Dust in Early Type Galaxies and Across the Hubble Sequence

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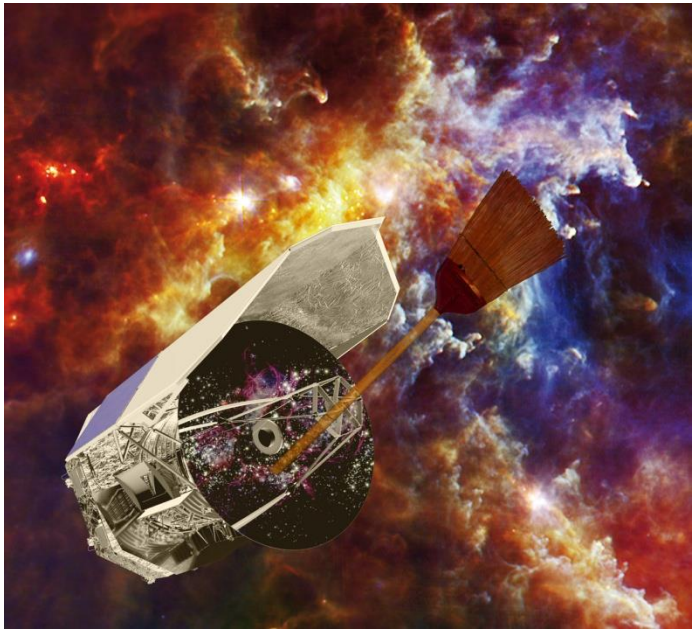
SAG2 & HeViCS teams

Universe Explored by Herschel
ArXiv: 1112.1408



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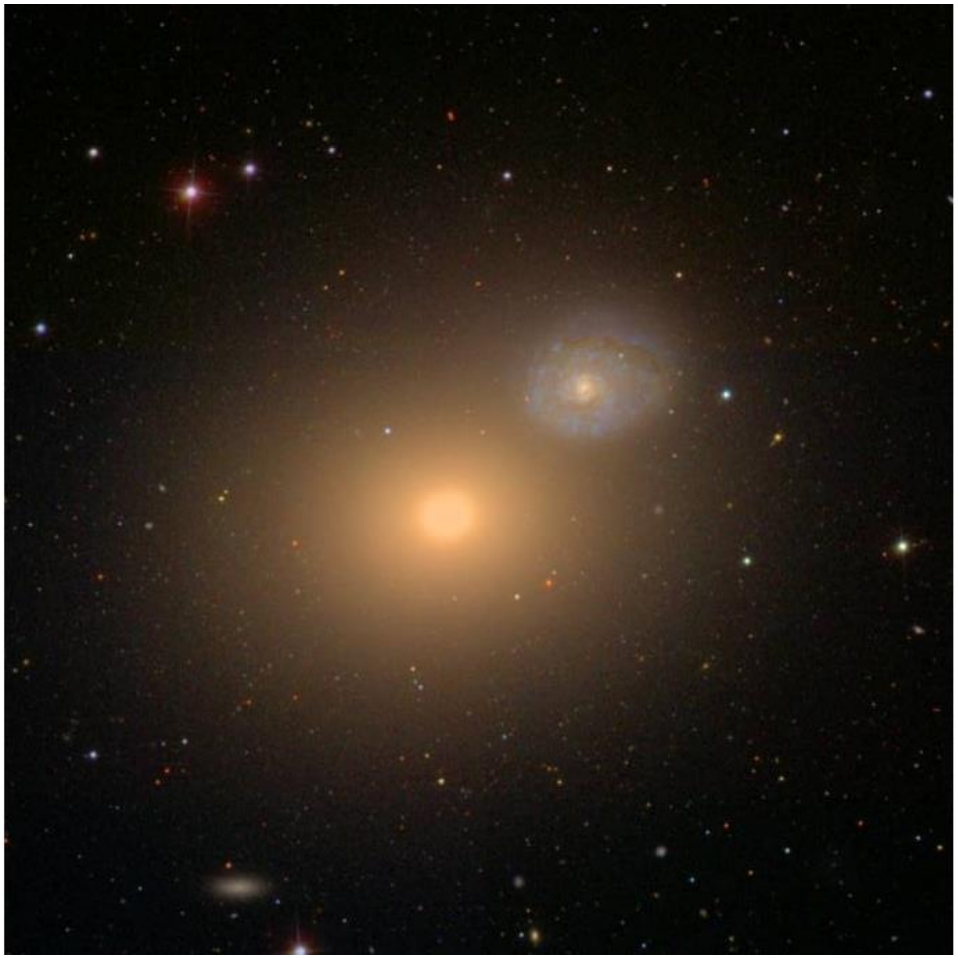
Dust in Early-Type Galaxies and across the Hubble sequence



Smith et al. 2012

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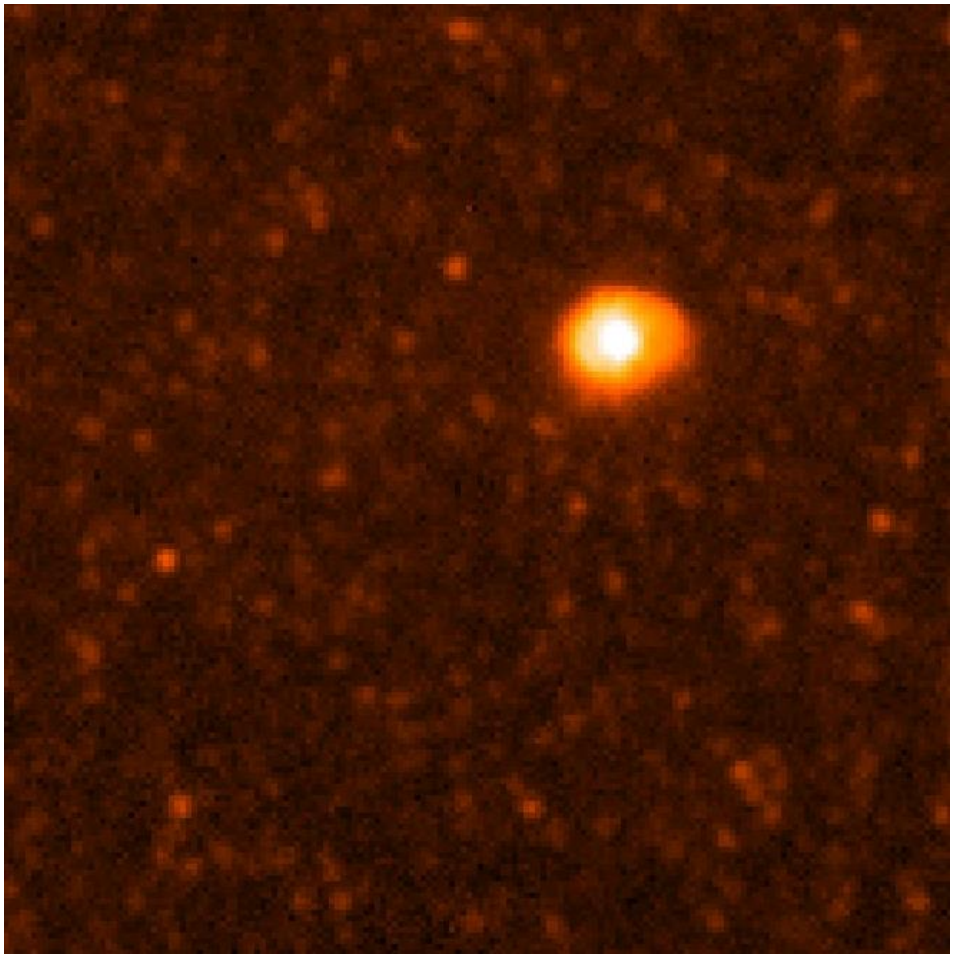


Smith et al. 2012

Dust in Early-Type Galaxies

- ETGs (especially E's) are thought to be:

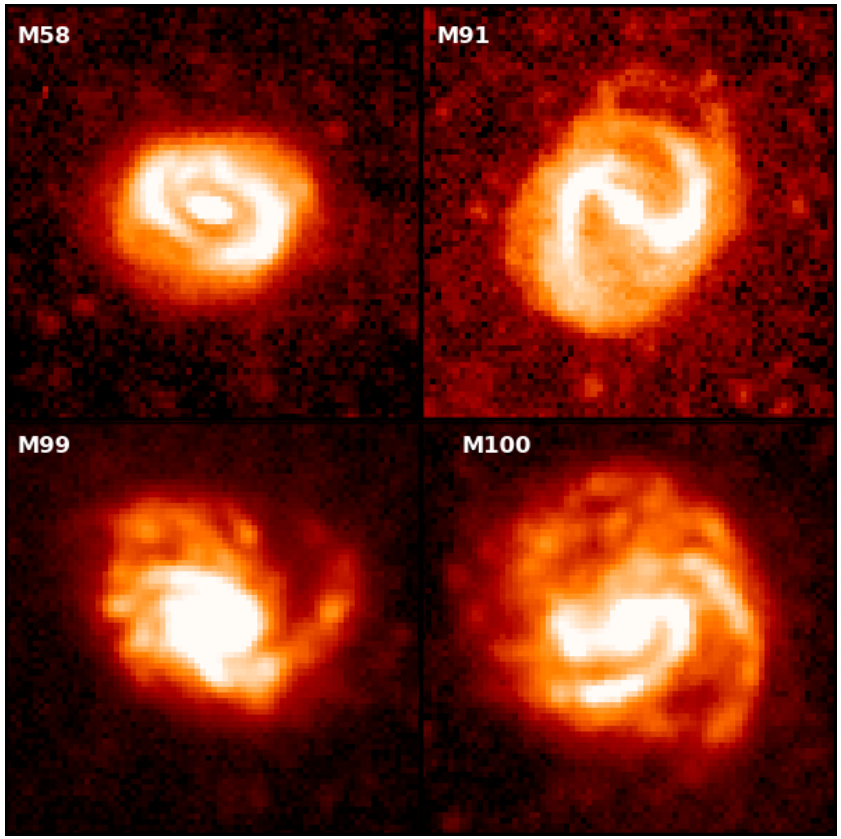
Red and Dead

&

Contain No ISM

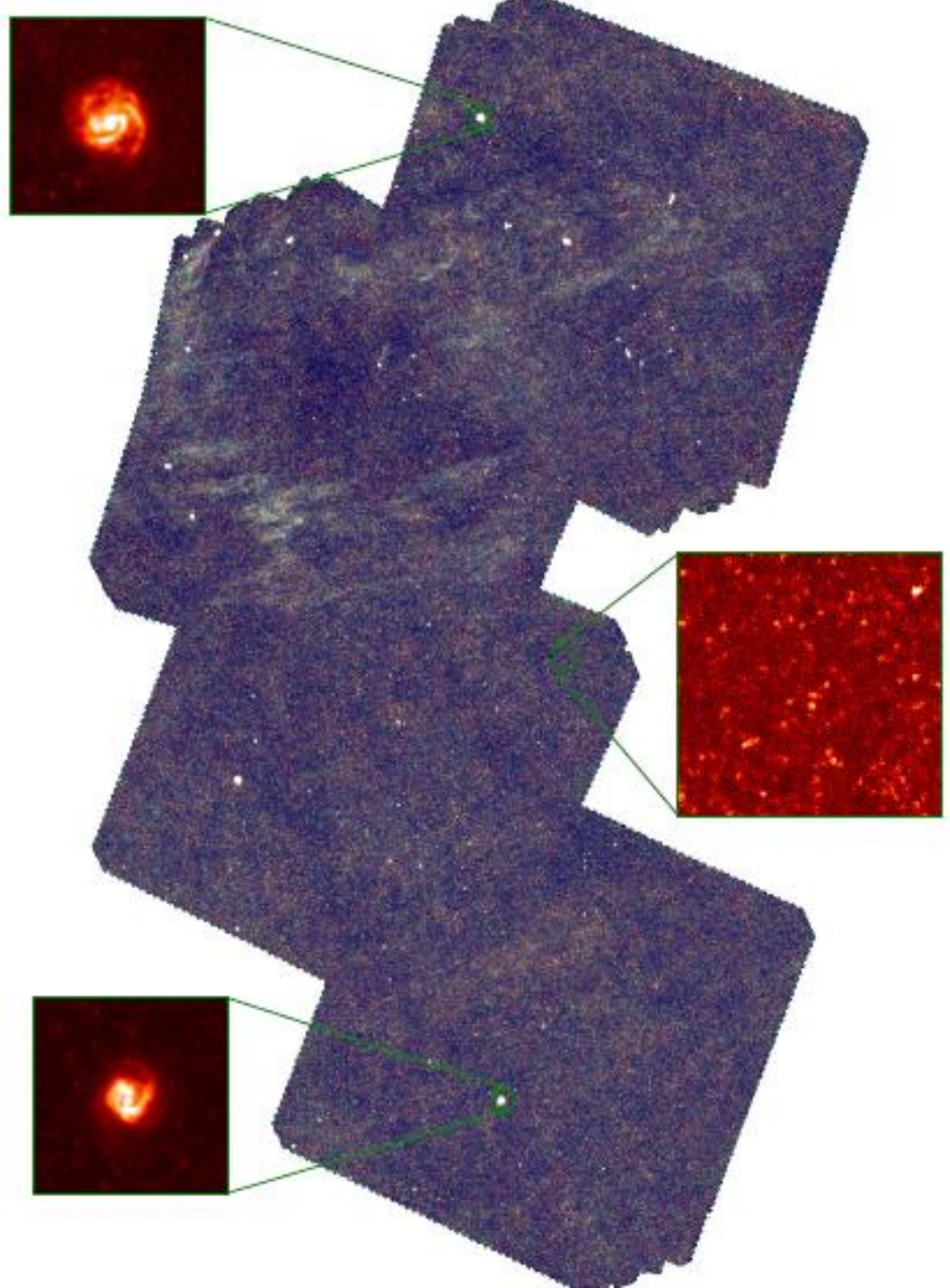
- How much ISM do these objects contain?
- Where is the origin of the dust?

Herschel Reference Survey



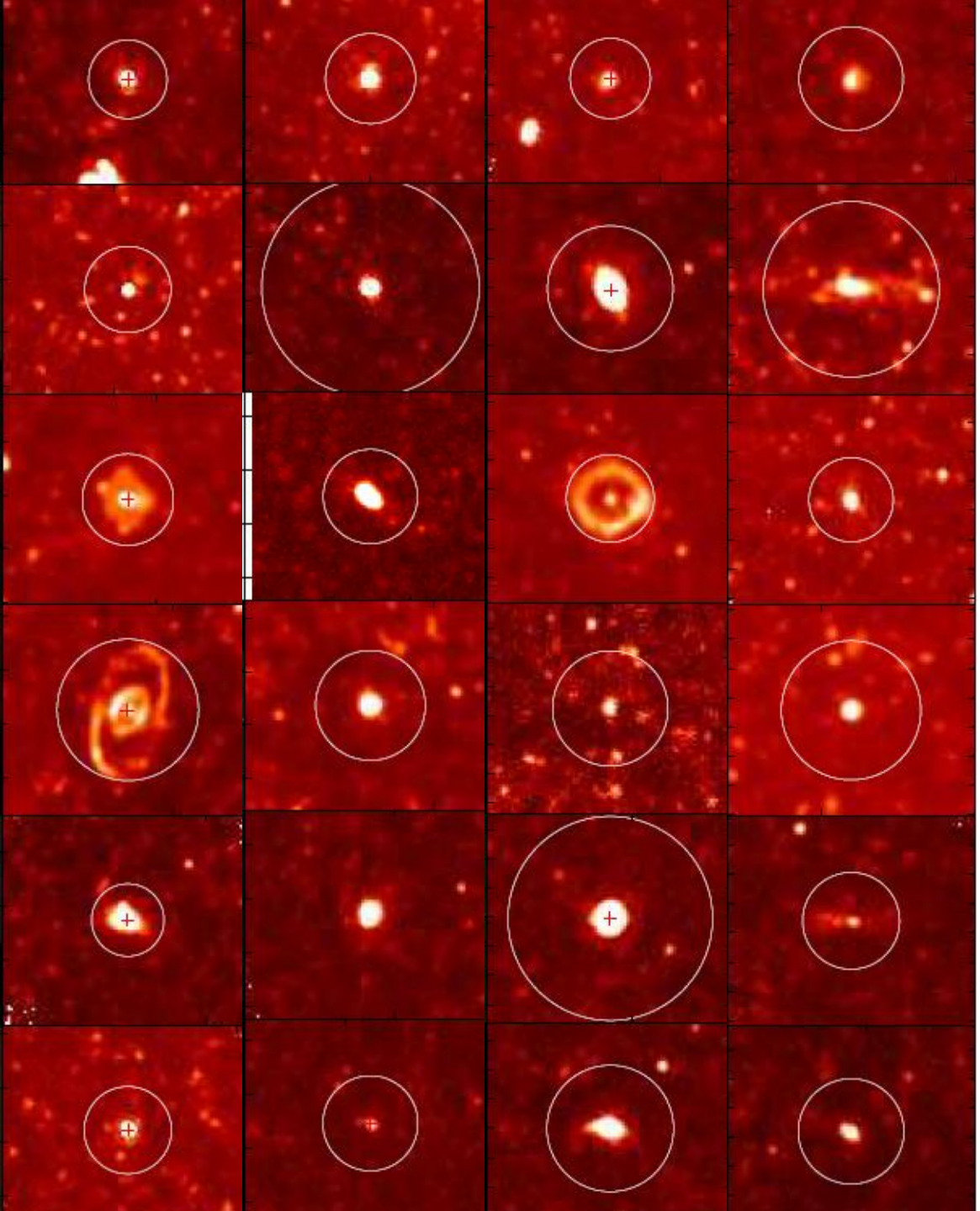
Largest Targeted Early-Type Survey with Herschel

