# Survey of FIR emission in Galactic supernova remnants

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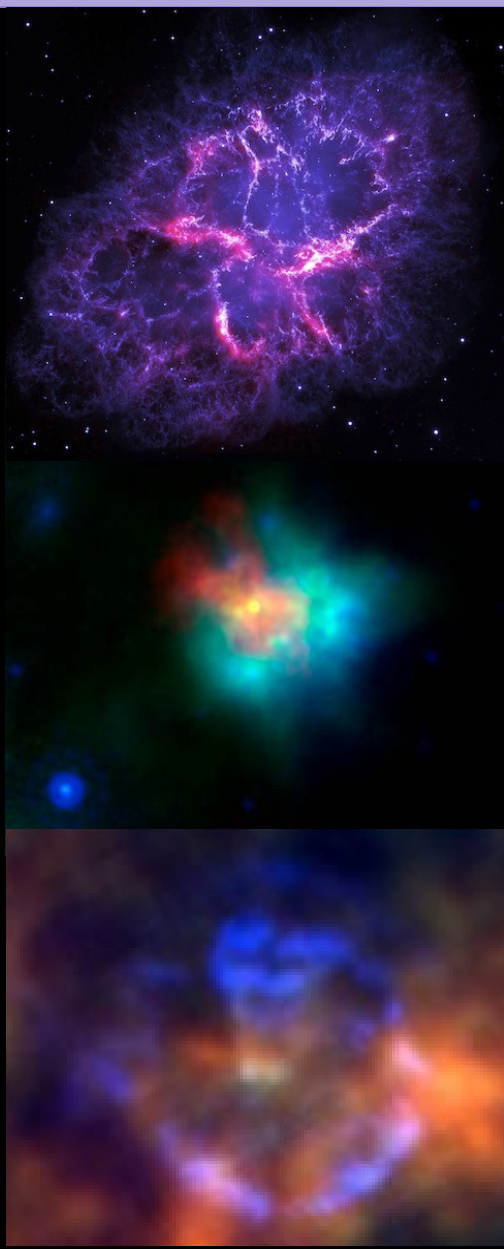
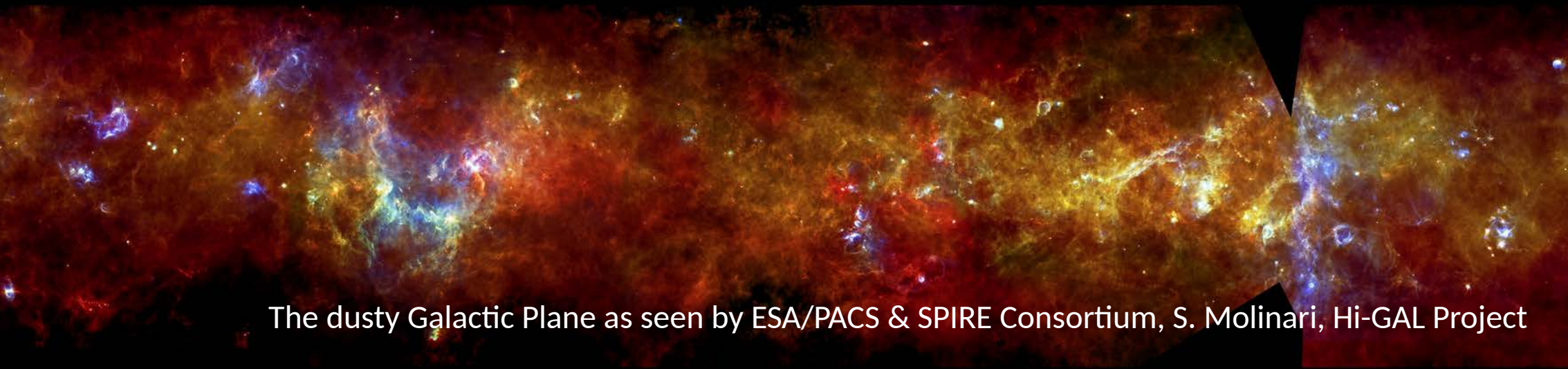
# Why study SNRs with Herschel?

- At Herschel wavelengths we are sensitive to cool dust (<50K)
- Theory predicts that supernovae can produce 0.1 – 1.0 $M_{\odot}$ of dust
- Interactions between supernova remnants and ISM cause shocks which may destroy large mass of dust
- Shocks may change the dust structure



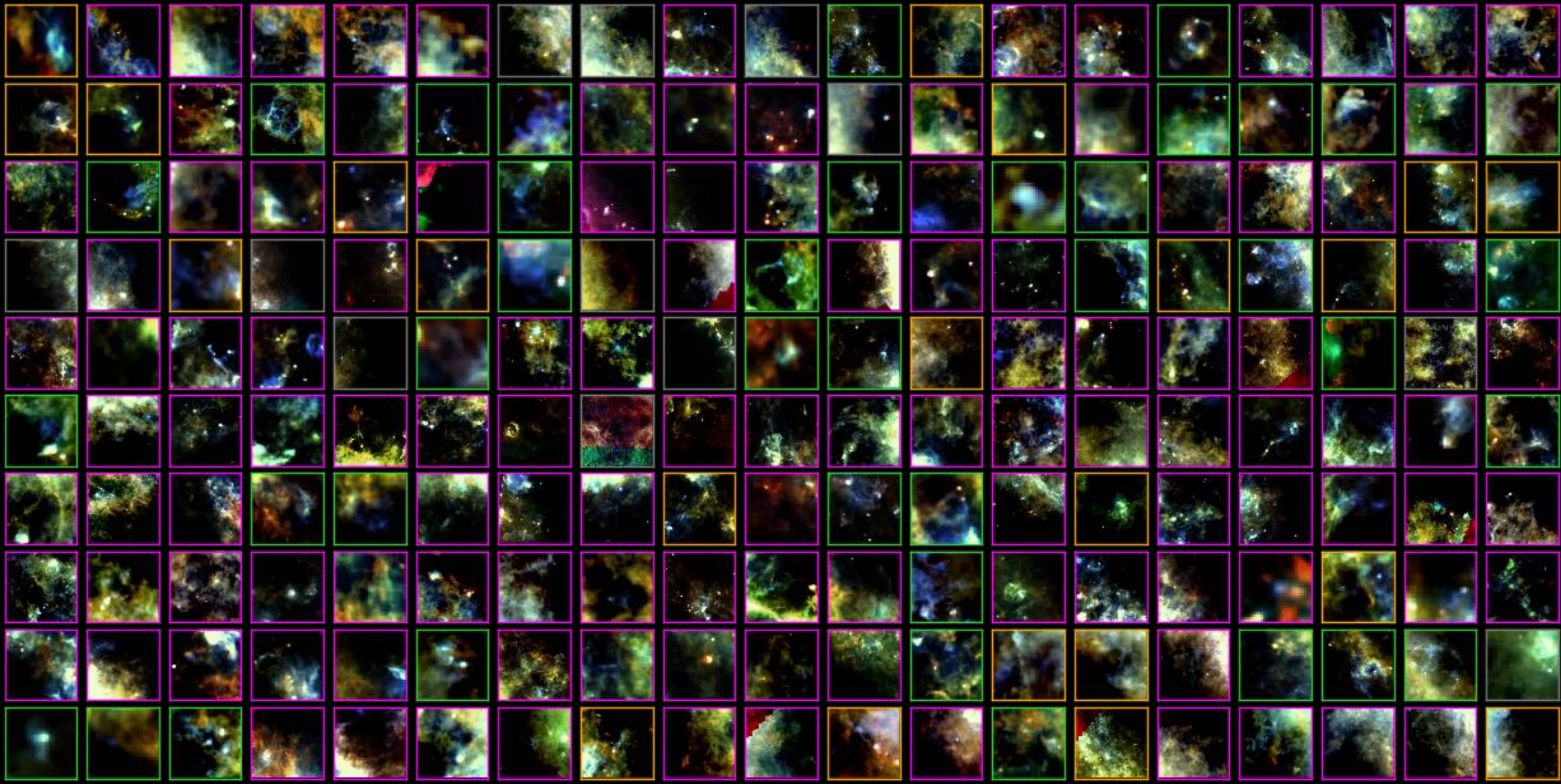
# Survey of Galactic FIR SNRs

1. Search for dust within Galactic supernova remnants
2. Measure mass of supernova ejecta dust
3. Analyse mass, temperature, and dust property variation across remnants



