CTB 109: a supernova remnant interacting with a molecular cloud

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Contents

Signs of SNR-MC interaction

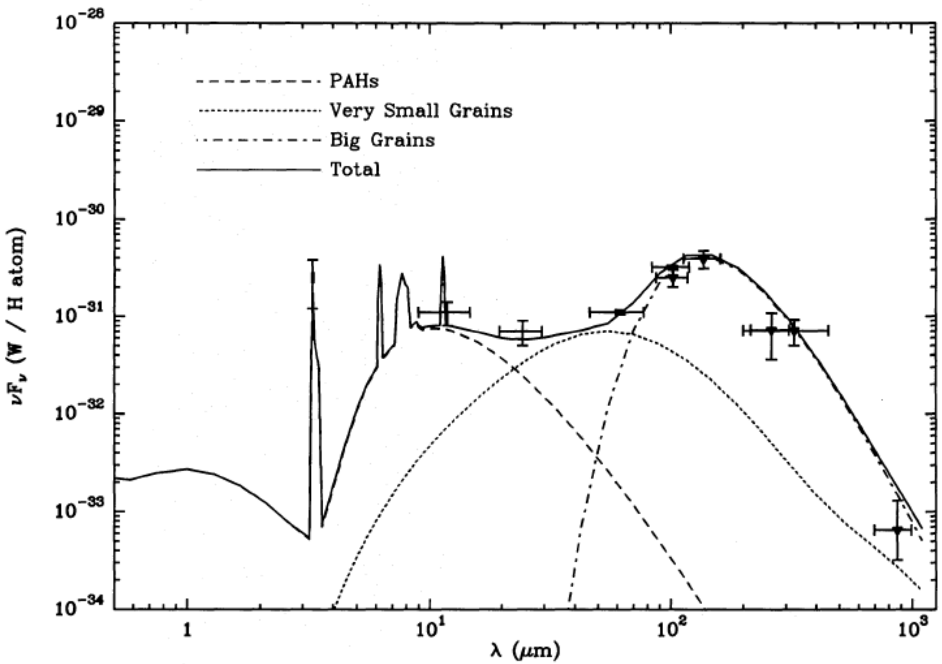
- Maser emission (e.g. OH 1720 MHz)
- Molecular line broadening/asymmetry
- Excited molecules
- Shocked NIR emission
- IR color suggesting a shock
- Morphological agreement of SNR-MC features

SNR-MC interaction in IR

- **Large surveys in IR enable systematic studies (e.g. WISE, Spitzer, AKARI, Herschel)**
- **IR emission origin:**
  - Line emission
  - Synchrotron emission
  - Thermal dust emission
  - PAH emission
- **IR traces different dust populations**

Dust spectrum in infrared

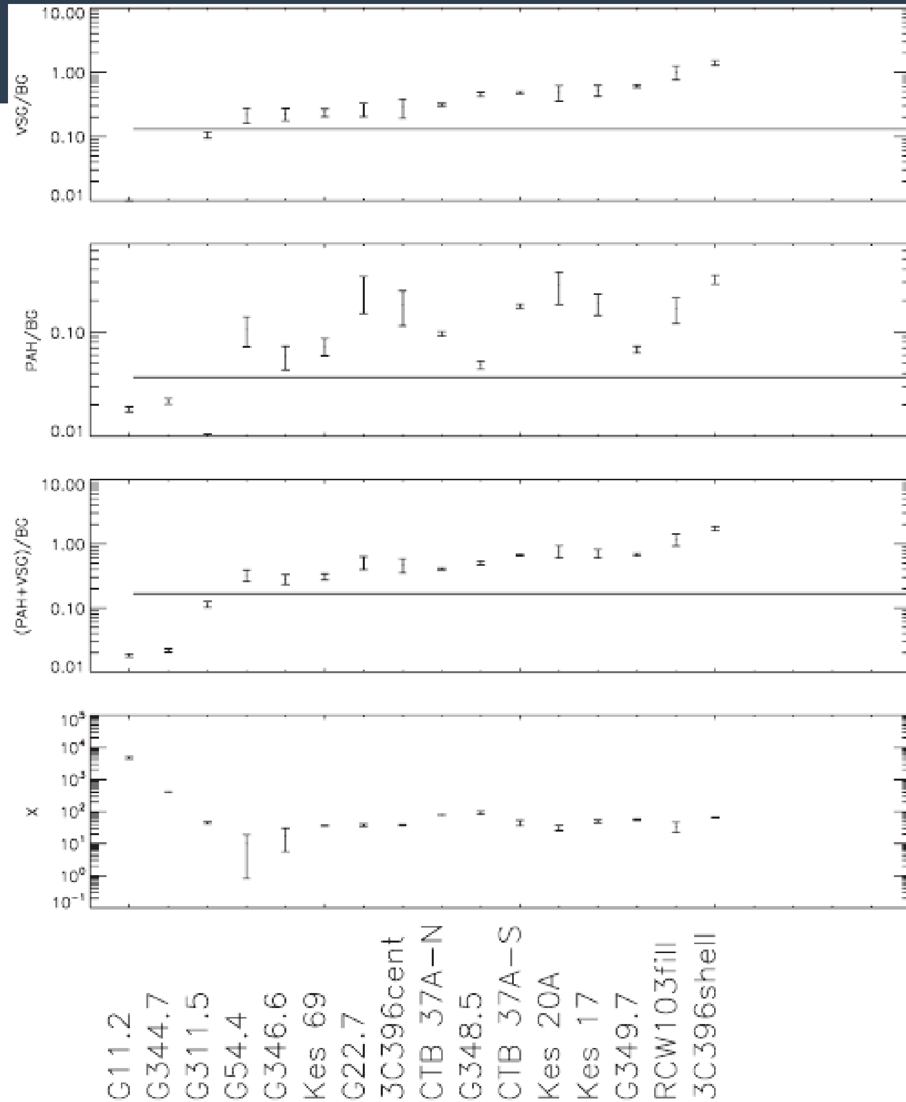
- **Dust is a mixture of different dust grain populations with different typical sizes → emission at different IR bands from different populations**