- Statistically complete sample of **322** galaxies
- Volume Limited 15 – 25 Mpc
- High-Galactic Latitude
- Very accurate Morphologies
- K-band selected
  - Avoid dust extinction
  - Good measure of stellar mass
  - Late-type $K_{stot} \leq 12$
  - Early-types $K_{stot} \leq 8.7$
- OT2 PACS program
- Use custom pipeline SPIRE pipeline BriGAdE



HeViCS

- PI – Jon Davies
- Otherwise known as DAVIES
- 8 parallel scans
- 100, 160, 250, 350 and 500μm
- 80 sq. deg
- Very deep compared to survey like H-ATLAS
- Noise ~ 0.3 × confusion for SPIRE

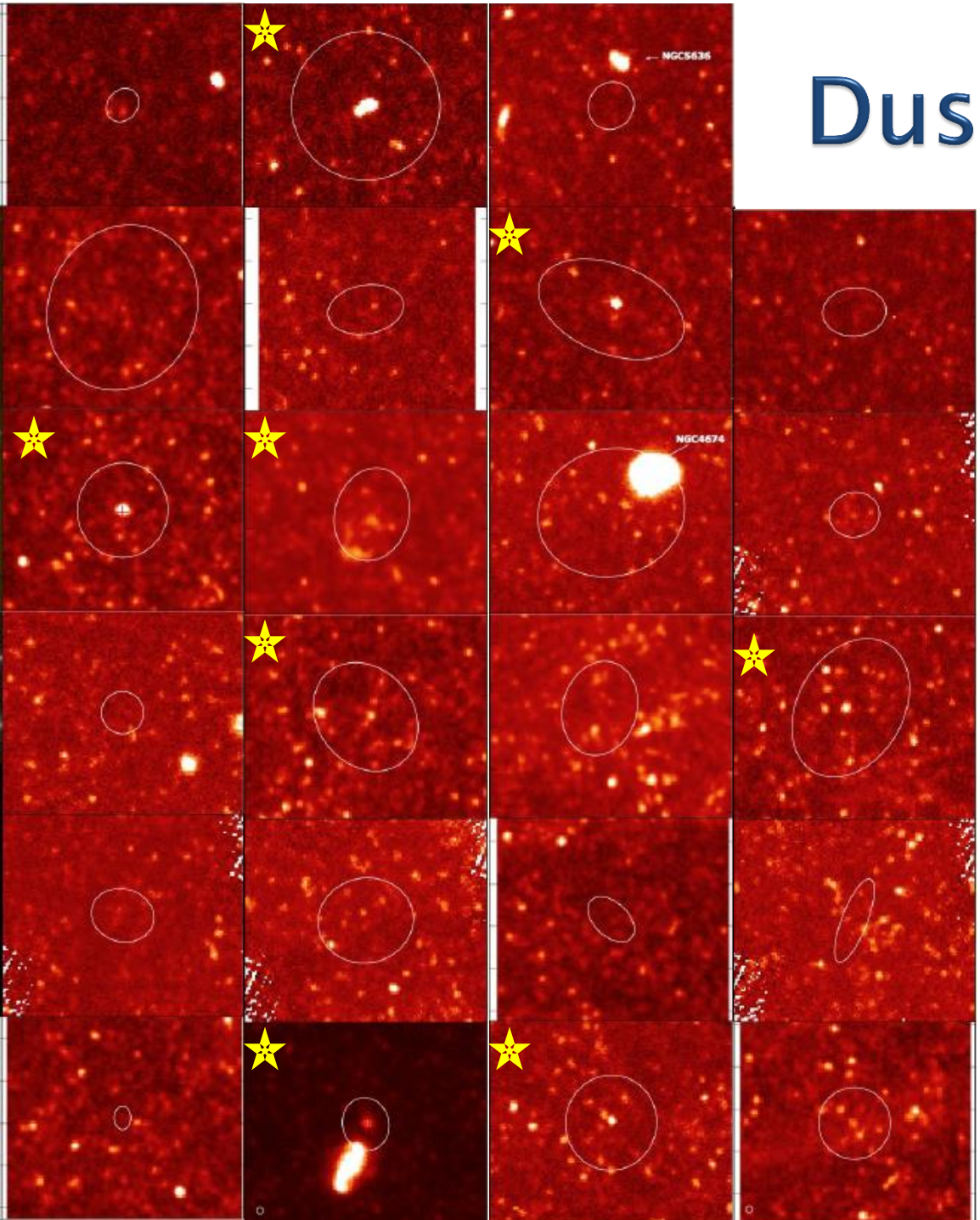


Dust in Early Type Galaxies (2)

S0 galaxies

- Large bulge and a definite disk of stars.
- No sign spiral arms
- No dust lane (if edge on)
- Little or no ISM -> little Star Formation

Dust in ETGs (3)



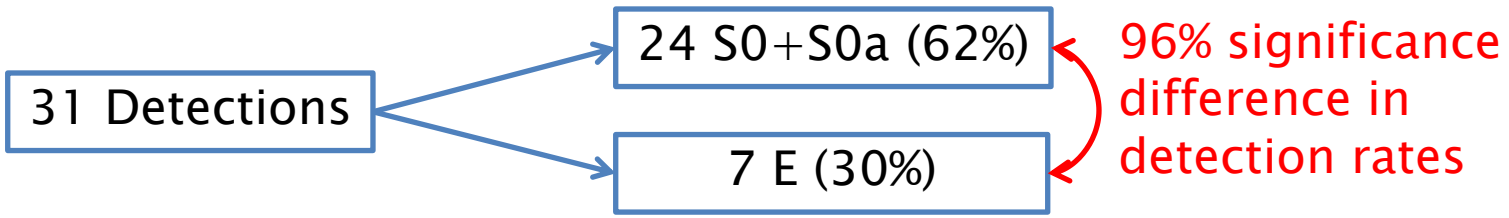
Ellipticals

- Smooth ellipsoidal shape.
- No disk/spiral arms
- Little or no ISM -> little Star Formation

★ = detected at 250μm S/N > 5 – with very conservative noise estimate

Detection Rates

- 62 Early Types in the Sample



- Previous IR works
  - IRAS (Bregman et al. 98) detected 12-17%
  - Temi et al. 04 with ISO 41% Elliptical and 79% S0 – biased to peculiar objects.

Detected Ellipticals

- What is special about 30% of Ellipticals?

