HUNTING *CORESHINE* WITH (WARM) SPITZER: FROM GRAIN GROWTH TO PLANET FORMATION

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Abstract: *"Hunting Coreshine with Spitzer"* (P.I. R. Paladini) is the largest (165.5hrs) approved Cycle-8 Warm Spitzer proposal in the Galactic science category. Goal of the 3.6 μm and 4.5 μm observations of 90 cold cores randomly selected from the Planck Early Cold Cores Catalog is an unbiased investigation of the *coreshine effect* which is thought to provide direct evidence for grain growth in cold, dense environments. A preliminary results indicates that ~50% of the sources are characterized by *coreshine.*

In Cycle 9, we requested an additional 42.5 hrs for a deep 4.5 μm follow-up of 10 sources included in the original sample. The analysis on the data – currently on-going – shows a positive detection for > 70% of the sources.

Coreshine Effect: at wavelengths > 3 μm, the scattering cross-section of grains <~ 0.1 μm decreases in the limit of Rayleigh scattering. Therefore, in cold cores, scatter light is expected to be negligible.
However, in these cold environments if larger grains are formed – for instance under the effect of gas turbulence (e.g. Ossenkopf 1993, Ossenkopf & henning 1994) -, these would be particularly efficient at scattering light in the mid-IR.

This effect – denoted *coreshine* (Pagani et al. 2010, Steinacker et al. 2010) - was found in the nearby core L183 (see Fig. 1 , center and left panels). The detailed 3D modeling of the core showed that the 3.6, 4.5 and 8 μm Spitzer IRAC data can be simultaneously explained only by including grains of sizes up to 1 μm.
Noteworthy, the bulk of *coreshine* thought to arise from the densest inner part of the core, as demonstrated by the remarkable correlation between the 3.6 μm emission and the extinction at 8 μm (see Fig. 1, left and right panels).