Désert et al. 1990: Dust emission spectrum with three grain populations

Dust processing in SNRs

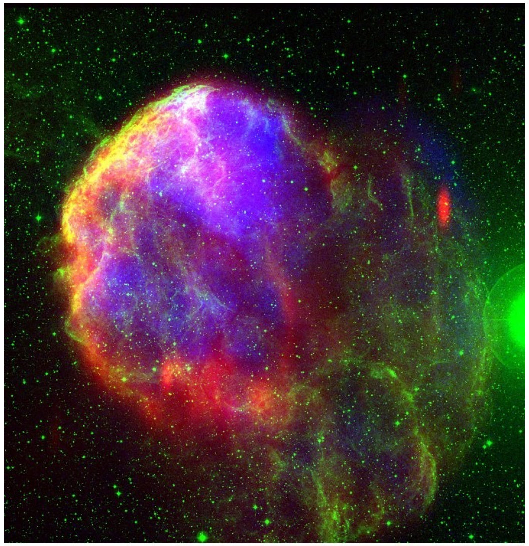
- **collisions with gas particles or other grains modify the grain size distribution → dust is destroyed or processed into smaller grains**



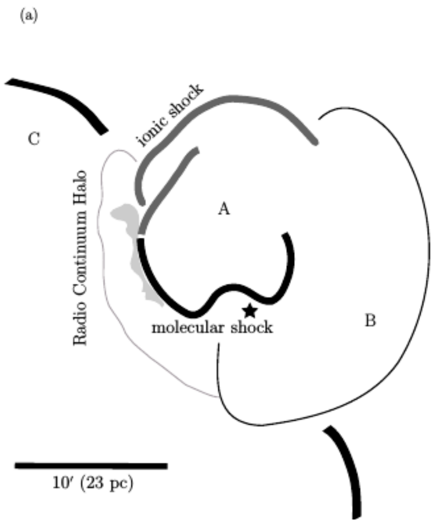
Andersen et al. 2011: grain ratios

SNR-MC interaction example: IC443

WISE 22/12/4.6 μm



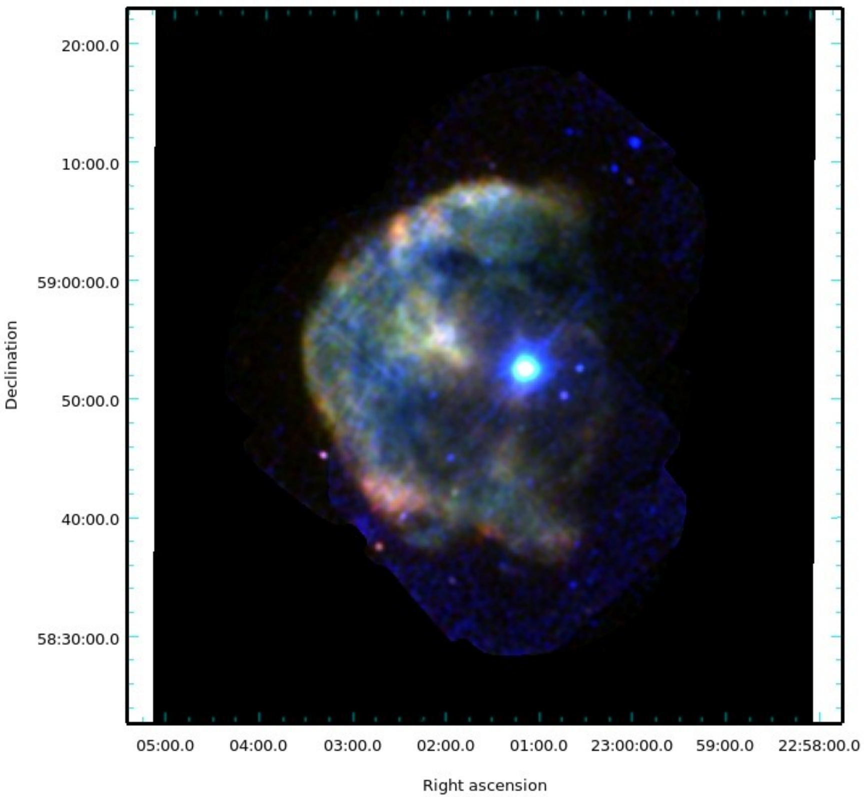
1420 MHz, optical, X-ray



Scheme by Lee et al. 2012

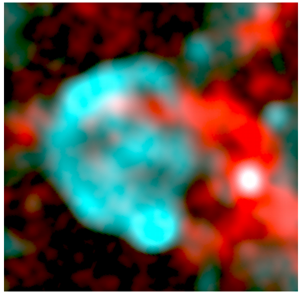
- **interaction with both atomic and molecular regions**
- **line emission strong but different observed lines**