7 Detections

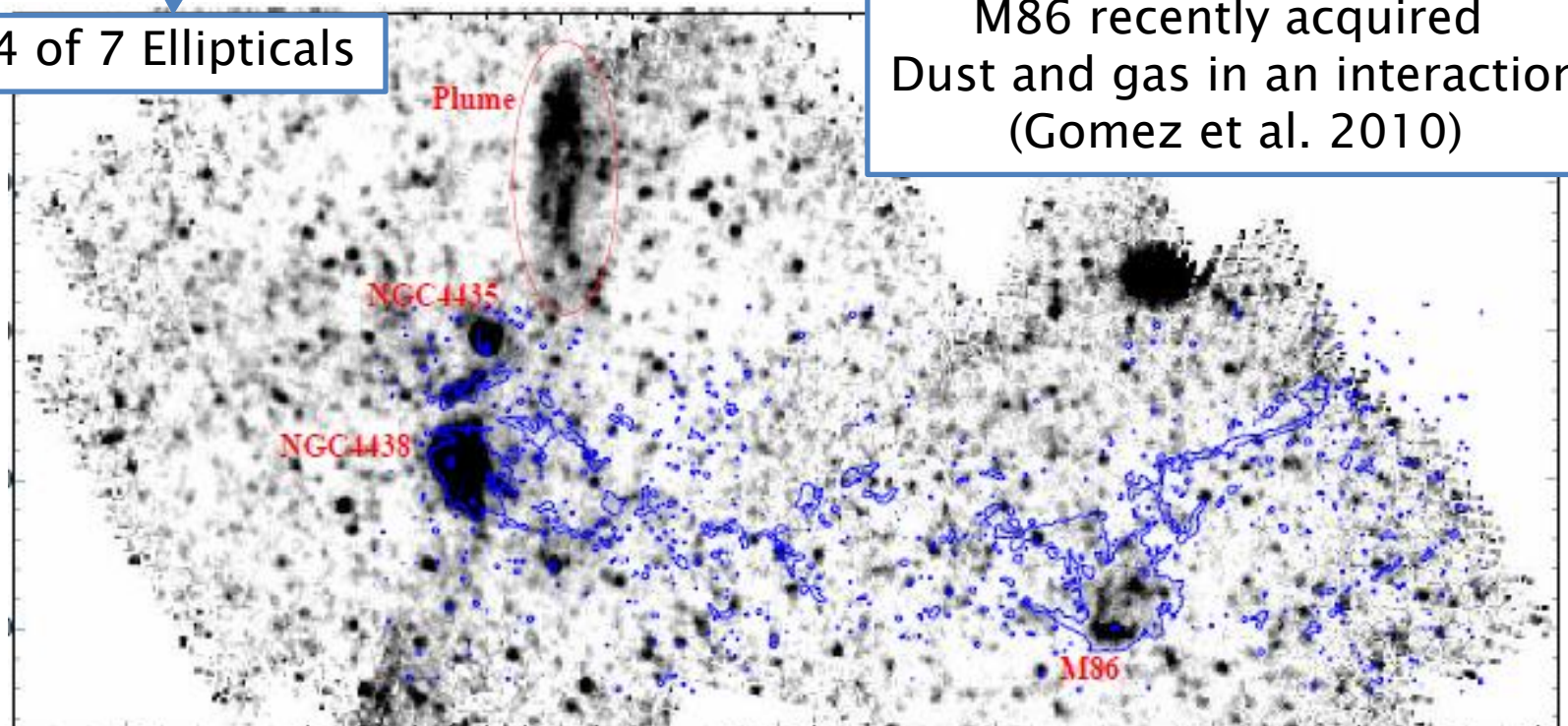
20 LINER ETGS
16 are detected

2 Bright AGN

1 "Pure Elliptical"

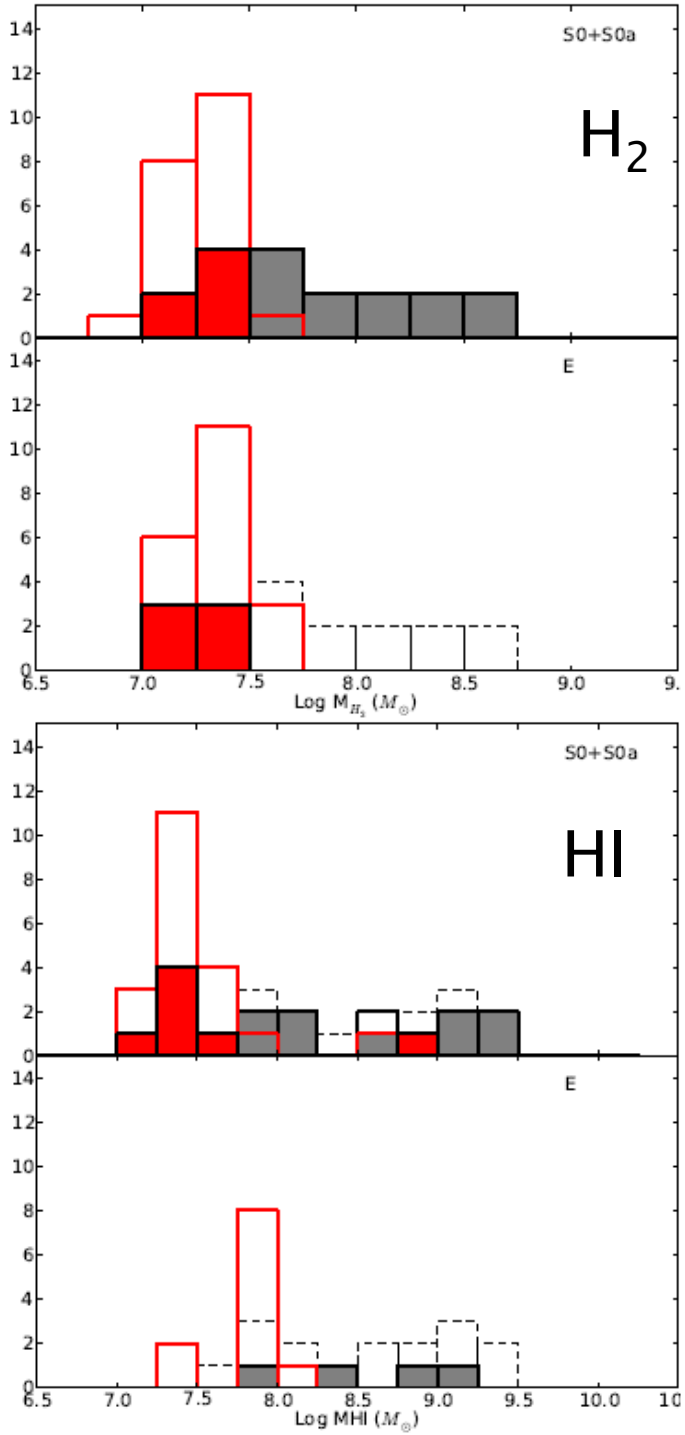
4 of 7 Ellipticals

M86 recently acquired
Dust and gas in an interaction
(Gomez et al. 2010)