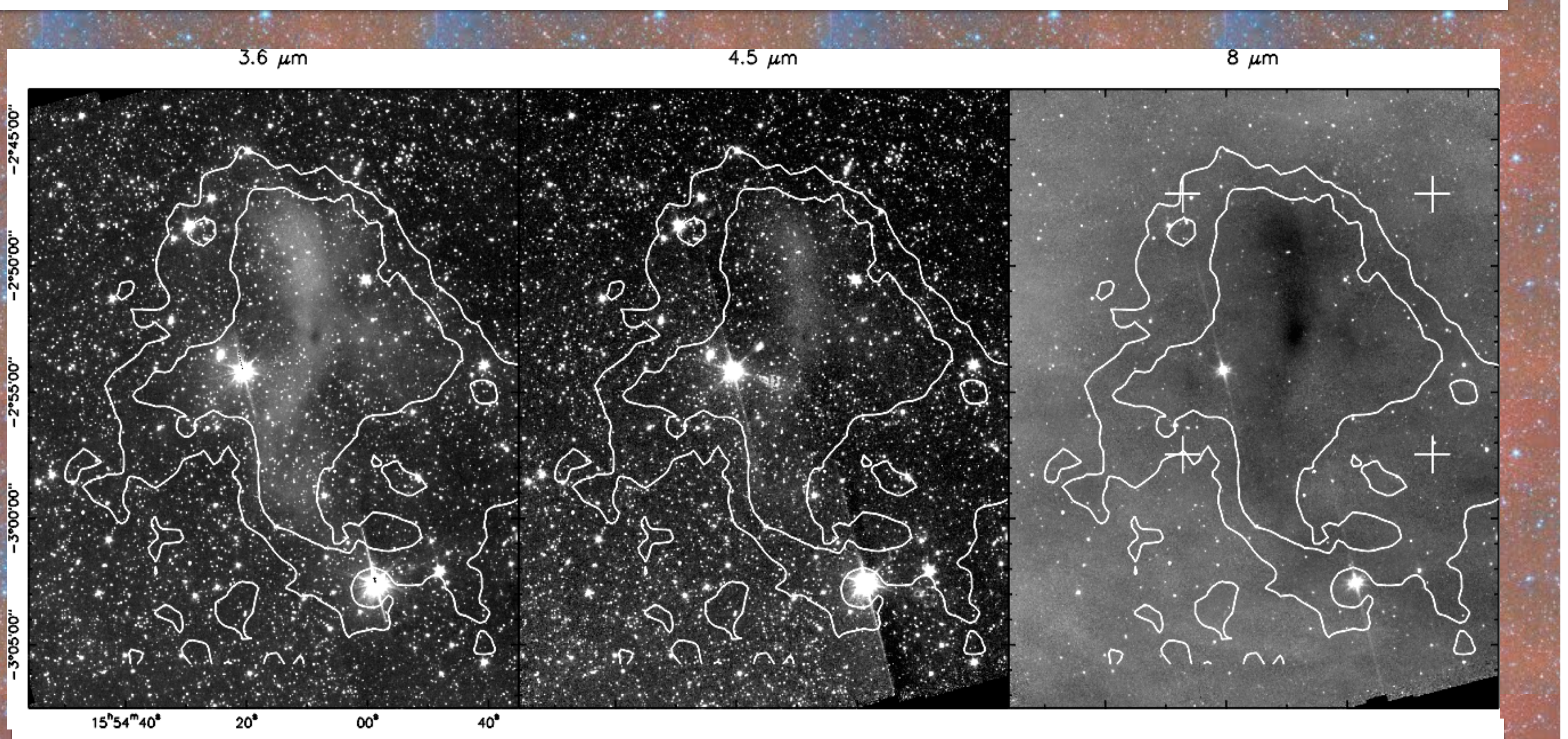

Fig 1 - The case of L183: strong evidence (Steinacker et al. 2010) of scattered light has been found for this close (~ 100 pc), low-mass core (~80 M_{sun}). The core shines at 4.5μm, a band not contributed to by PAH features. The spatial correlation of the shorter wavelengths emission with the extinction at 8μm indicates that the *coreshine* traces the densest part of the core.
Modeling of the core shows that grains as large as 1 μm have to be present in the core to account for this effect.