CTB 109 overview



Sasaki et al. 2004

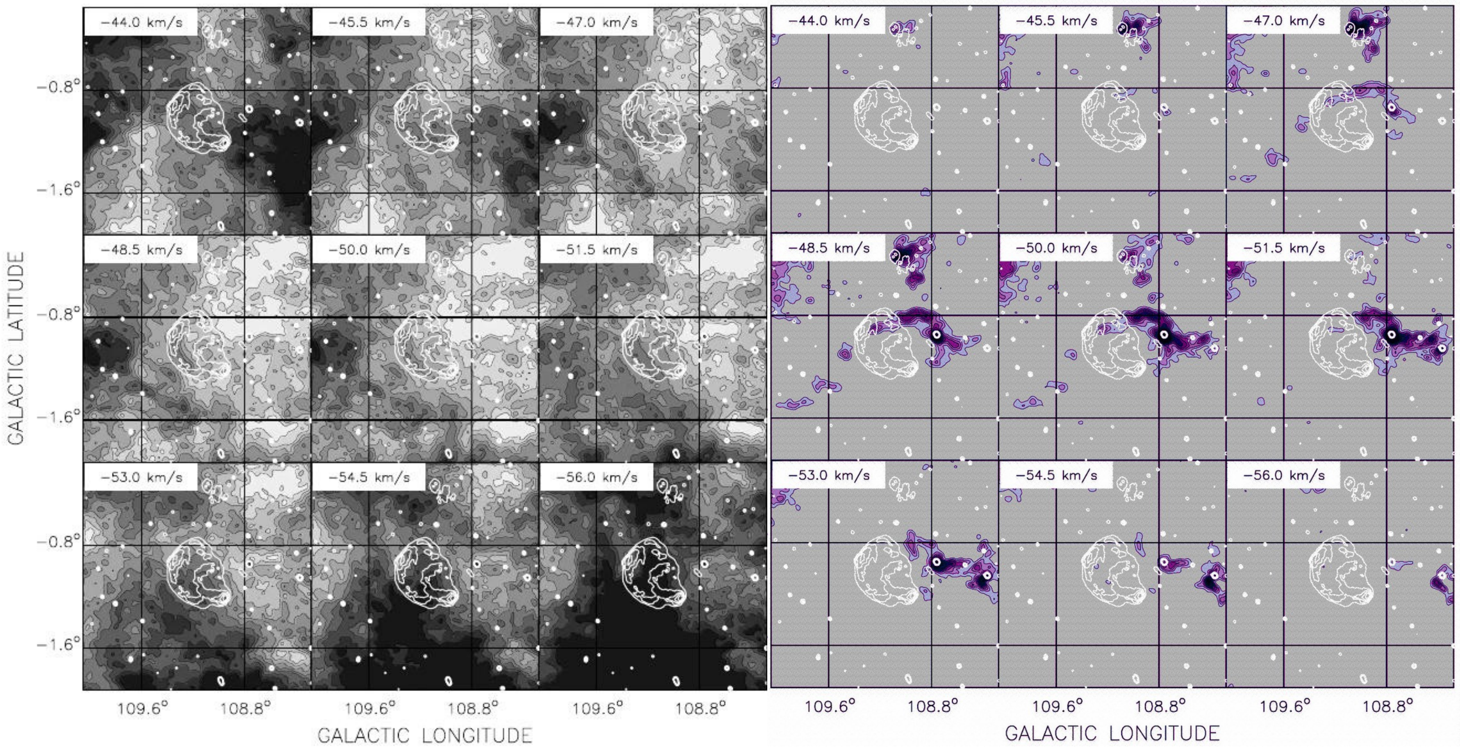
- **3.2 kpc, radius ~18’, age ~10-15 kyr**
- **“CO arm” in front of the SNR**
- **X-ray bright “Lobe” close to the center**



CO (red), 408 MHz (cyan) (CGPS)

CTB 109 overview: surroundings

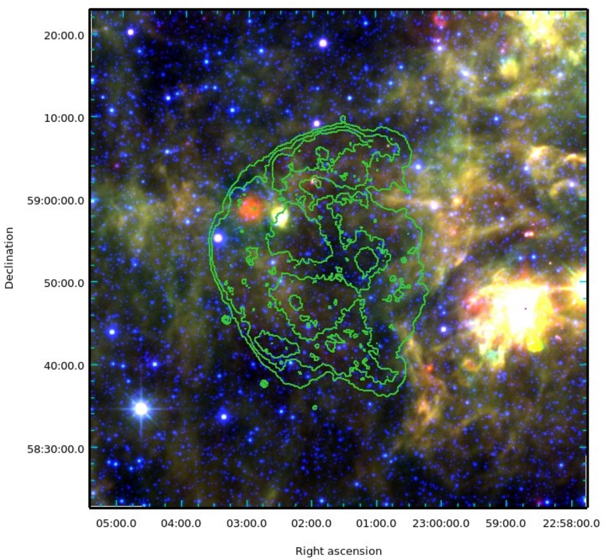
- **in the west, CO farther away from the SNR than HI**
- **HI shows material NW and SE of the SNR**