The dusty Galactic Plane as seen by ESA/PACS & SPIRE Consortium, S. Molinari, Hi-GAL Project

# All 190 SNRs covered by the HiGal survey of the Galactic Plane



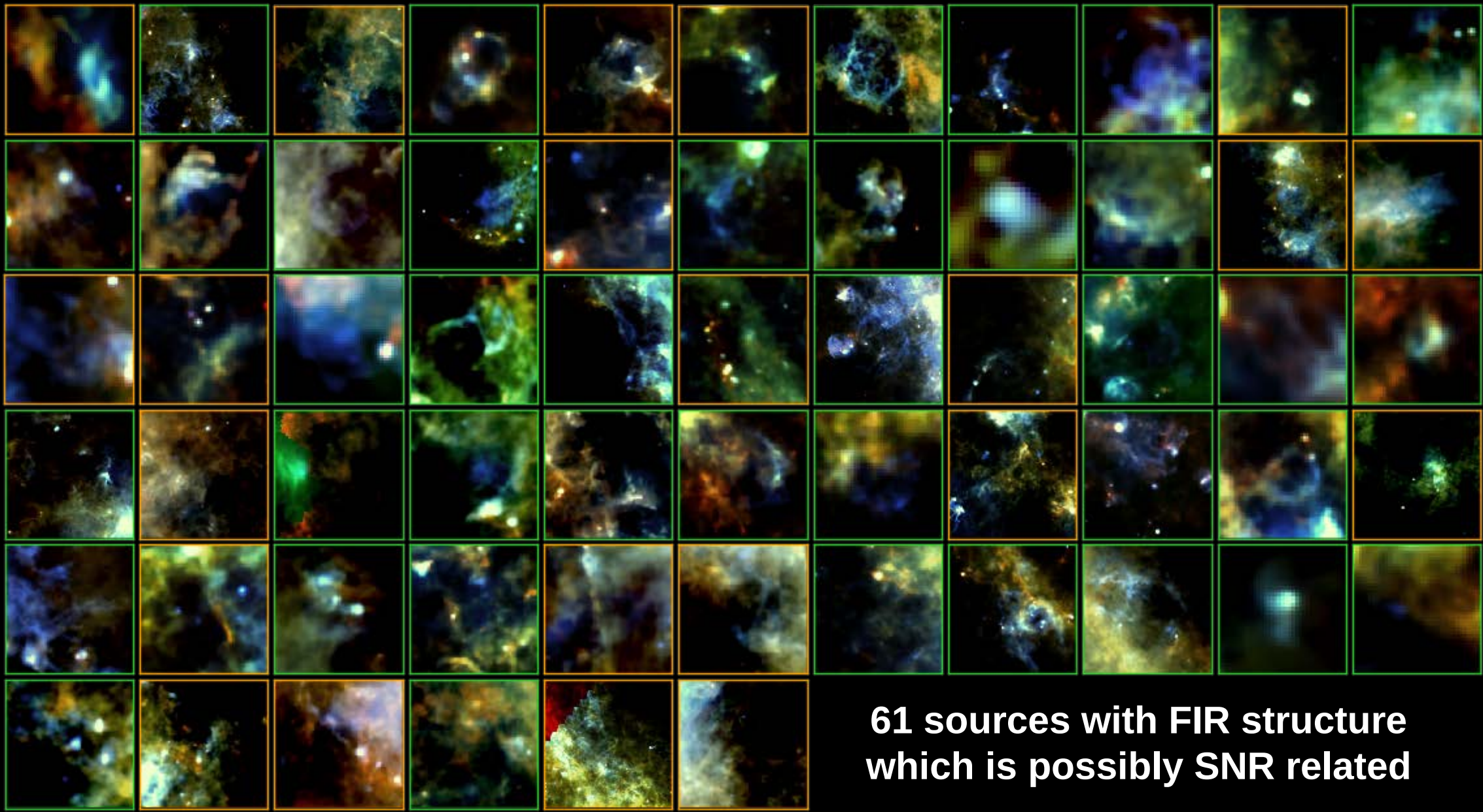
FIR detection of SNR dust

Possible detection - confused

Unrelated FIR

No detection

*Chawner + in review*

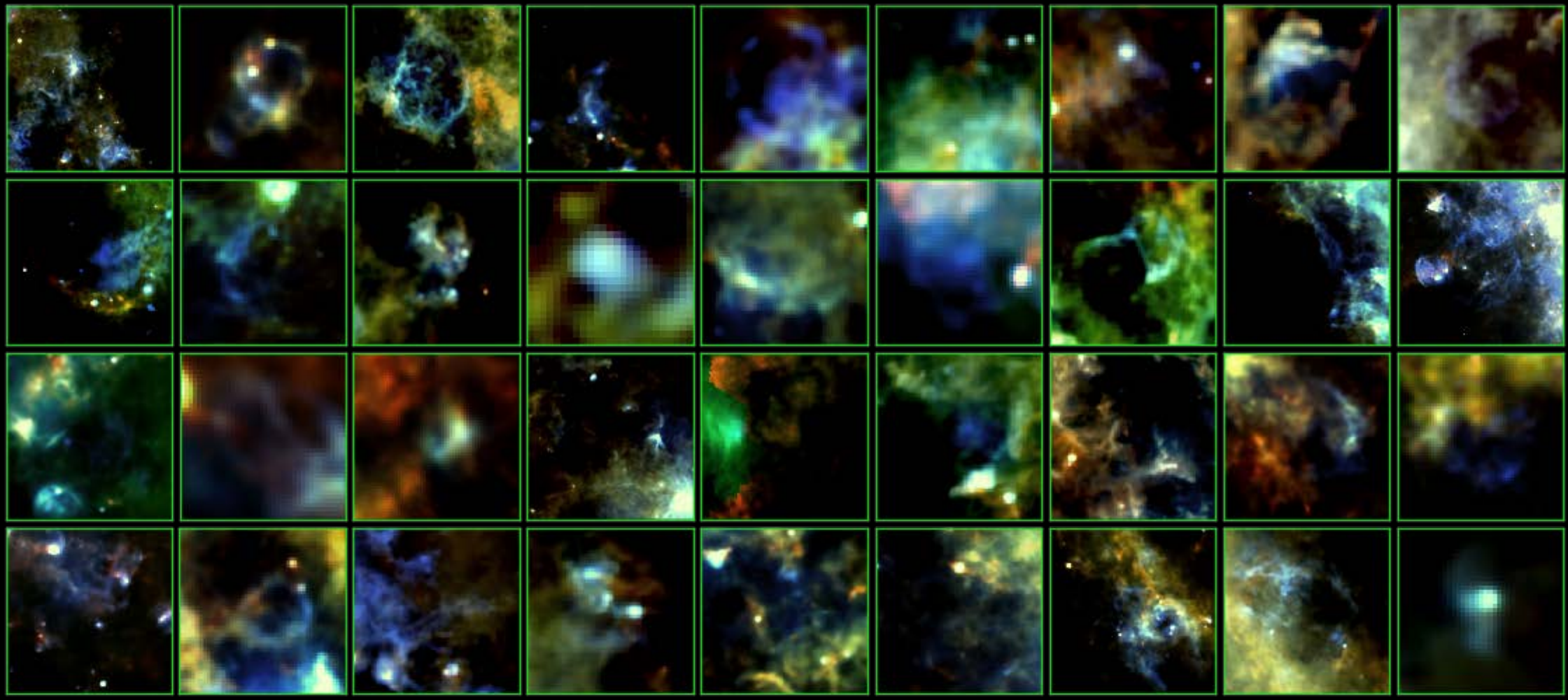


**61 sources with FIR structure which is possibly SNR related**

FIR detection of SNR dust

Possible detection - confused

*Chawner + in review*