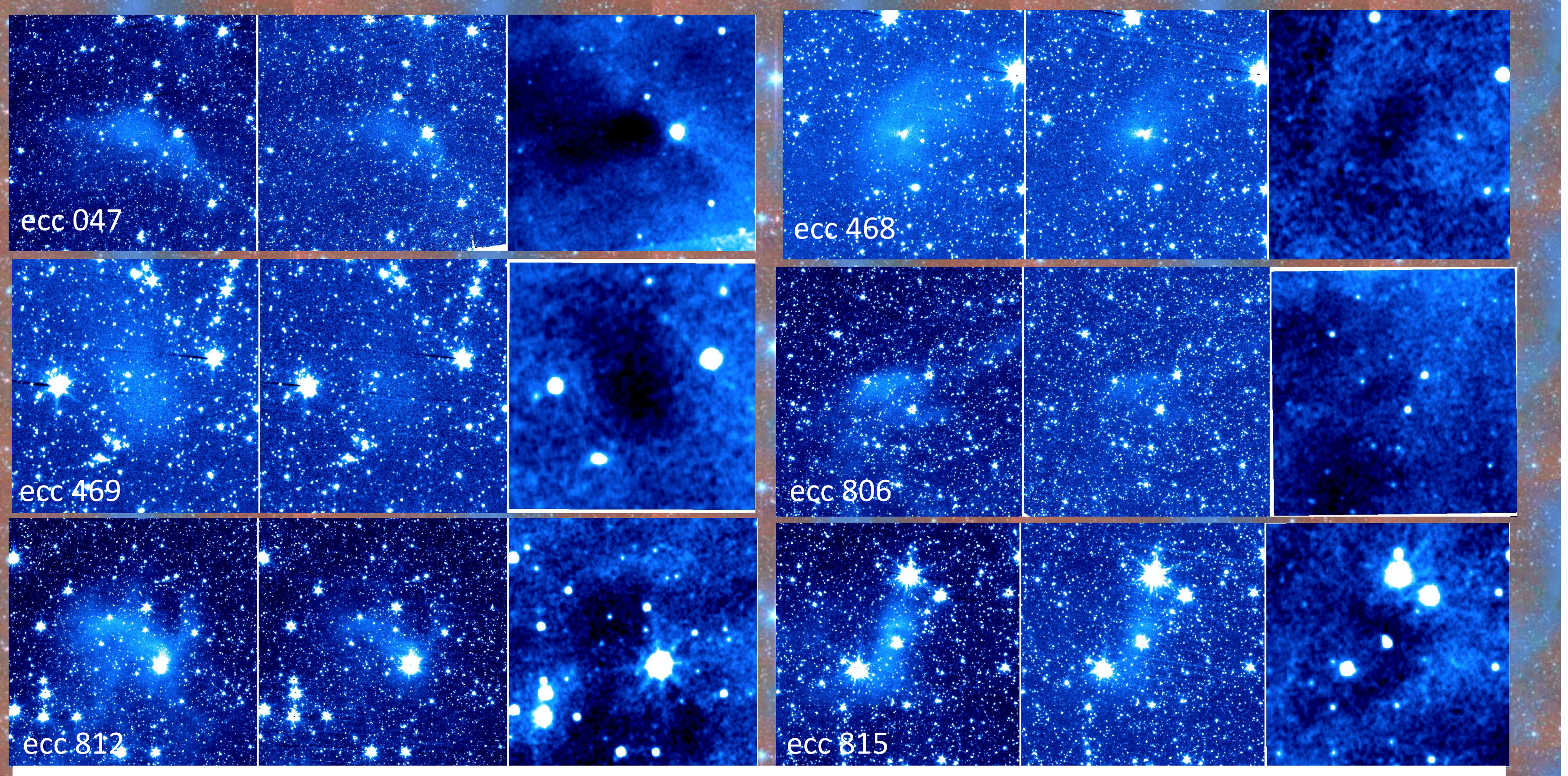

Fig 2 – Examples of Cycle 8 *coreshine* detections: for each source, the IRAC 3.6 and 4.5 μm data and the WISE 12 μm data are shown (left to right). Source notation is from the Planck Early Cold Cores Catalog.

Warm IRAC Cycle 8 Observations: one of the main goals of the survey was to test whether the *coreshine* effect is present in the cores regardless of their particular mass and environment. For this reason, we randomly selected – through a Monte Carlo sampling technique – a set of 90 cores drawn from the Planck Early Cold Cores Catalog (Planck Collaboration, 2011s), which contains 915 cores homogeneously distributed across the sky, and characterized by $T_D < 14$ K and S/N > 15.

For these 90 cores, we have performed deep IRAC 3.6 and 4.5μm observations, achieving a sensitivity of ~0.008 MJy/sr in both channels. A preliminary analysis of the data indicates that the *coreshine* effect is detected in at least 50% of the sources in the sample (see Fig. 2). A particularly high concentration of *coreshine* appears towards the Taurus Molecular cloud.

Warm IRAC Cycle 9 Observations: The justification for further IRAC observations is provided in Fig. 3. The Figure illustrates the predicted radiation due to *coreshine* in the IRAC 3.6 and 4.5 μm bands for a 1 M_{sol} core at d ~ 150 pc. The simulation shows that the 3.6 to 4.5 μm ratio varies as a function of grain size: the larger the grains, the smaller the ratio. To check this effect, it is important that the S/N in both IRAC bands is comparable. In the Cycle 8 data, *coreshine* is clearly detected at 3.6 μm, while it is either barely detected at 1-sigma or below the noise threshold at 4.5 μm.

Therefore, we performed deeper IRAC 4.5 μm follow-up observations of 10 cores selected from the original Cycle 8 sample, with a sensitivity of 0.005 MJy/sr. These observations were completed in early July 2013. The analysis of these data, currently on-going, reveals that at least 70% of the sources *shines* at 4.5μm.