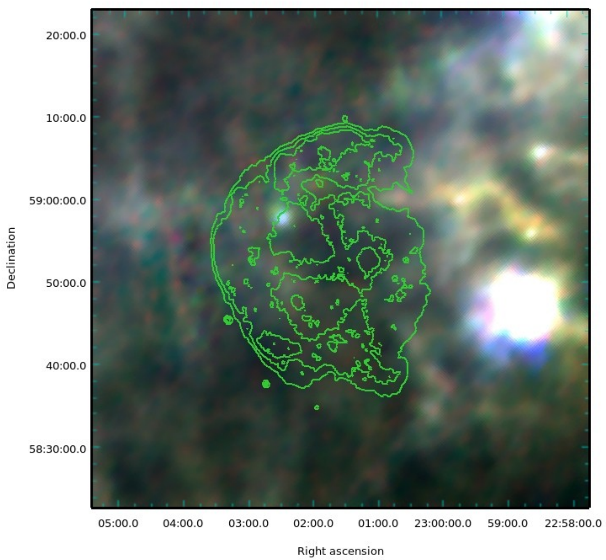
Kothes et al. 2002: HI and CO channel maps (CGPS)

CTB 109 overview: infrared

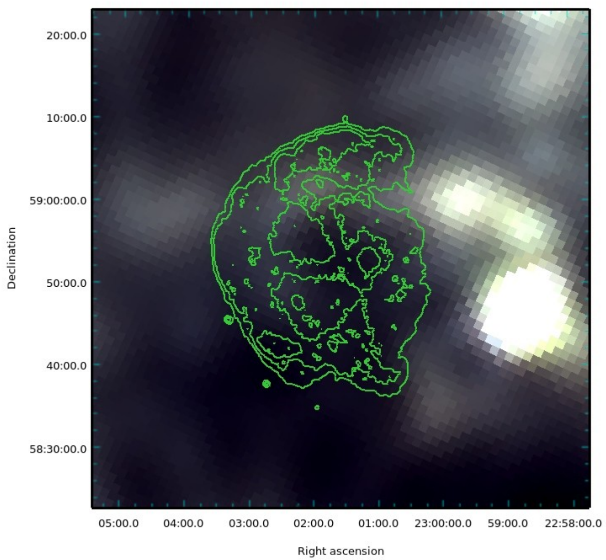
- **IR source next to the Lobe, no obvious emission in a shell or the center**
- **CO arm extends from the MC**



WISE: 22, 12, 4.6 μm



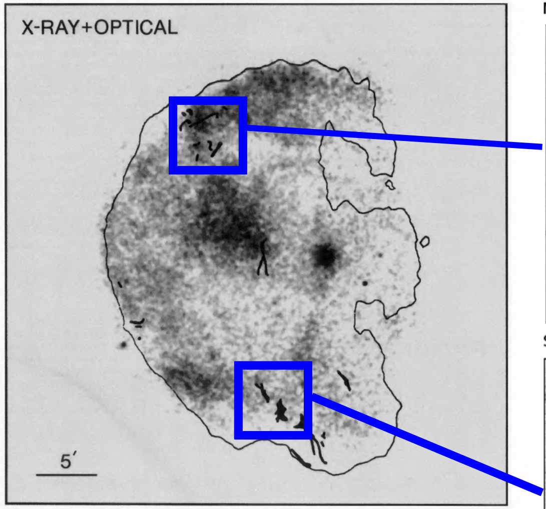
AKARI: 160, 140, 90 μm



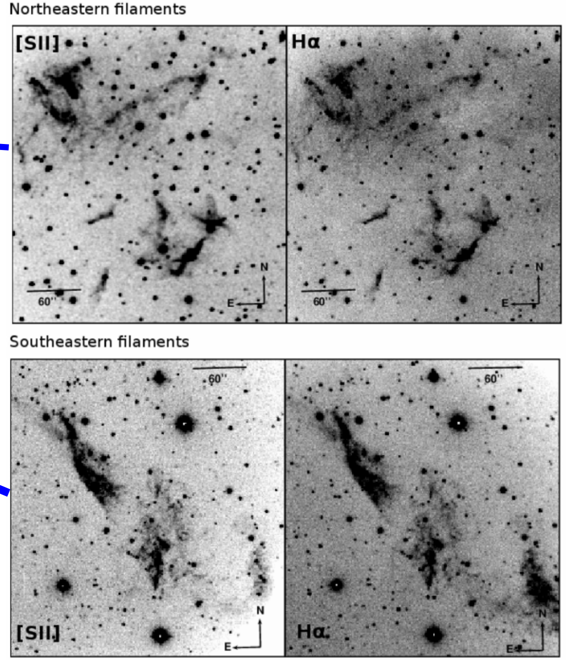
Planck 850, 550, 350 μm

CTB 109 observations: interaction (opt.)