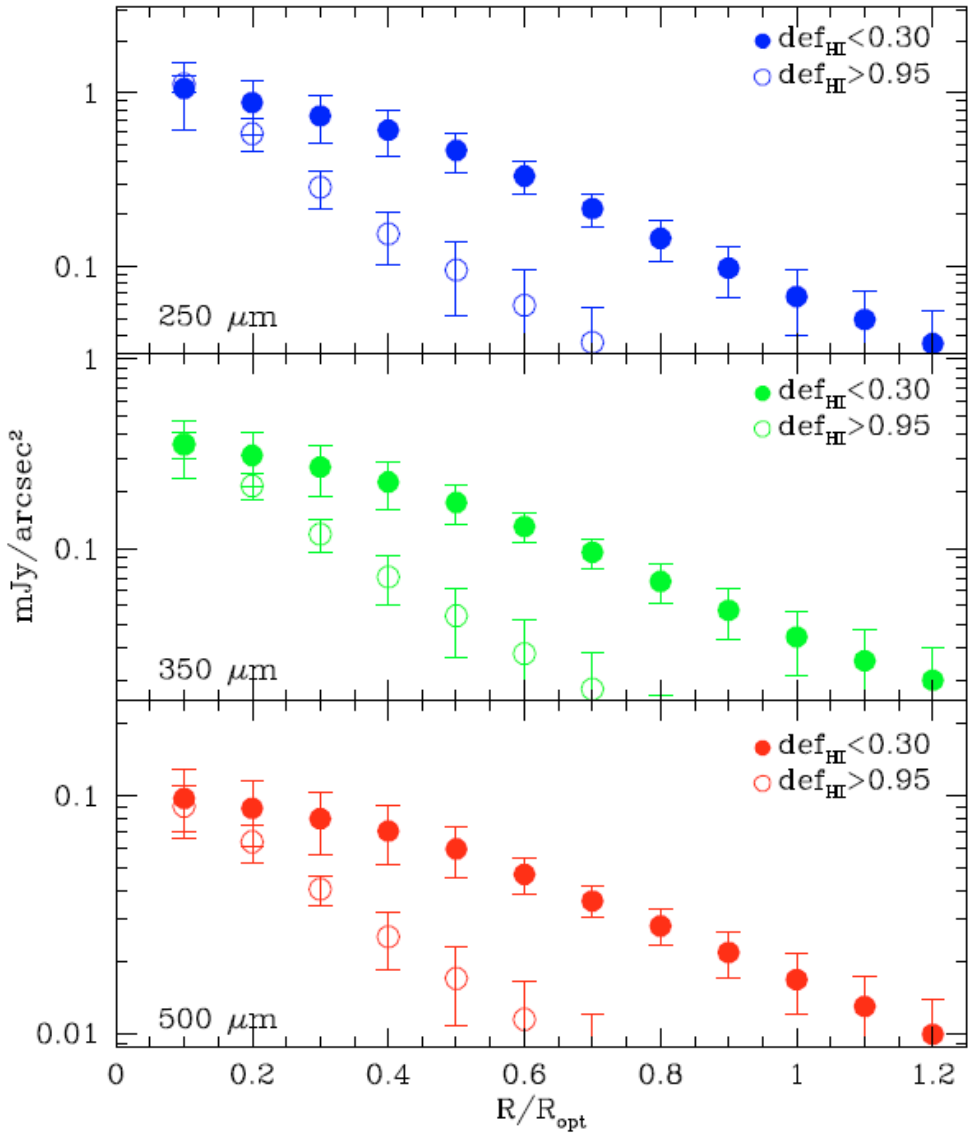


Gas Comparison

- ATLAS^{3D} survey of 260 galaxies detect 22% in CO. 28% of our objects.
- HI exists for 79% of our sample – 35% detected.
- **Suggests Herschel is the most sensitive way of detecting the ISM**

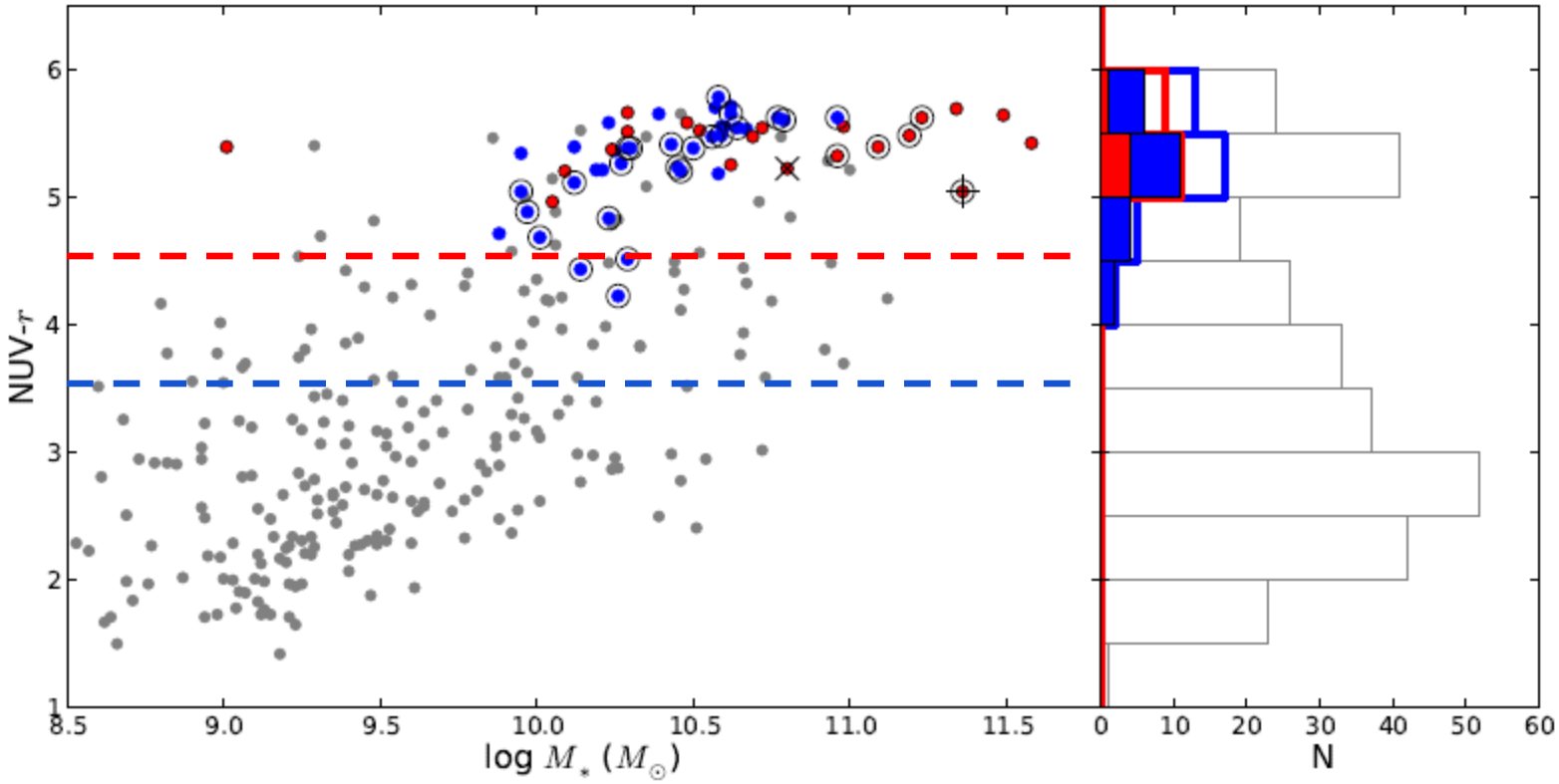


Environment



- Know dust is affected along with gas (Cortese et al. 2010)
- In Virgo
  - 53% S0
  - 29% E
- Outside Virgo
  - 89% S0
  - 33% E
- Not enough objects to be statistically significant

NUV – r

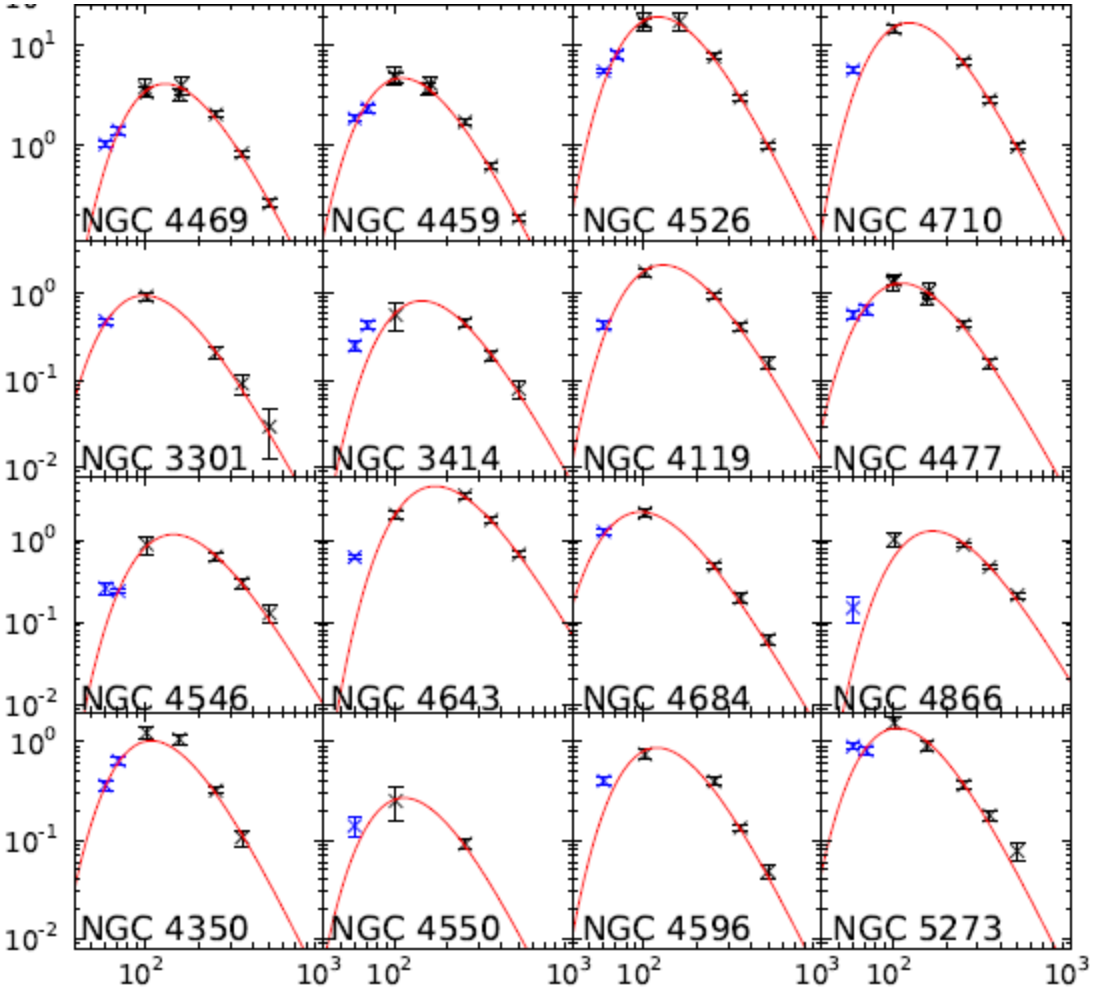


- Still detect many quiescent galaxies NUV – r > 5.4
- Still have inter-stellar material