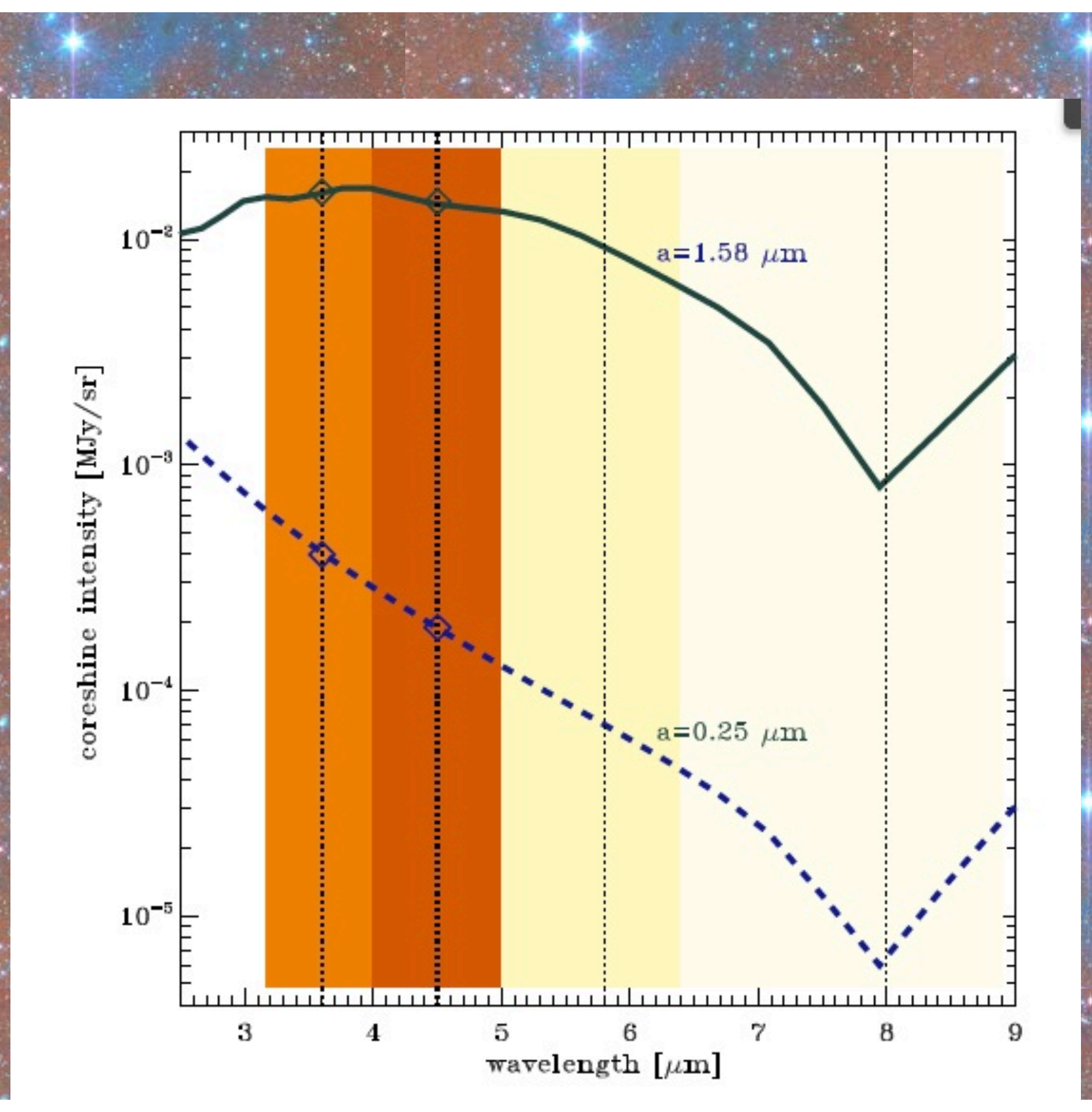

Fig 3 - Coreshine emission at 3.6 μm vs. 4.5 μm: the dashed and solid blue lines denote, respectively, 0.25 μm- 1.58 μm-radius grains. The vertical bands and dotted black lines represent the 4 IRAC bands and their reference wavelengths during the Spitzer cryo mission (*courtesy of J. Steinacker*).