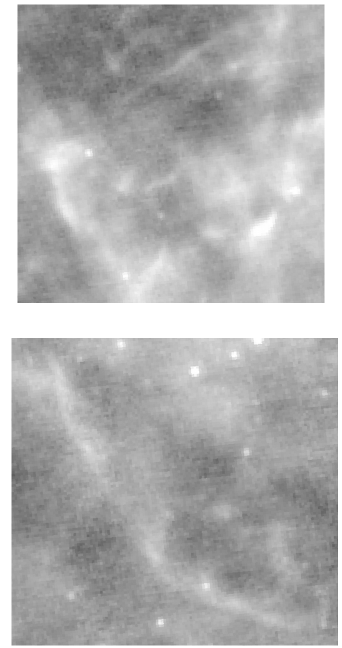
Fesen&Hurford, 1995



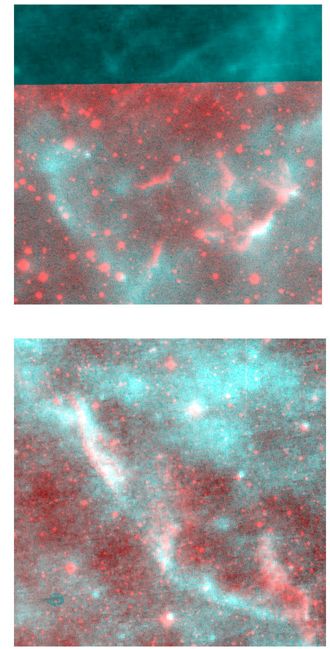
Sánchez-Cruces et al. 2018



24 μm



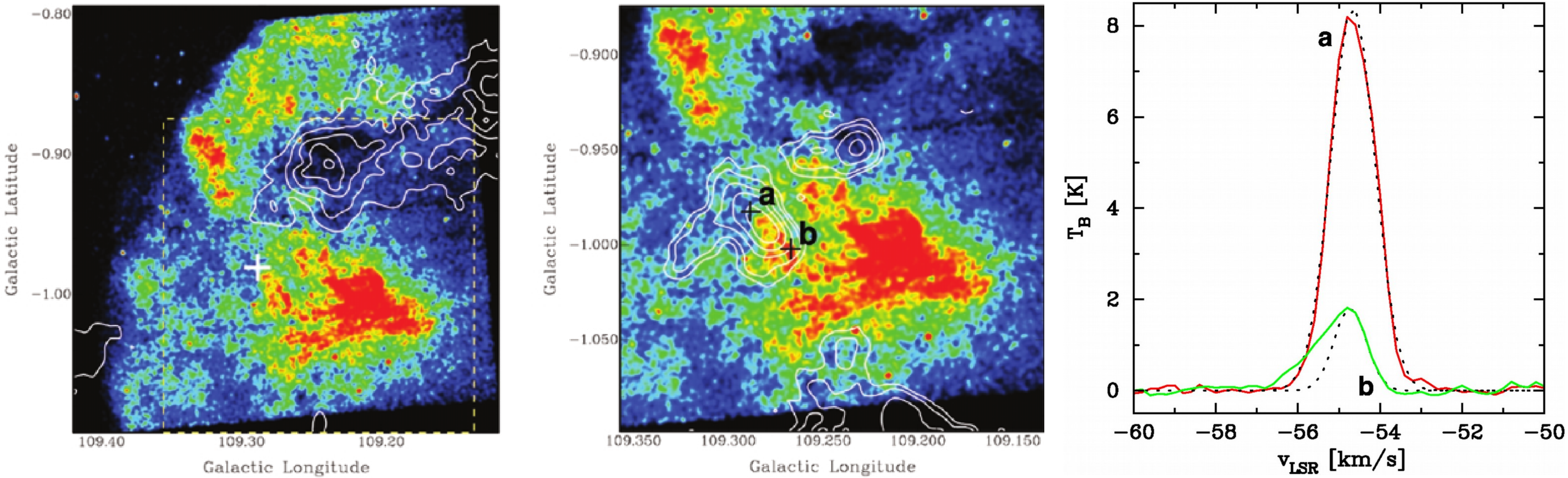
24 μm (cyan), Hα (red)



- **Hα filaments indicate shocks - bright IR counterparts at 24 μm**

CTB 109 observations: interaction (CO)