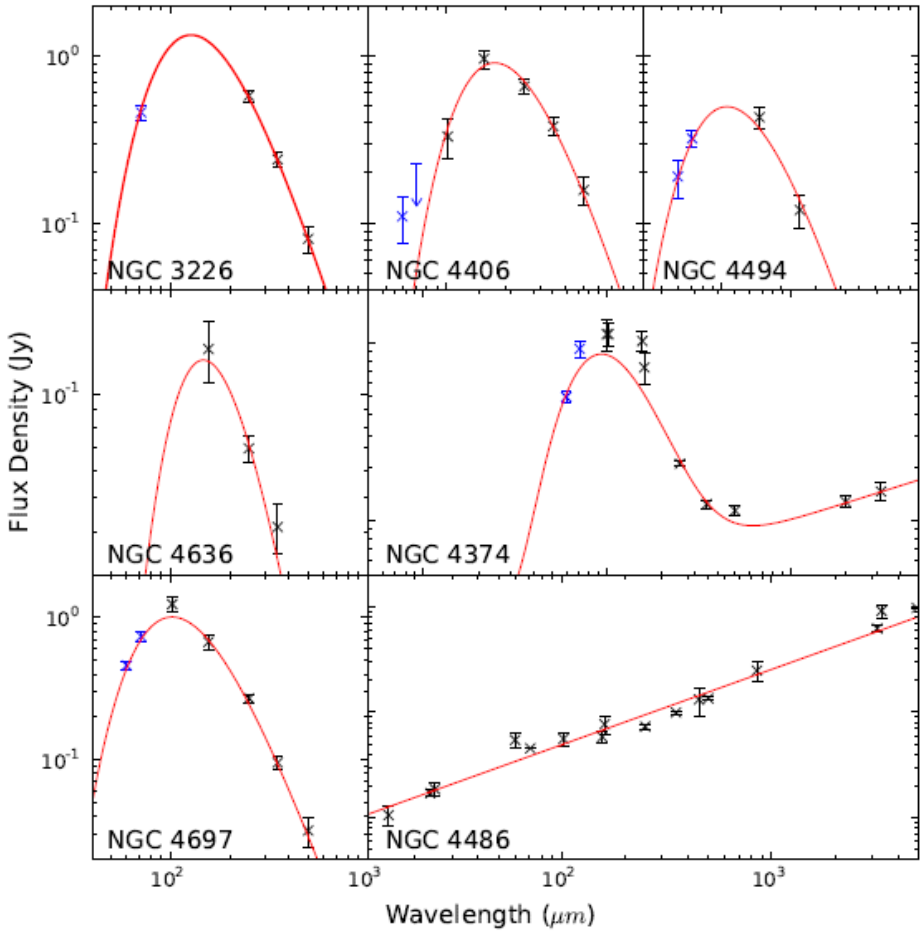
SED fitting

- Fit modified BB model with $\beta = 2$
- Mean $T_D = 23.6$ K, range 16 – 30 K
- Higher than Spirals (average ~18K)

S0 SEDs



SED fitting (2)

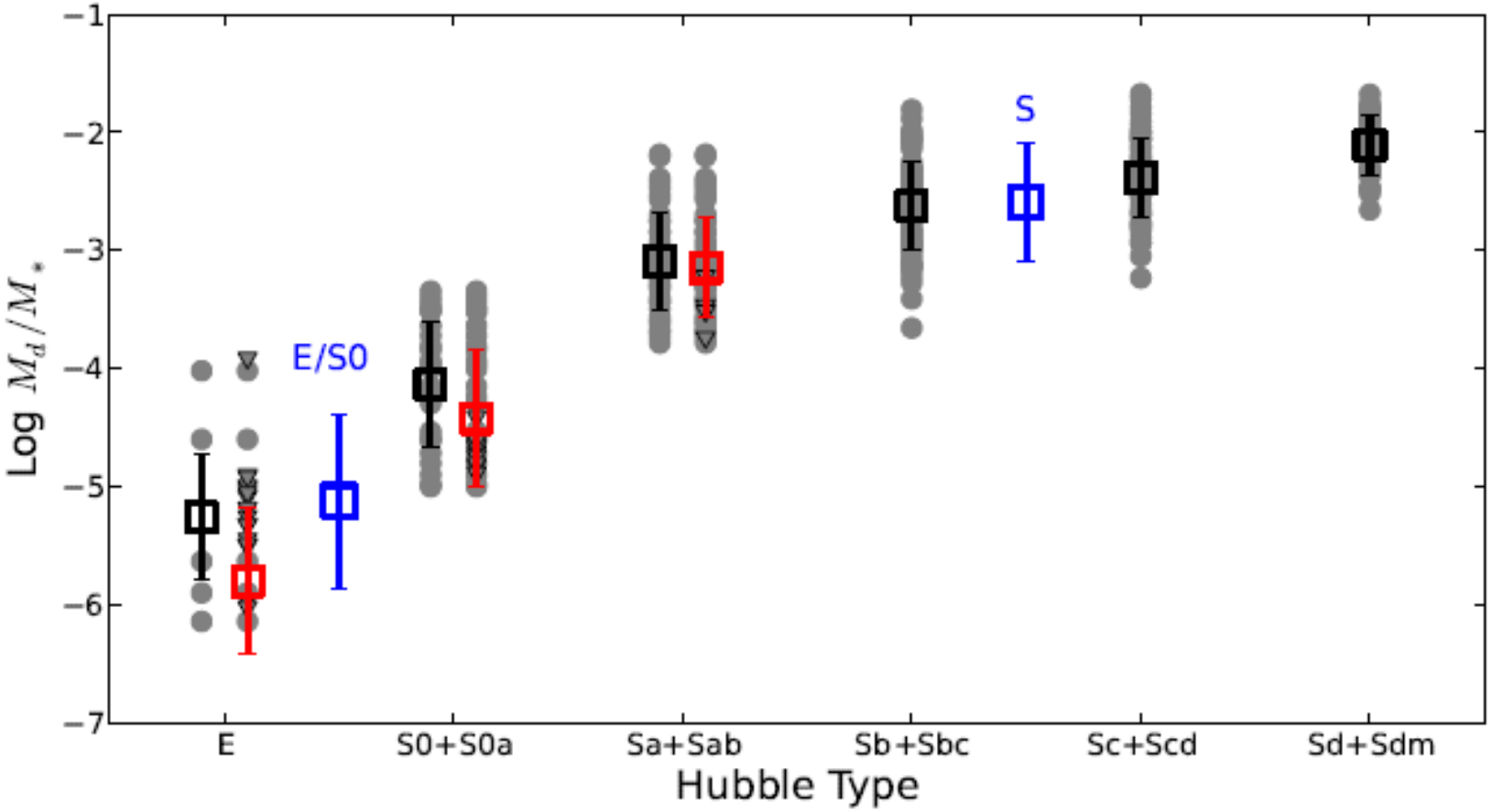


E SEDs

- Mean M_{dust} $10^{6.14}$ $M_{\odot}$
- Similar M_{dust} to other local galaxy survey (KINGFISH)
- H-ATLAS (wide-area Herschel survey) detect 5%. Average M_{dust} is 25× larger
- Could be rare CenA like object or S0 galaxies
- Using stacking found mean $10^{6.3}$ $M_{\odot}$ with mean T ~25 K.