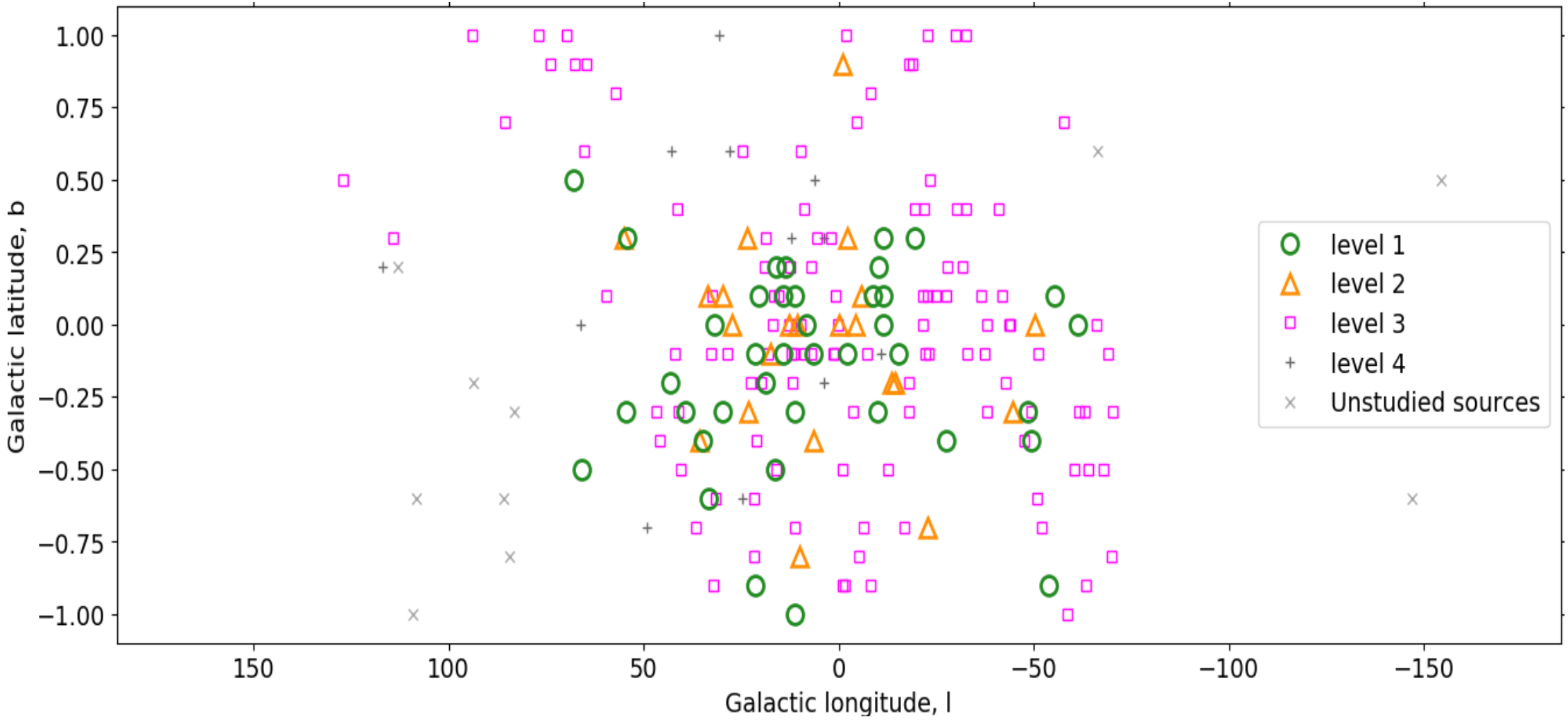
39 detections of SNR associated dust from 190 candidates

~20% detection rate

*Chawner + in review*

# Where are our SNRs?

*Chawner + in review*




**Level 1 : SNR detection with Herschel**

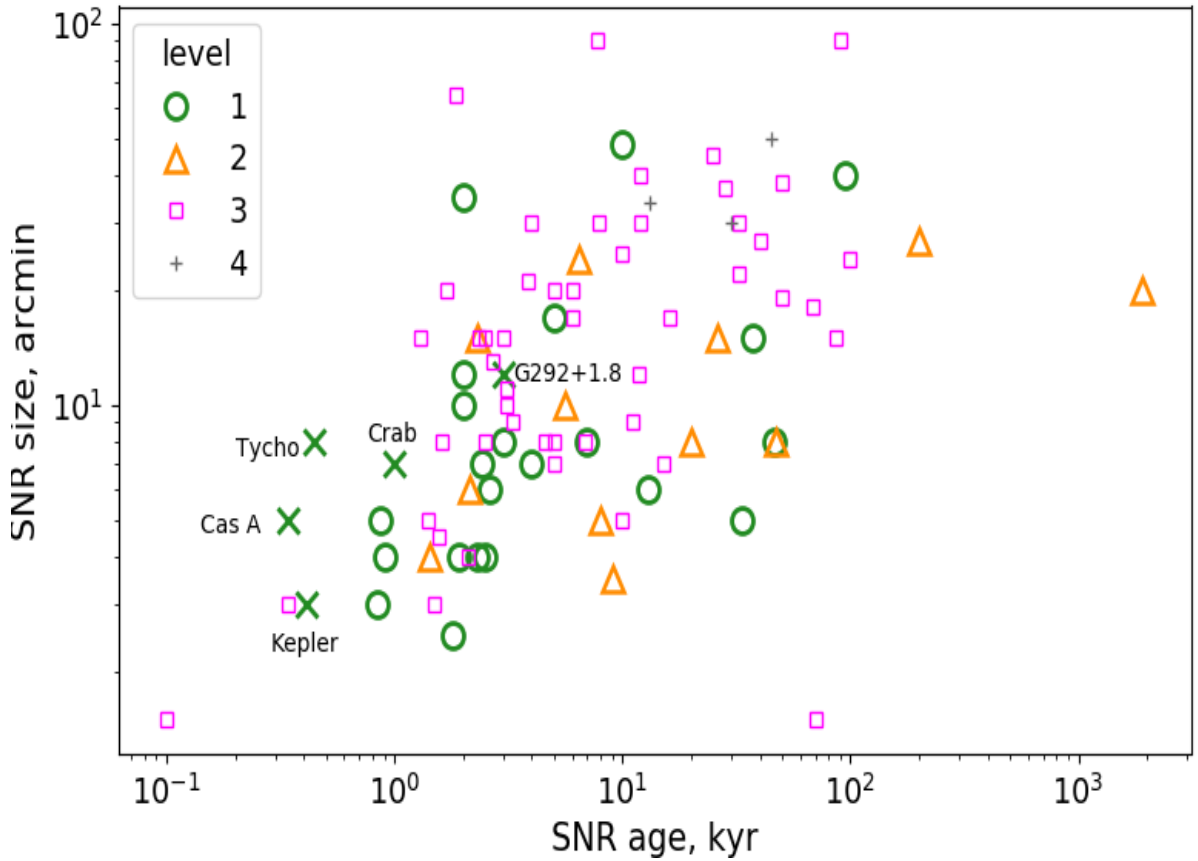
**Level 3 : detection of unrelated FIR**

**Level 2 : confused detection**

**Level 4 : no detection of FIR structure**

# What are our SNRs?

*Chawner + in review*


Unfilled bars indicate historical SNRs:

Cas A, Crab, G292.0+1.8, Kepler, Tycho

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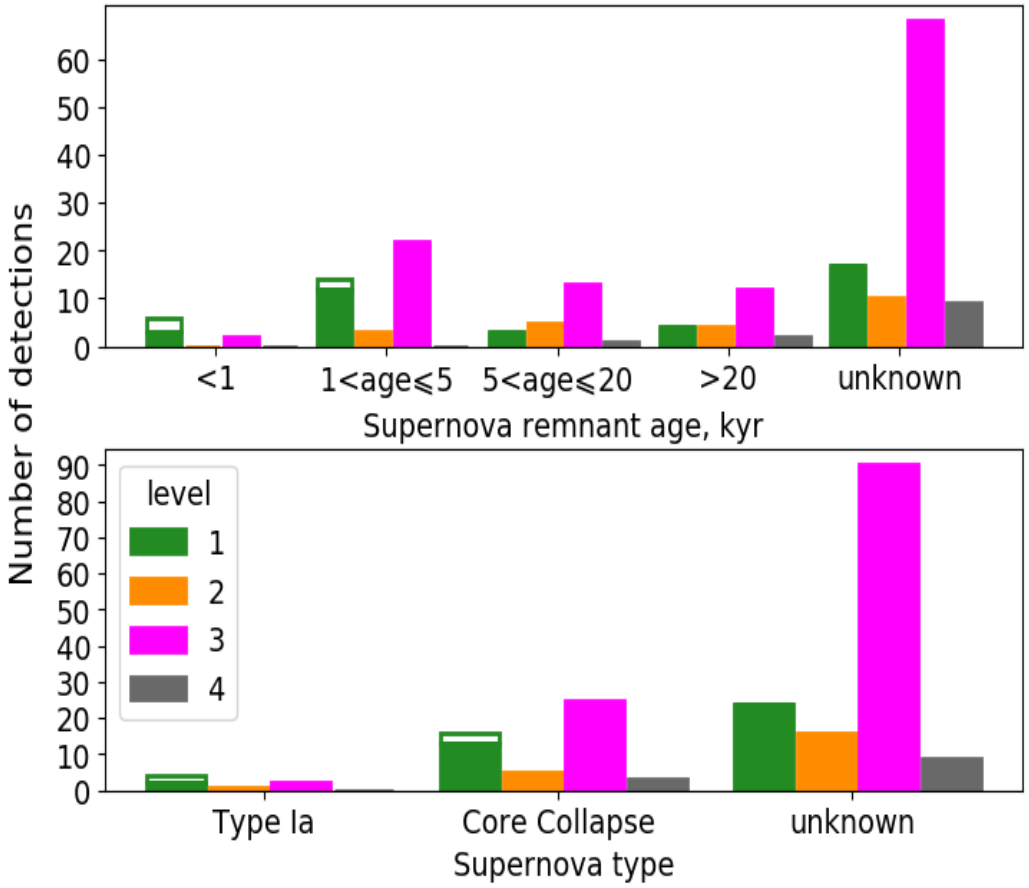
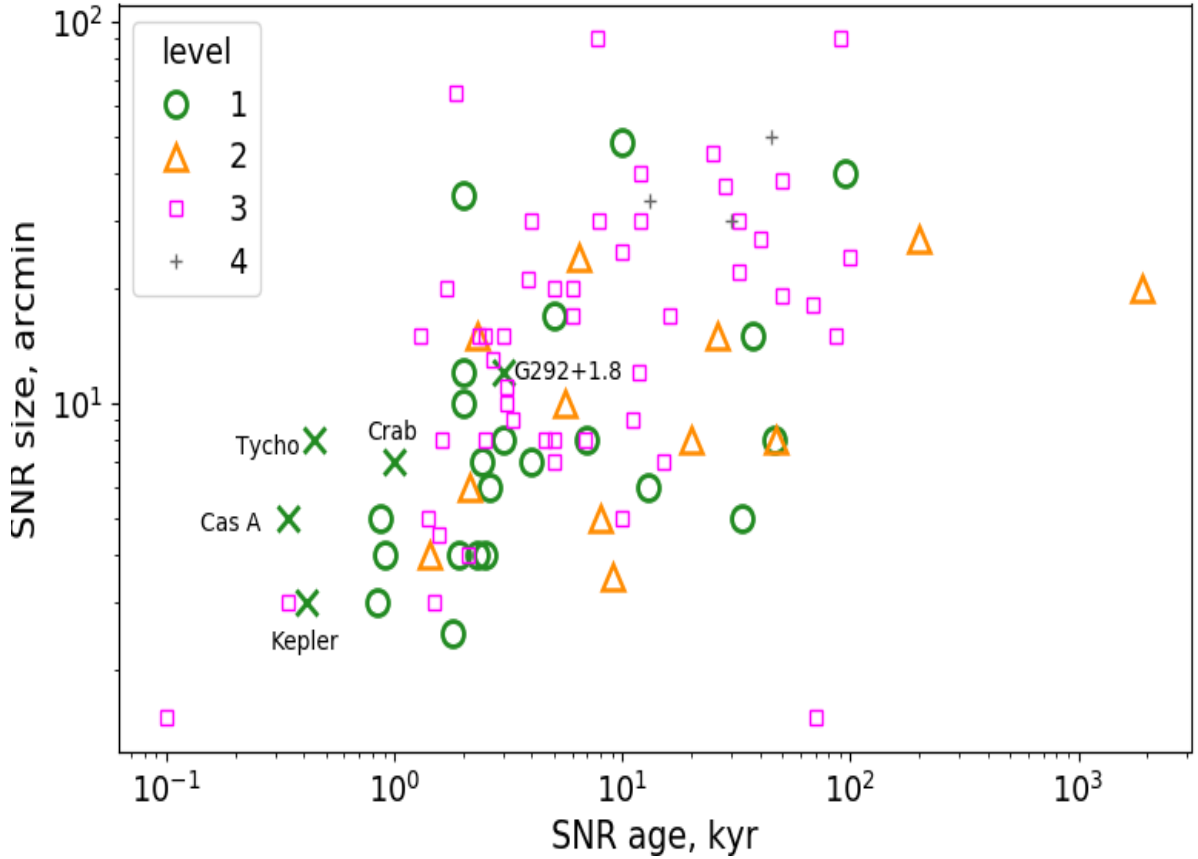
*Chawner + in review*