Sasaki et al. 2013: CO observations around the Lobe

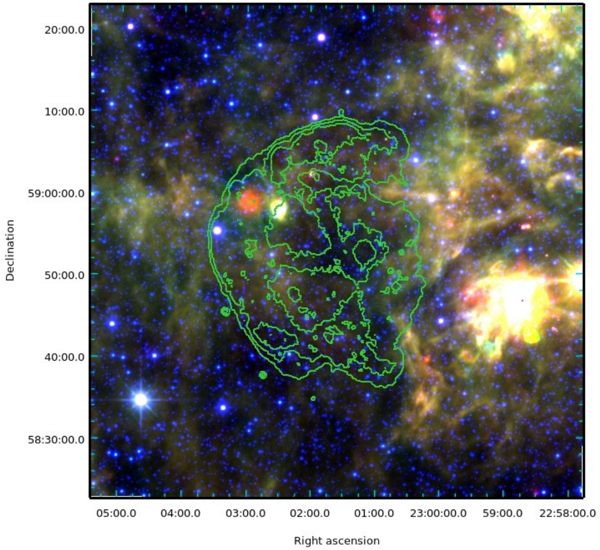


- **Asymmetry in position b → interaction**

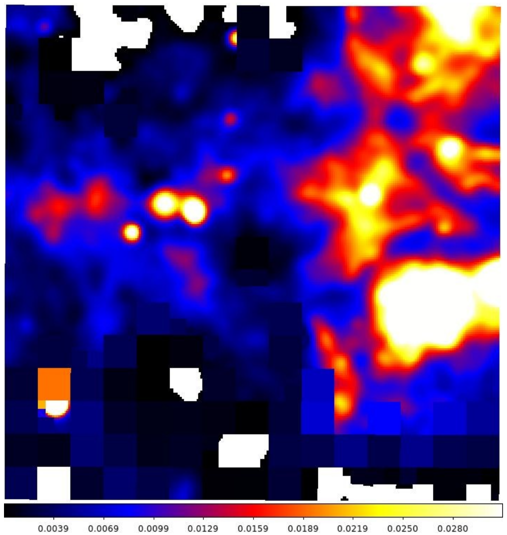
CTB 109: IR flux determination

1) generate pixels where S/N is high enough

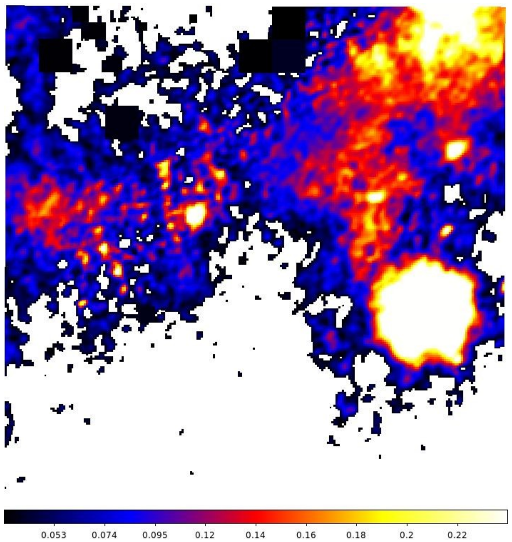
2) create flux density images



WISE 22 μm



AKARI 65 μm



Temperature determination: simple

- **Assume modified black-body emission: $F \sim \nu^{\beta} B_{\nu}(T_d)$ → F1/F2 yields a temperature for dust**

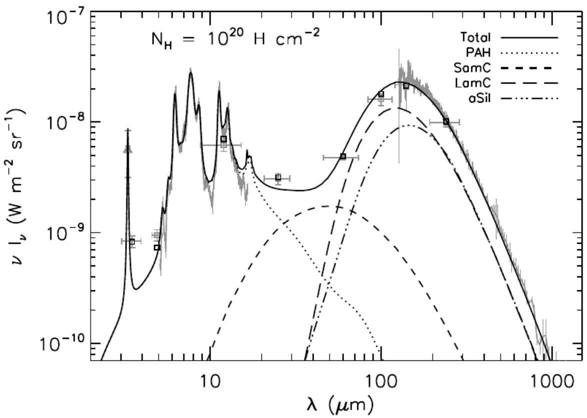
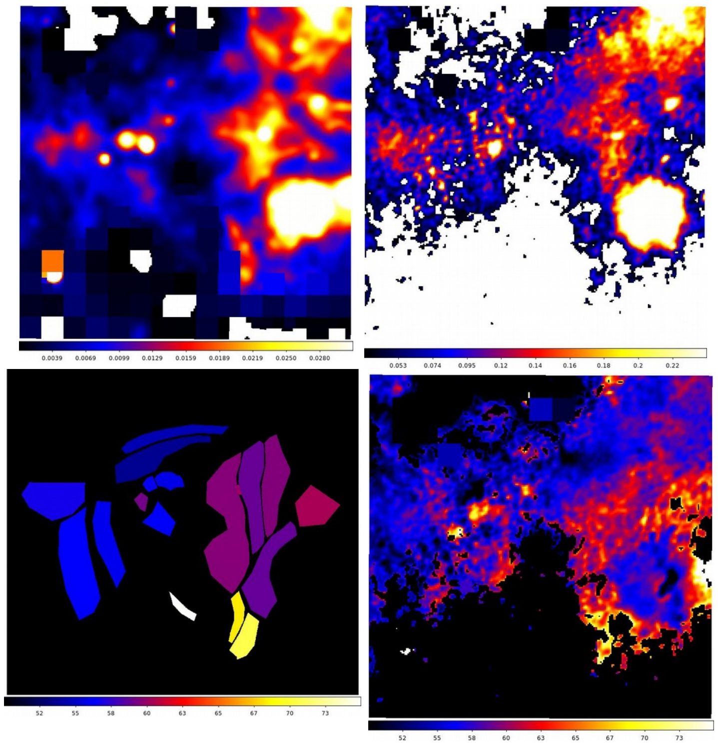


Fig. 2. Dust emission for the DHGL medium. Grey symbols and curves indicate the observed emission spectrum (see Sect. 4.1) for $N_H = 10^{20}$ H cm^{-2}. The mid-IR (~5–15 μm) and far-IR (~100–1000 μm) spectra are from ISOCAM/CVF (ISO satellite) and FIRAS (COBE satellite), respectively. The triangle at 3.3 μm is a narrow band measurment from AROME balloon experiment. Squares are the photometric measurments from DIRBE (COBE). Black lines are the model output and black squares the modeled DIRBE points taking into account instrumental transmission and color corrections.

Dust emission for diffuse high-Gal. latitude medium (Compiegne et al. 2011)