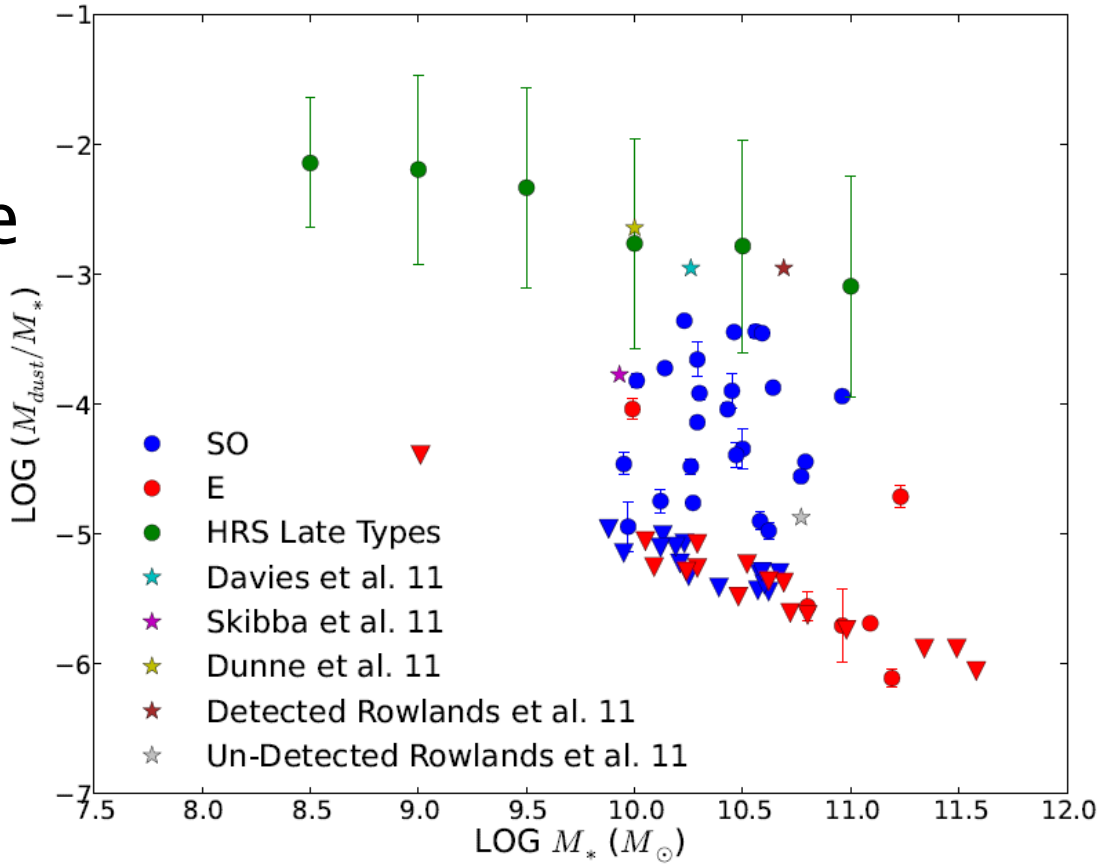
Morphology Segregation

- Order of magnitude decline Sp -> S0 -> E
- Variation larger for Early Types.



M_{dust} / $M_\star$

- Significant difference of $M_{dust}/M_\star$ at constant $M_\star$
- 2 anomalous E's show interactions.



Origin of Dust

- 3 potential origins of dust in ETGs

1. Dust is formed by the old stellar population

2. Dust has similar (but uncertain) source to late-type galaxies

3. The dust has been acquired externally

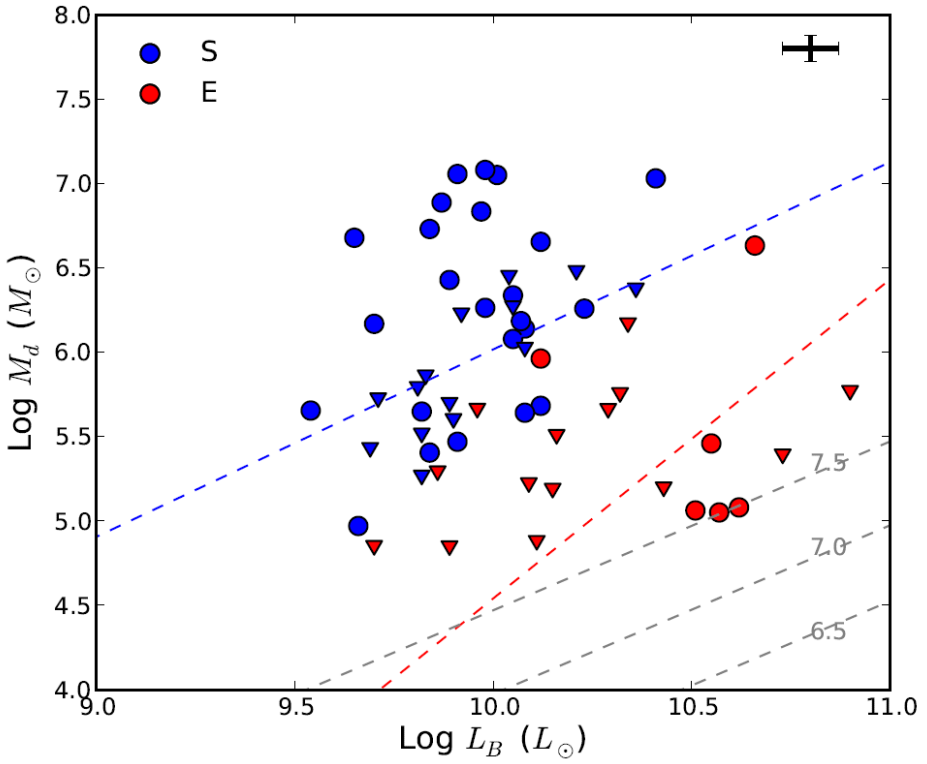
Testing (1) – Comparisons with Optical and X-ray

- Compare FIR luminosity, starlight and emission from hot ISM
- Source of X-ray emission
  - If hot gas is mass loss from stars, L_X correlates with L_B (seen in Temi et al. 2004).
- Find correlation L_X and L_B
- Correlations with Dust:
  - Very weak correlations (not significant) with Herschel.
  - Large scatter suggests dust could be from other sources – tidal interactions, mergers