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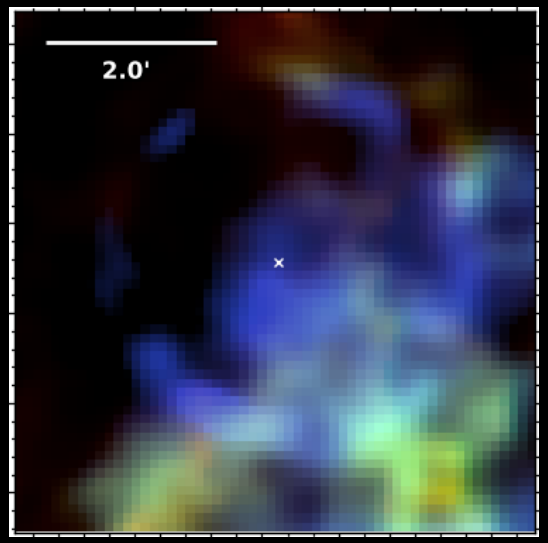
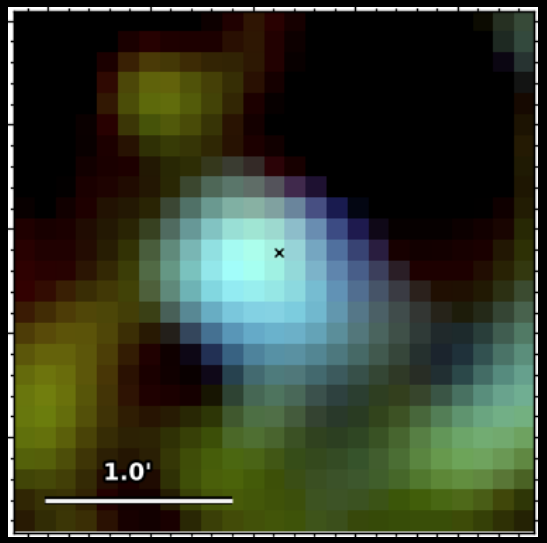
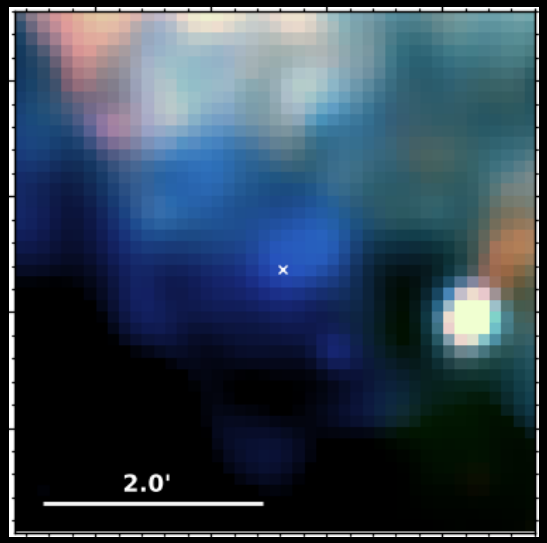
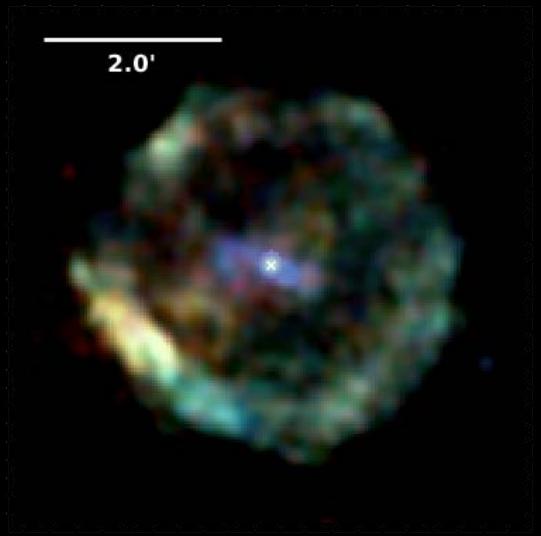
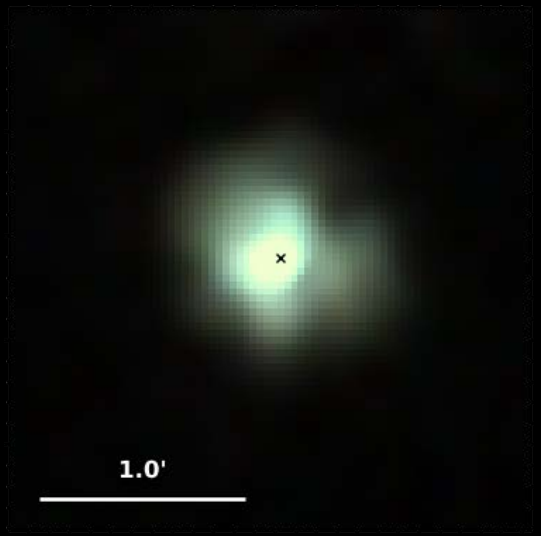
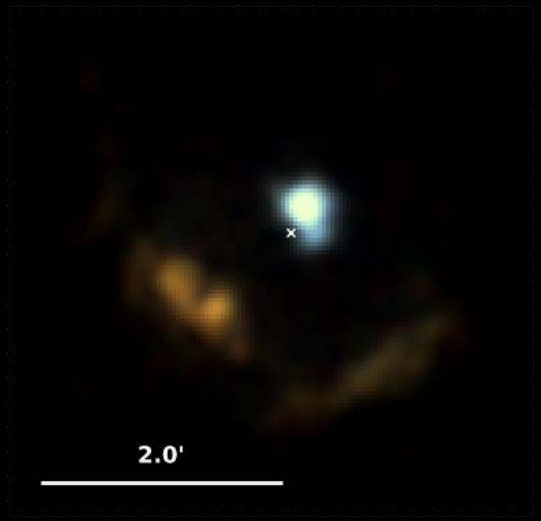
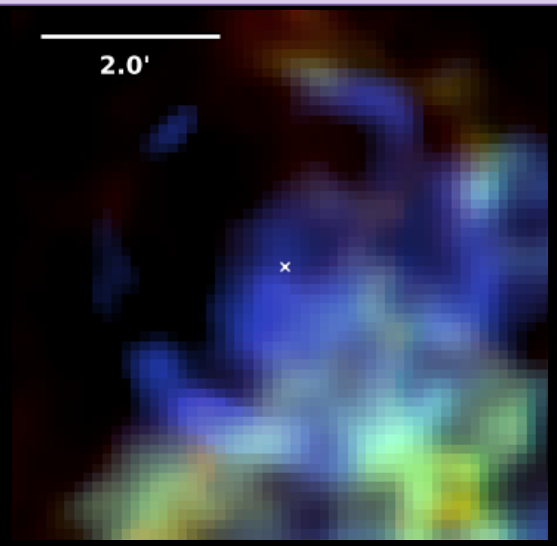
# Dust in Pulsar Wind Nebulae

| | G11.2-0.3 | G21.5-0.9 | Kes 75 |
|---|---|---|---|
| Far-Infrared<br>Herschel<br>70 - 250µm |  |  |  |
| X-Ray<br>Chandra |  |  |  |