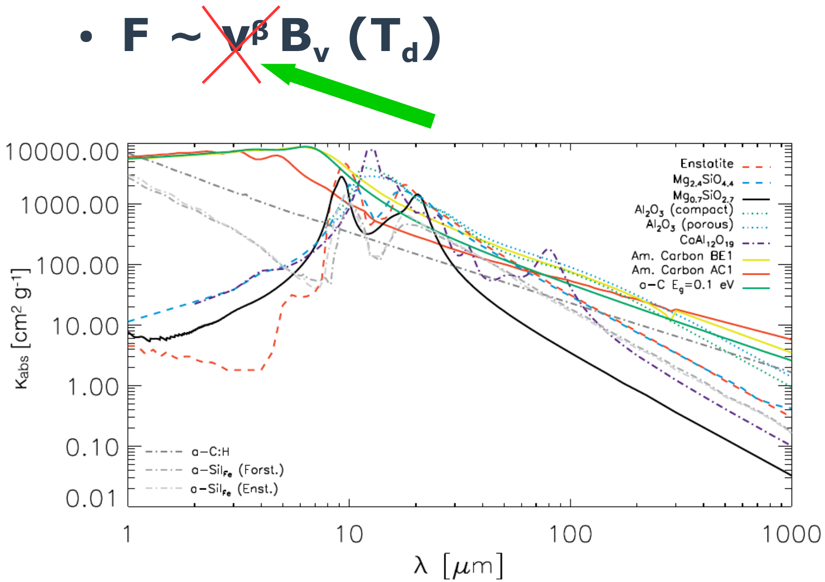
Flux densities: 22 and 65 μm



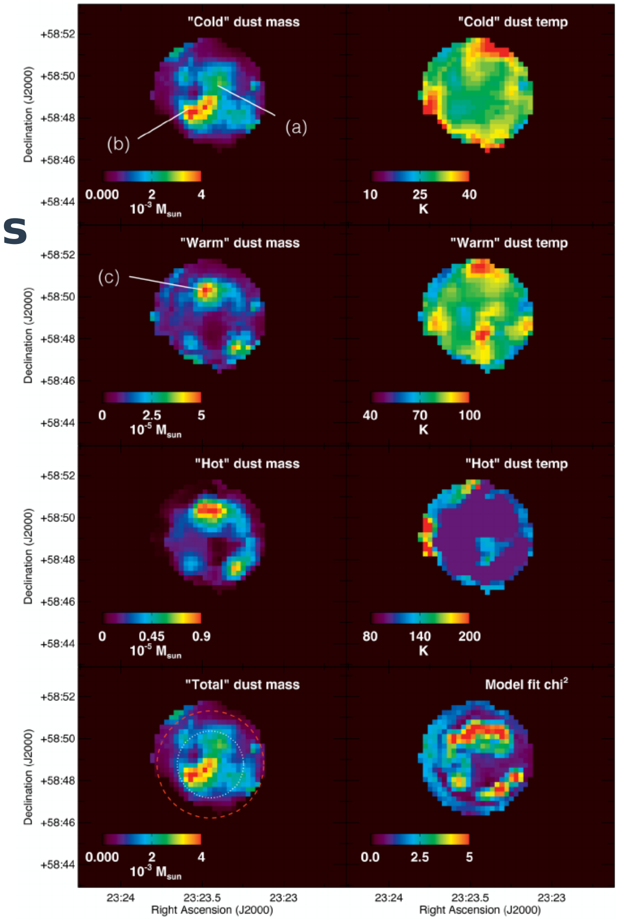
Temperature from F22/F65

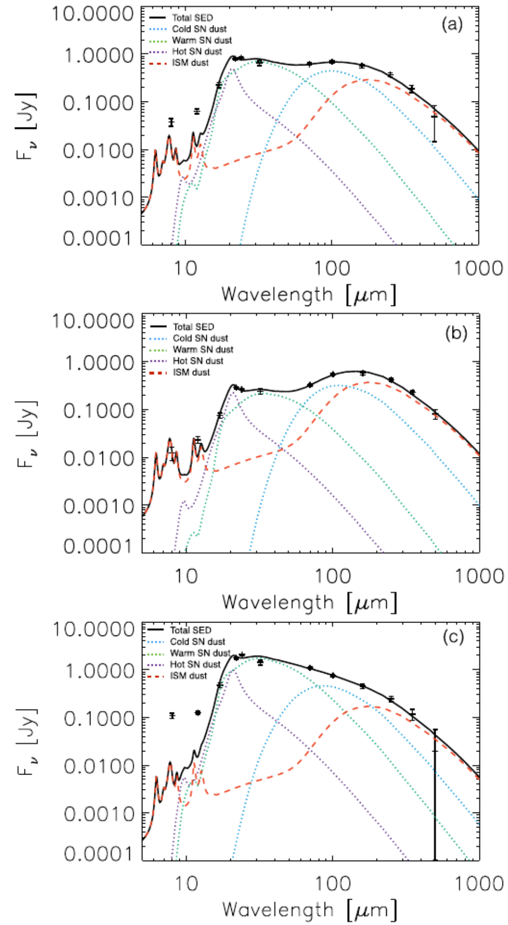
Temperature determination: complex

- **Fit a dust model with chosen populations → relative strength of populations over the image → T_d and mass maps**
- **$F \sim \nu^{\beta} B_{\nu}(T_d)$**