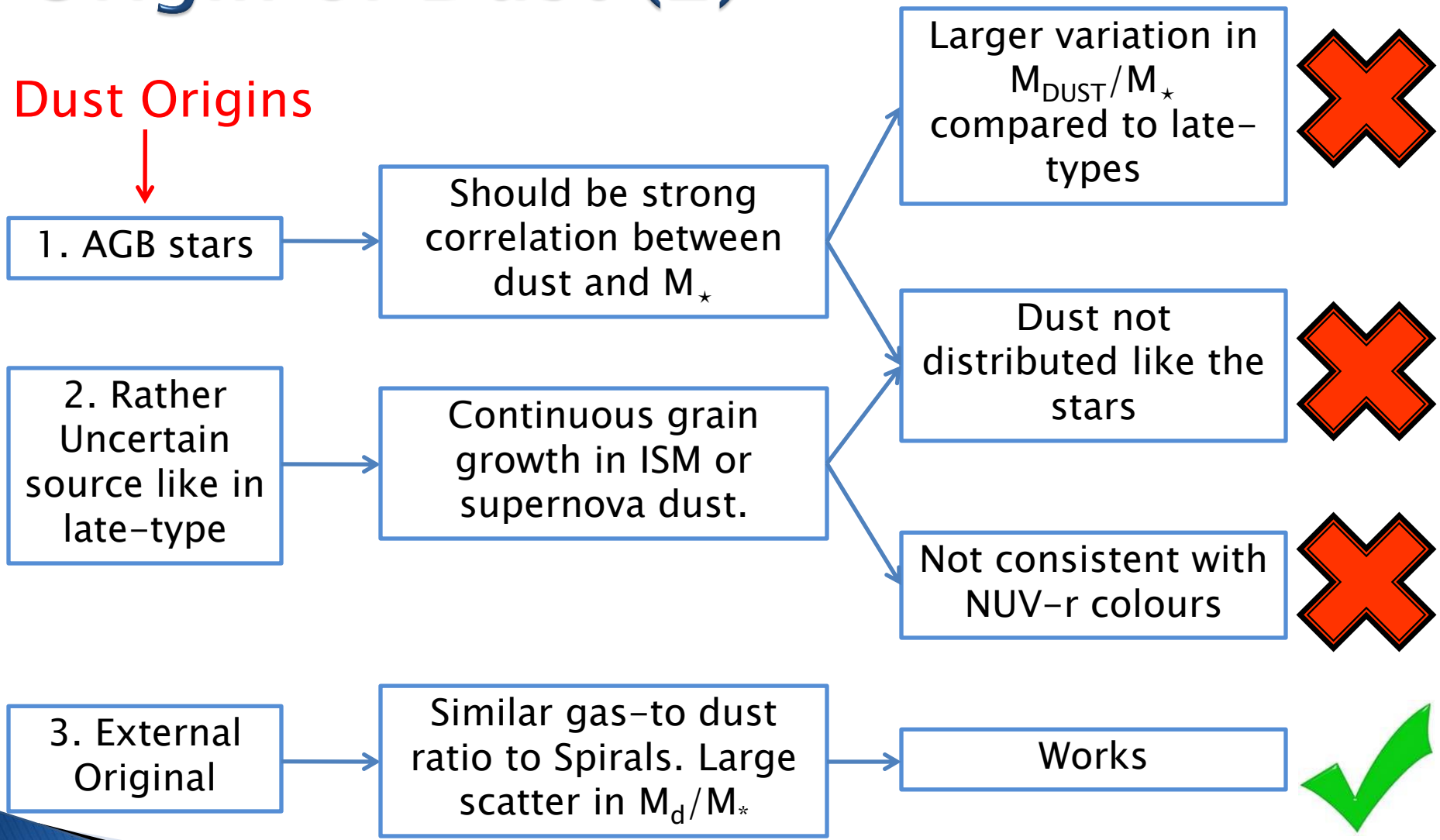
Testing (1) – Stellar Mass Models

- Models:
  - Dust created from stellar mass loss
  - Dust destroyed in Sputtering (expected 10^6–10^7 yr)

- If dust formed in AGB stars should be small scatter in M_d/M_* (especially compared to S)

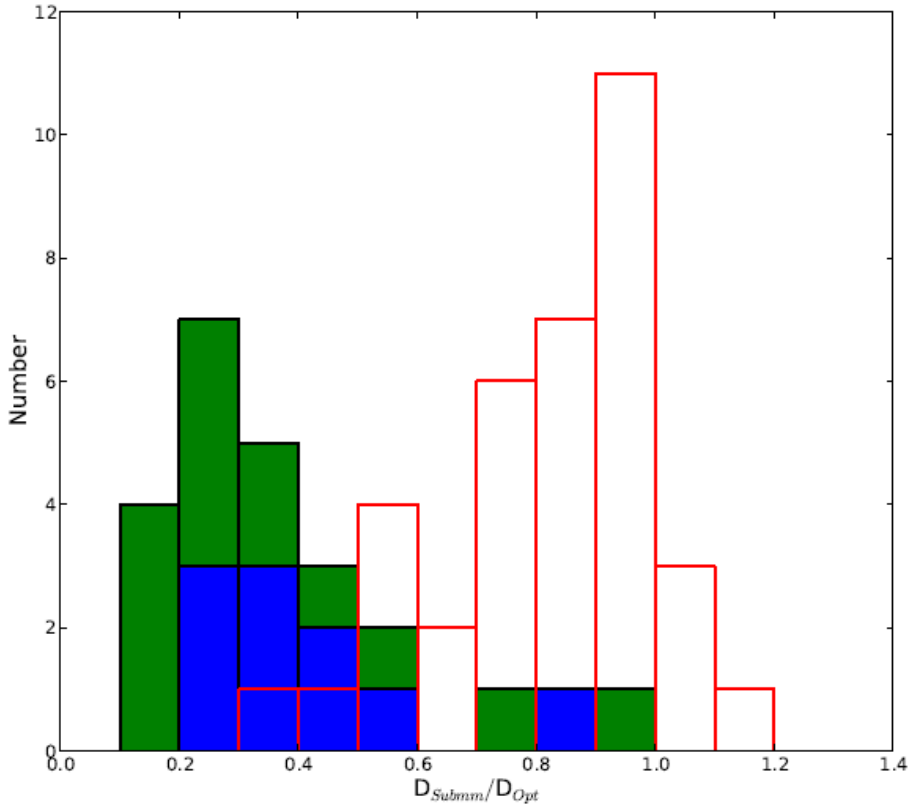


Origin of Dust (2)

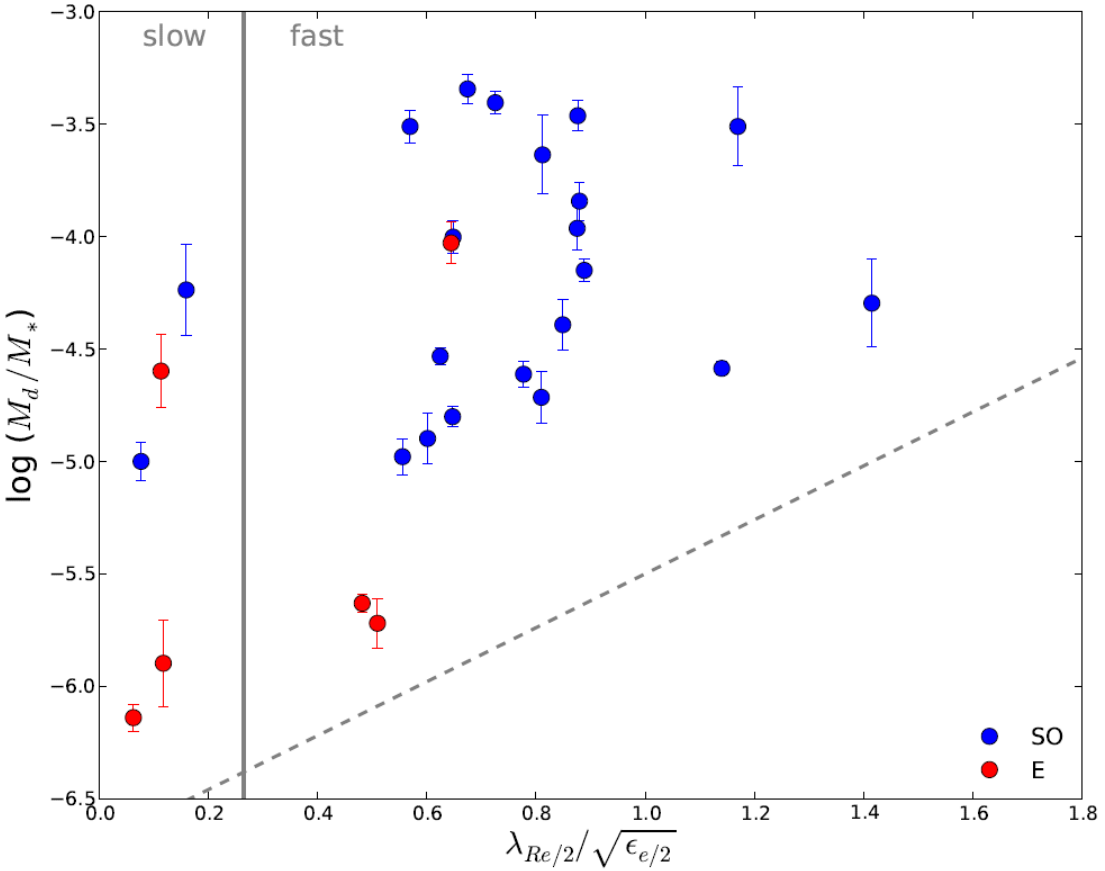


Dust-Depleted Disks in S0s

- Shown S0s contain less mass of ISM per mass than early type spirals.
- Just change in bulge to total mass ratio?
- S0s -> 0.1 – 0.2
  Sab-Sbc -> 0.2-0.4
- Alternatively look at ratio of D_{submm}/D_{opt}
- Must be a change of M_d/M_* in the disk



Slow/Fast Rotators



- ATLAS^{3D} suggest physically more meaningful to fast/slow rotators.
- 66% ATLAS^{3D} E are fast rotators, with disk-like kinematics
  - No Clear distinction.
  - Morphological separation clearer

Future ETG Work

- Current work has 2 limitations
  - Due to HRS magnitude cut biased to high stellar mass objects.
  - Dominated by Virgo cluster – need more field objects
- HEART – Herschel proposal to look at all ATLAS^{3D} galaxies
  - Obtained 36 galaxies in last few days of mission
  - Yet to analyse which objects were covered
- HeFoCS – Fornax data has been taken in OT2
  - Fornax is a more relaxed cluster
  - Similar depth to HRS
- Coma cluster – covered by H-ATLAS
  - More massive cluster

THANK YOU FOR LISTENING

Questions?

ArXiV
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