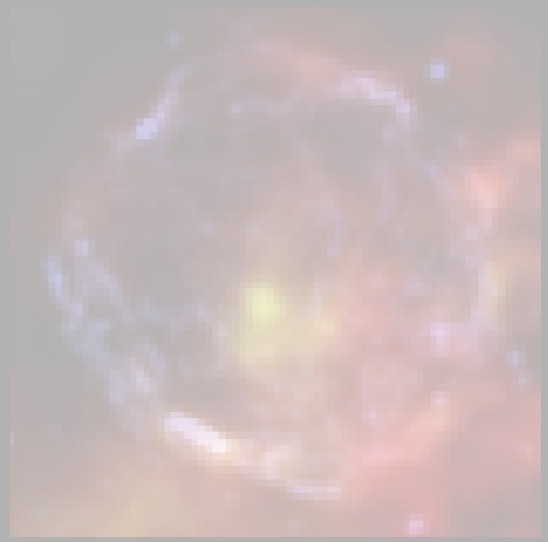
*Chawner + 2019, arXiv:1811.00034*

# Point process mapping to estimate dust mass

*Chawner + 2019, arXiv:1811.00034*




***R = 250μm, G = 160μm, B = 70μm***



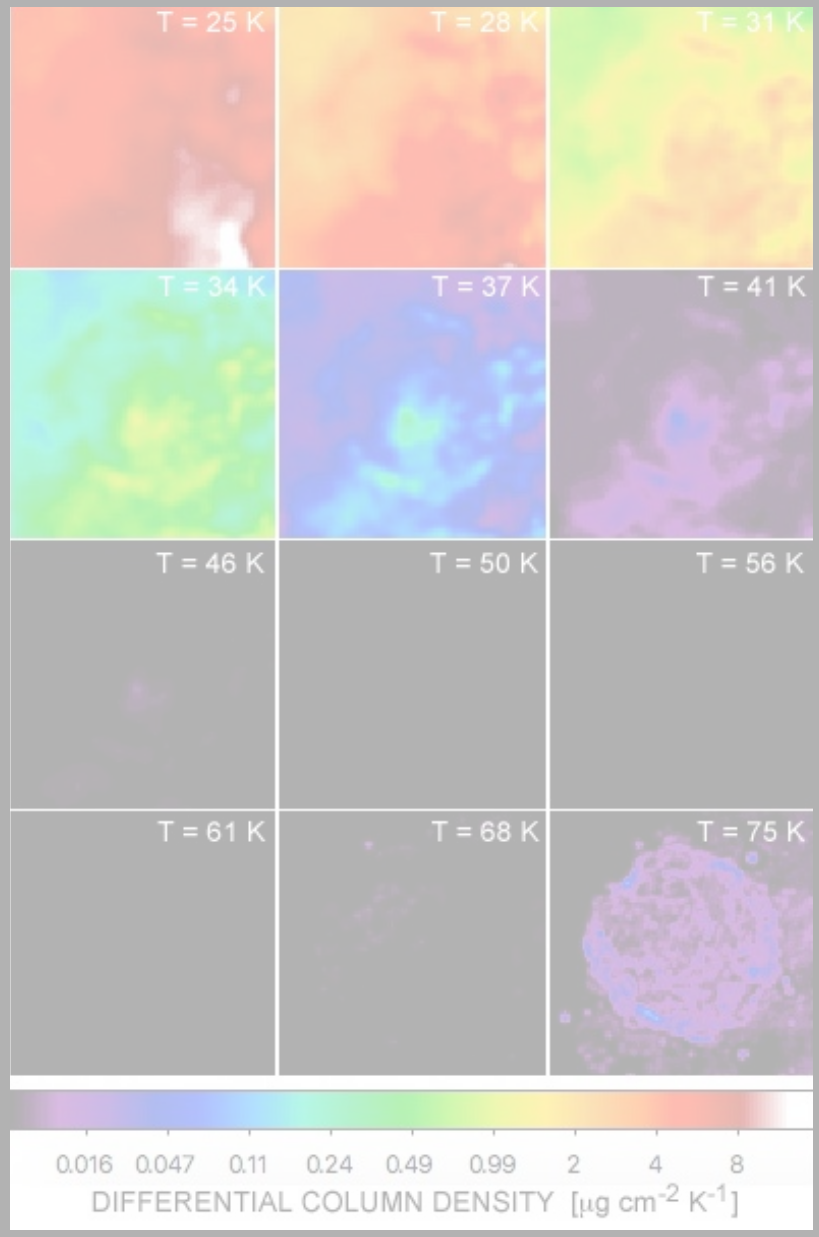
***R = 31K, G = 41K, B = 75K***

## Traditional SED Fitting

- Convolve to lowest resolution (~18" at 250*μm*; ~36" at 500*μm)*
- Assume only 1 or 2 temperatures to estimate dust mass

## PPMAP

- Search for dust at the highest available native resolution (~5" at 70*μm)*
- Look for dust in multiple temperatures slices – identify different heating sources



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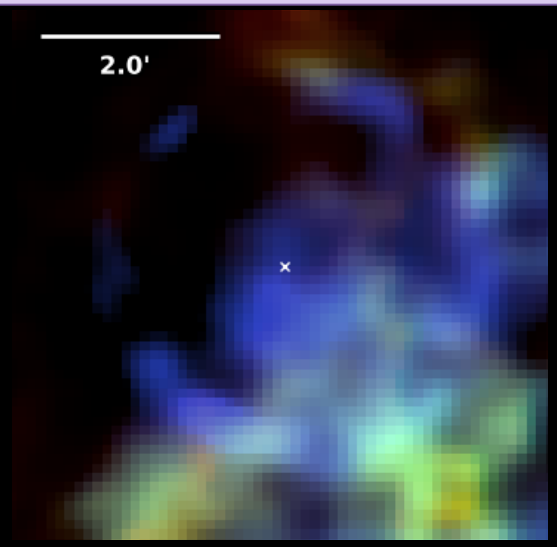


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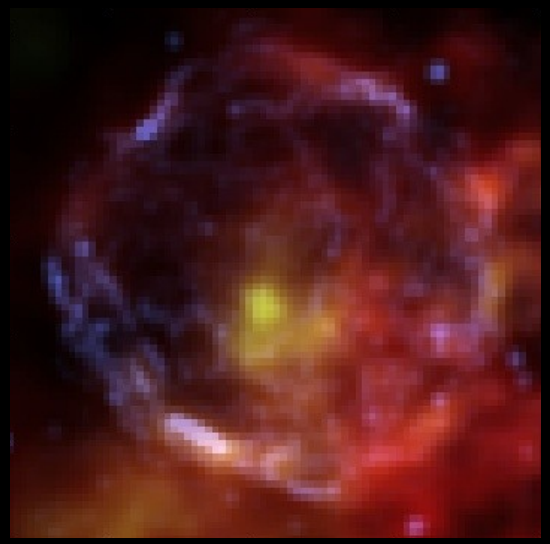

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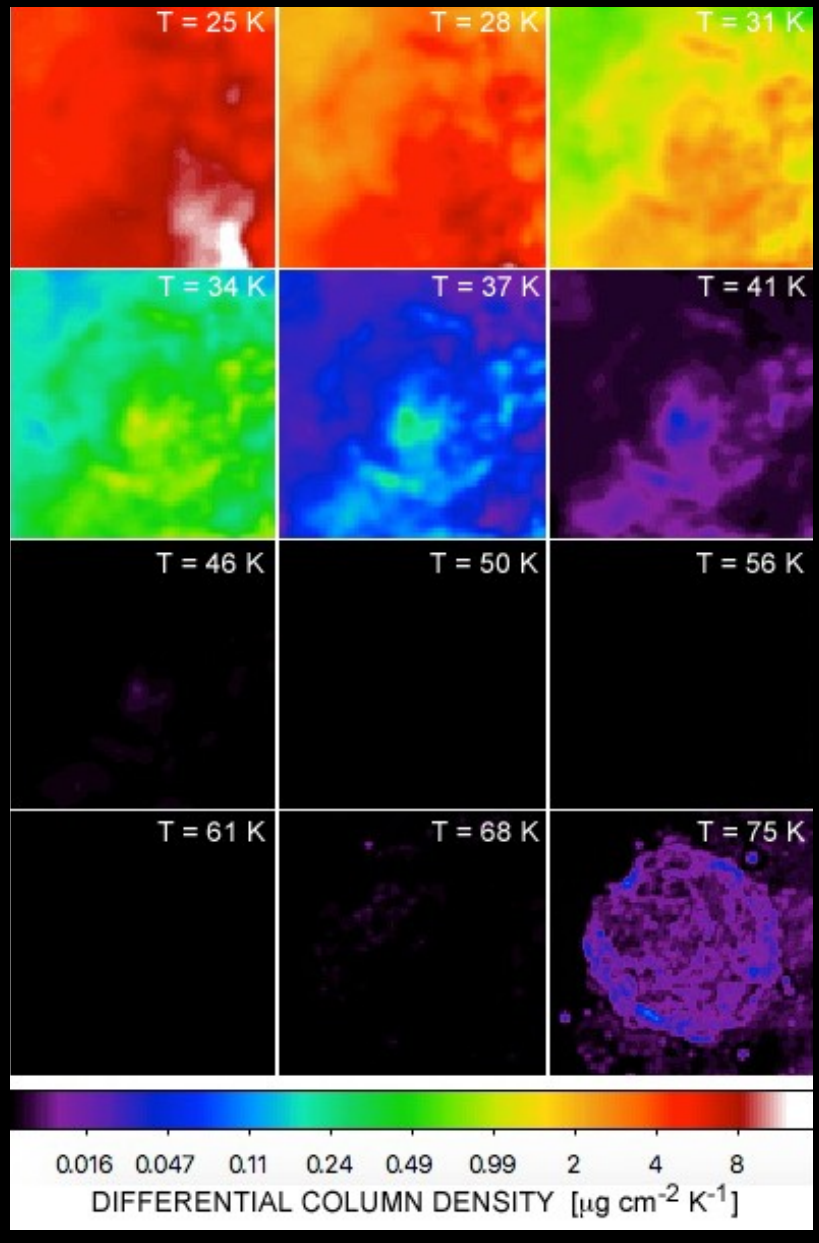
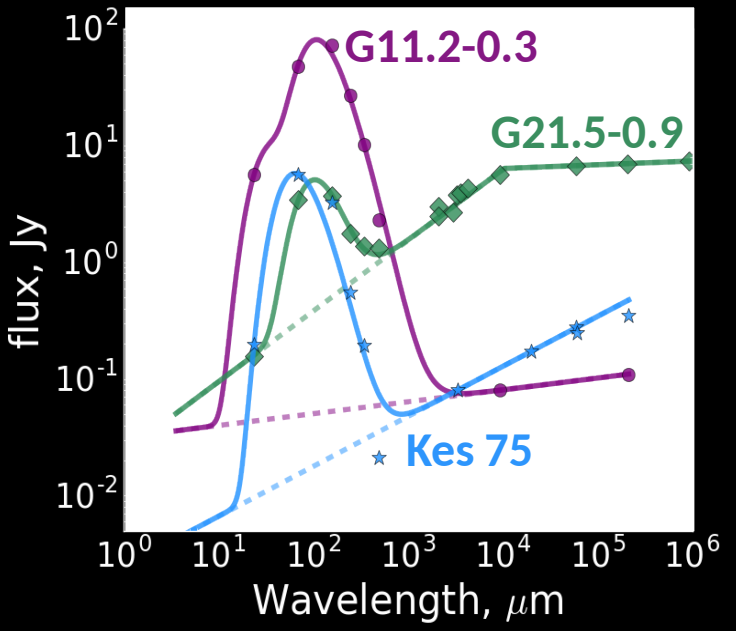