De Looze et al. 2017: Dust SED fitting in Cas A

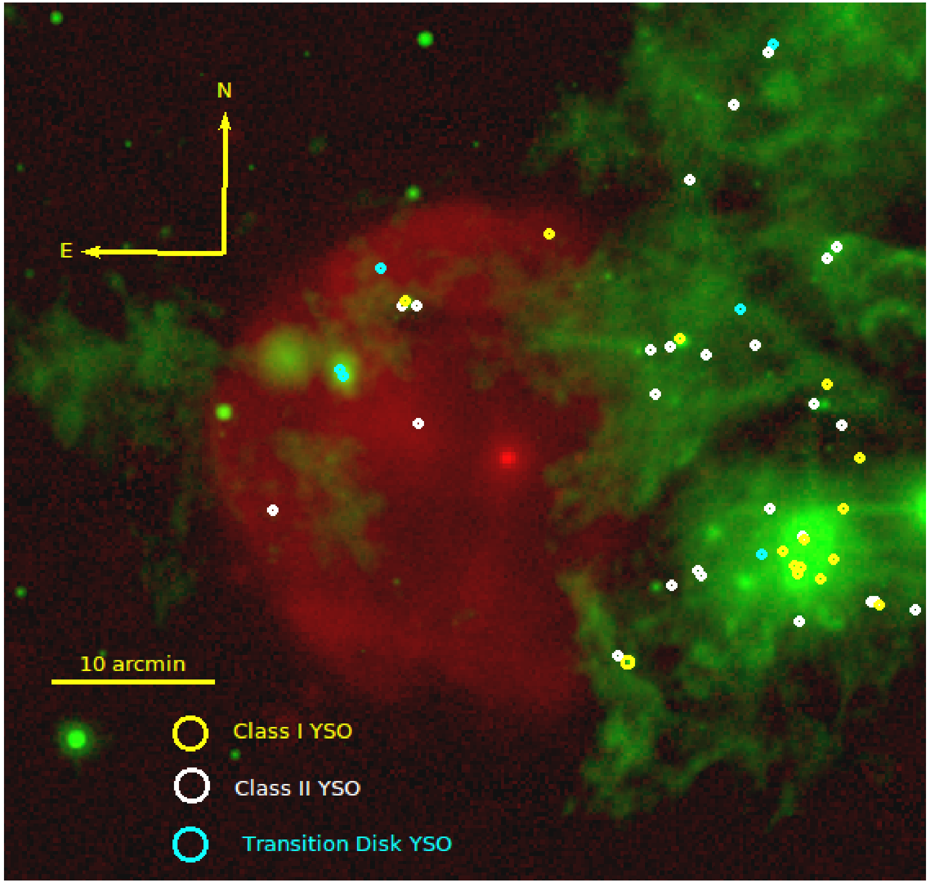




Summary

- IR observations require careful interpretation due to line emission, geometries, and dust processing
- Dust properties depend on SNR parameters

CTB 109: what about the YSOs?



- Class I: ~1-5 x 10^5 yr
- Class II: ~few x 10^6 yr
- transitional disk: no NIR or MIR excess, but in MIR to FIR a Class II excess

Credit: B. Dinçel

CTB 109 observations: ejecta

Sasaki et al. 2013: Chandra observations of the Lobe, Si overabundance

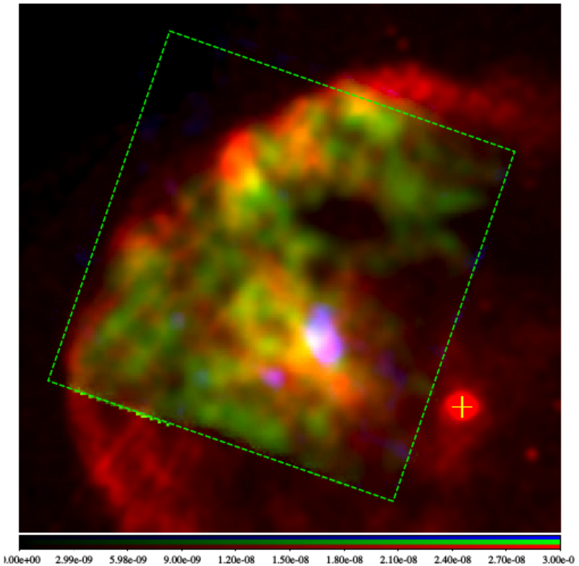
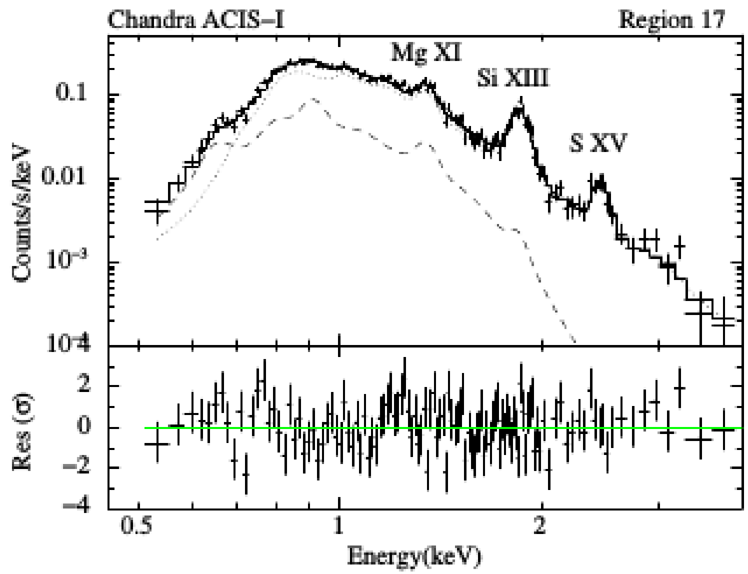


Fig. 10. Three-colour image consisting of a red image for the soft band *XMM-Newton* image (0.3–0.9 keV, Sasaki et al. 2004), a green image for Mg (1.25–1.45 keV) – continuum, and a blue image for Si (1.7–2.1 keV) – continuum. The Mg and Si images were created from the *Chandra* data. The green dashed box indicates the field of view of the *Chandra* ACIS-I. The yellow cross indicates the present position of the AXP 1E 2259+586.



Why study of interaction is important?

- SN provide turbulence to the Galaxy
- SN shocks modify conditions in existing regions (e.g. possibly Solar system)
- Triggering star formation

Appearance of interacting SNRs

- **Ambient ISM properties (n, T) → shock properties**
- **Geometry**
- **SNR evolution stage**
- **Extinction, foreground sources**