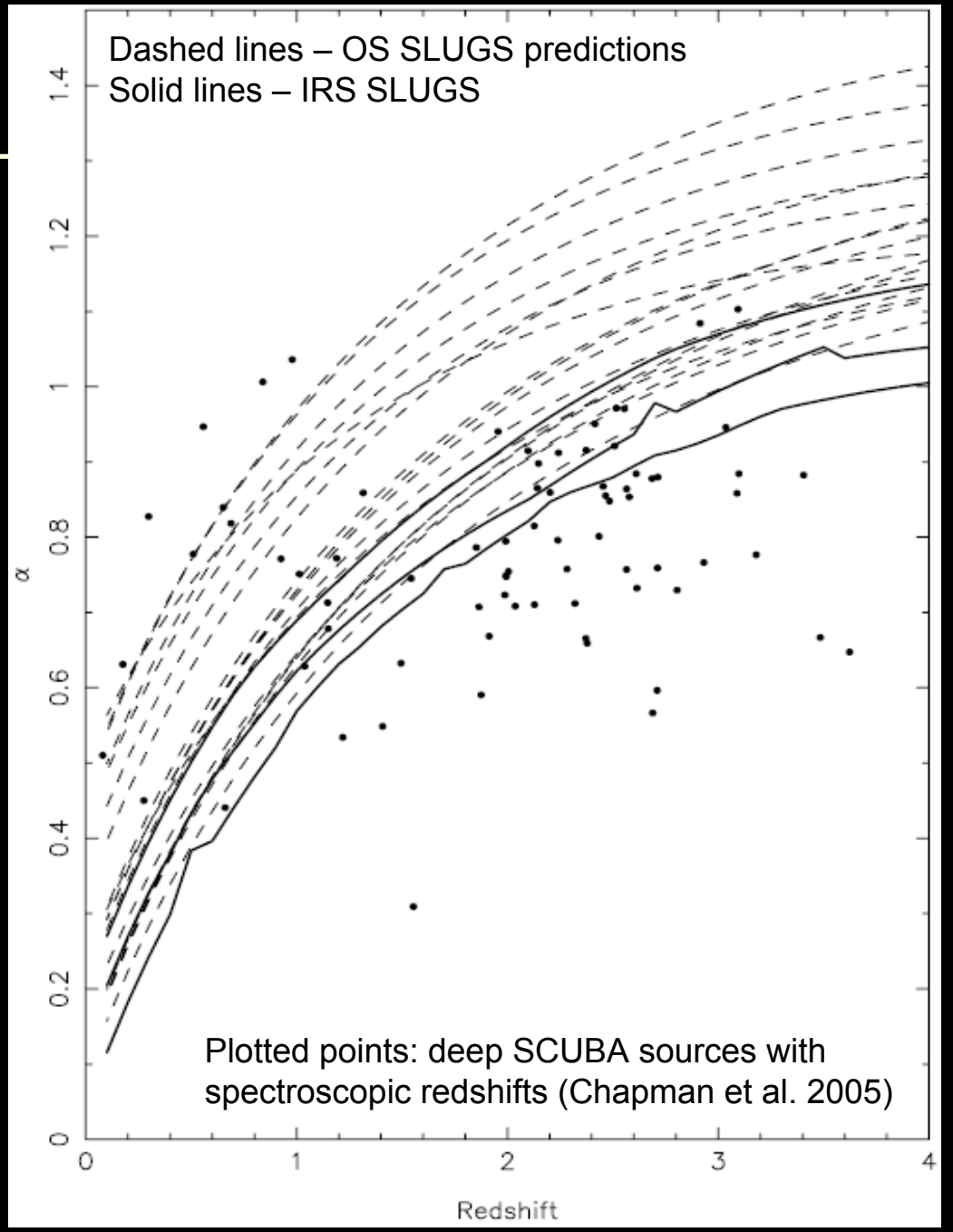
– Use this to assess reliability of CY method

α-redshift relation

- Source could be IRS-like and high-z or OS-like and low-z
- Temp affects position on α–z diagram
- Difficult to get reliable estimates of redshift in this way

Deep SCUBA sources:

- No correlation, but…
- Brighter in radio (or fainter in FIR) than the predictions for our local SLUGS samples
- A number of possible explanations



α-redshift relation: possible explanations

i. Correlation between α and luminosity at given z
   - Unlikely
     - No evidence for sufficient correlations out to high redshift

ii. Chapman sources: FIR and radio emission comes from AGN
   - Unlikely:
     - Not strong x-ray sources
     - Radio morphologies not typical of AGN
     - Optical spectra often starburst not AGN

iii. Redshifts of Chapman sources are unreliable
   - Unlikely
     - Test this using subsample with robustly determined redshifts (Aretxaga et al. 2007) and find no difference

iv. Relation between FIR and radio different at high and low z
   - Very different conditions compared to today → surprising if relation were the same
   - We feel is the most likely explanation

Summary

- 60-, 100- (*IRAS*), 450- and 850-μm (SCUBA) fluxes are well fitted by a two-component dust model with dust emissivity index β=2
- **Ratio of mass of cold dust to mass of warm dust** much higher for our OS galaxies than for *IRAS*-selected galaxies
- FIR-radio correlation for OS SLUGS much stronger than submm-radio, **evidence that massive star formation is cause of FIR-radio relation**
- Much more scatter in α–z relation for "normal" galaxies than for bright IRAS galaxies
  - **For CY method to be reliable as redshift estimator for deep submm sources, first need measurement of dust temp**
- α–z relation: deep submm galaxies brighter sources of radio emission than predicted from properties of local galaxies
  - **possible explanation is evolution of FIR-radio relation**