# How much dust is there?

*Chawner + 2019, arXiv:1811.00034*

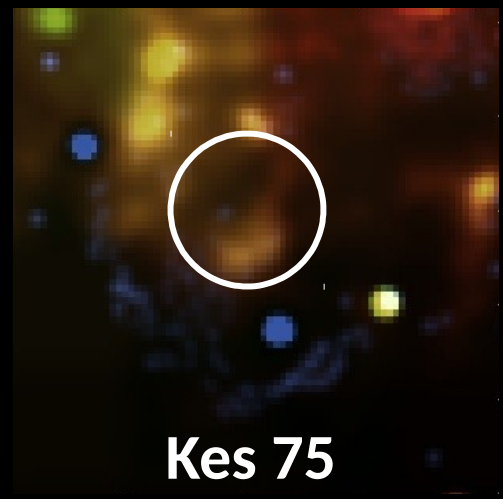
| | G11.2-0.3 | G21.5-0.9 | Kes 75 |
|---|---|---|---|
| SED fit dust mass ($M_\odot$) | 1.1 ± 0.4 | 0.12 ± 0.02 | 0.3 ± 0.3 |
| PPMAP dust mass | 0.34 ± 0.14 | 0.29 ± 0.08 | 0.51 ± 0.13 |





***R = 31K, G = 41K, B = 75K***


***R = 25K, G = 34K, B = 37K***

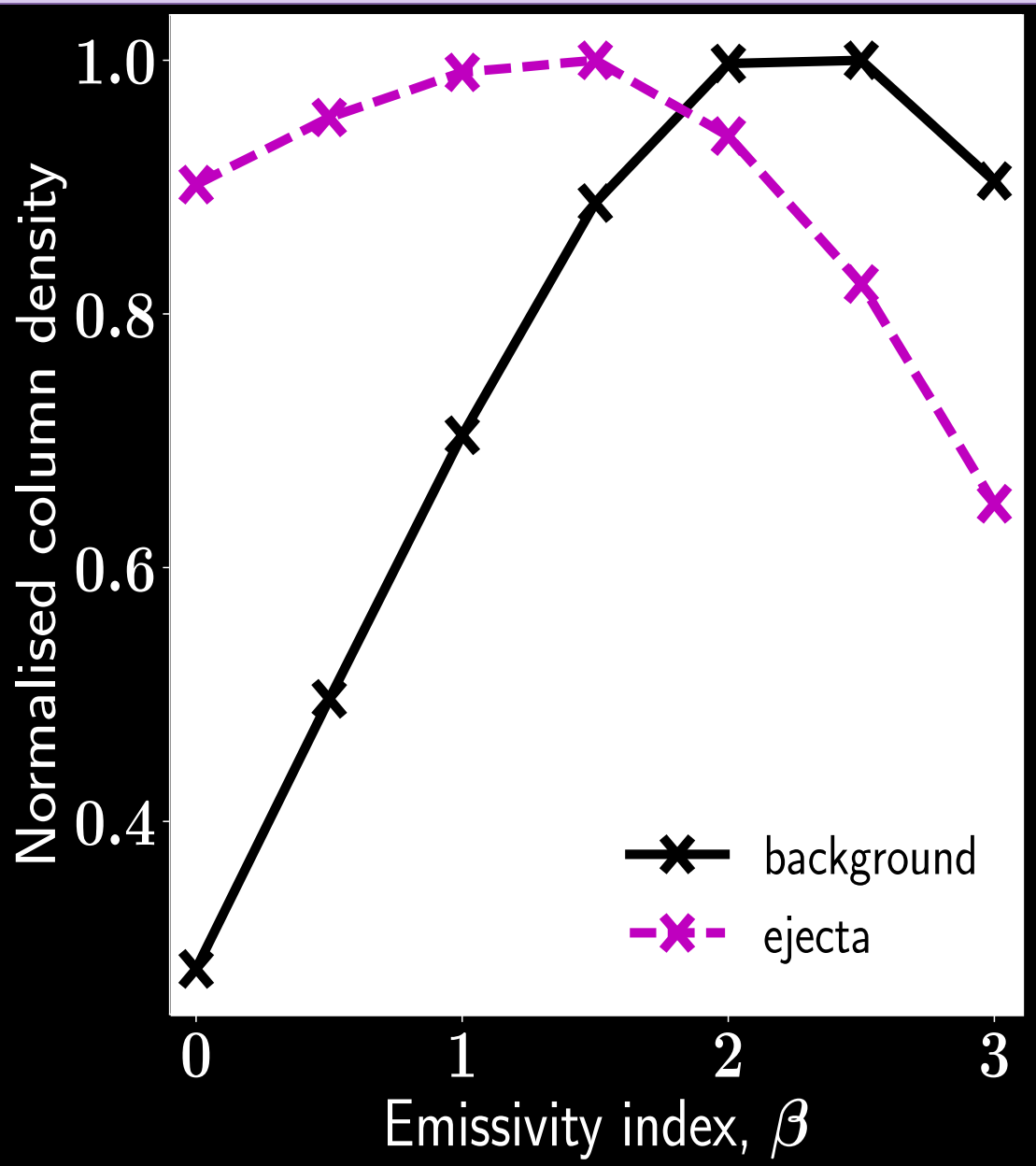



***R = 28K, G = 31K, B = 75K***

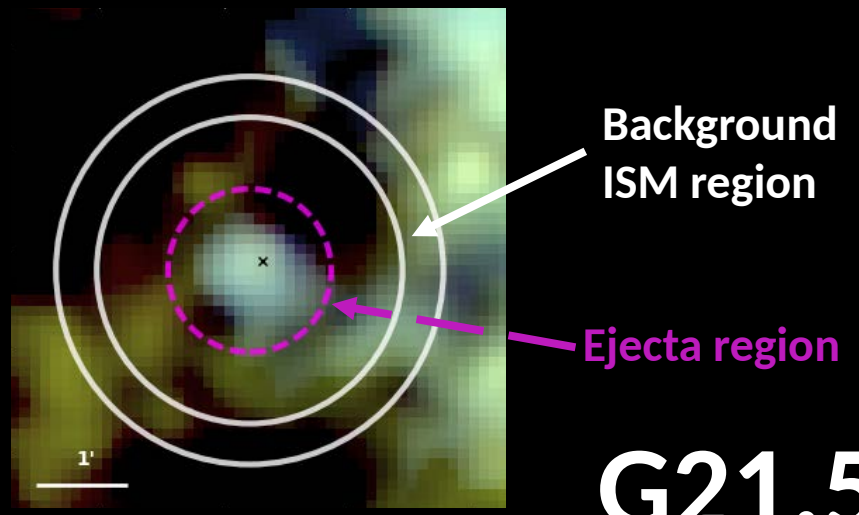
See also Temim+ in prep and Felix Priestley's poster

# Are the SNR & ISM dust different?

*Chawner + 2019, arXiv:1811.00034*




- β depends on dust properties e.g. grain size, carbonaceous vs silicate
- We can use PPMAP to probe β and compare dust properties in different regions
- Some evidence for variation in dust properties of SNR and ISM material

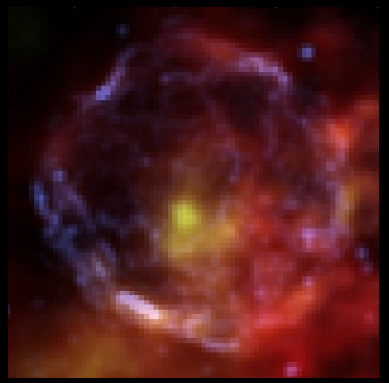


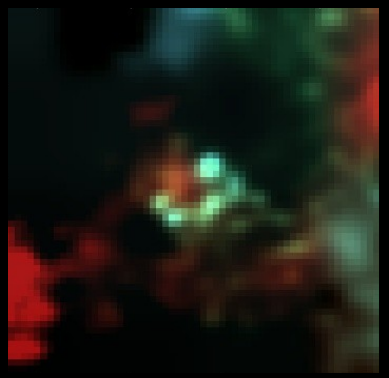

**G21.5-0.9**

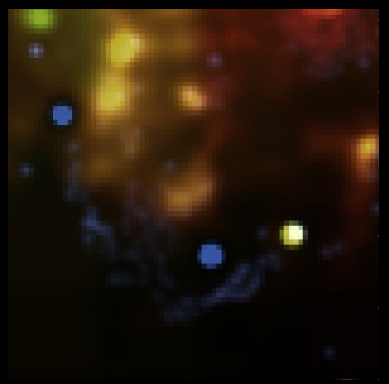
# Conclusions

*Chawner + 2019, arXiv:1811.00034 & Chawner + in review (MNRAS)*

- Add 38 sources to the sample of dusty supernova remnants
- Detect 3 supernova remnants containing ejecta dust heated by pulsar wind nebulae
- Analysis of dust mass indicates supernovae may produce significant amounts of dust
- Marginal evidence for variation in dust properties of G21.5-0.9 compared with surrounding ISM







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COSMIC DUST

# Point Process Mapping, PPMAP

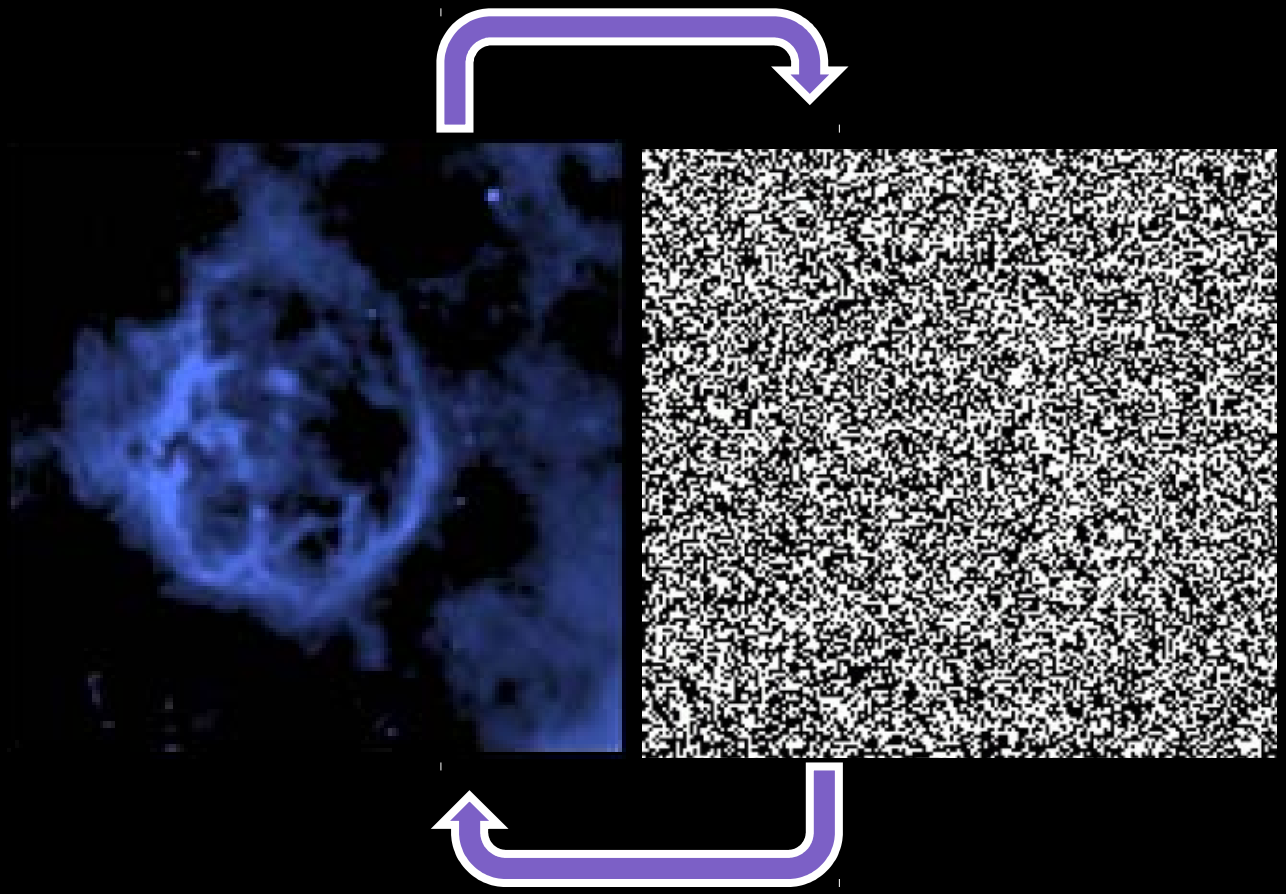
Column density = x

Structures are made up of building blocks with:

- Unit column density
- Unknown temperature & emissivity

Ref: PPMAP, Marsh et al. 2015, 2017

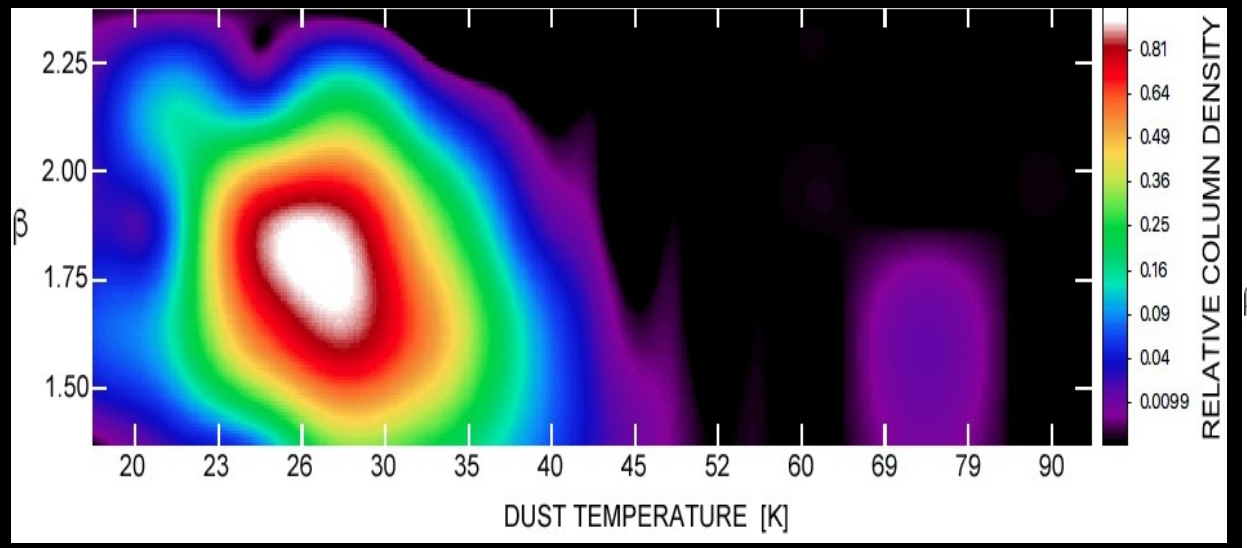
# Point Process Mapping, PPMAP



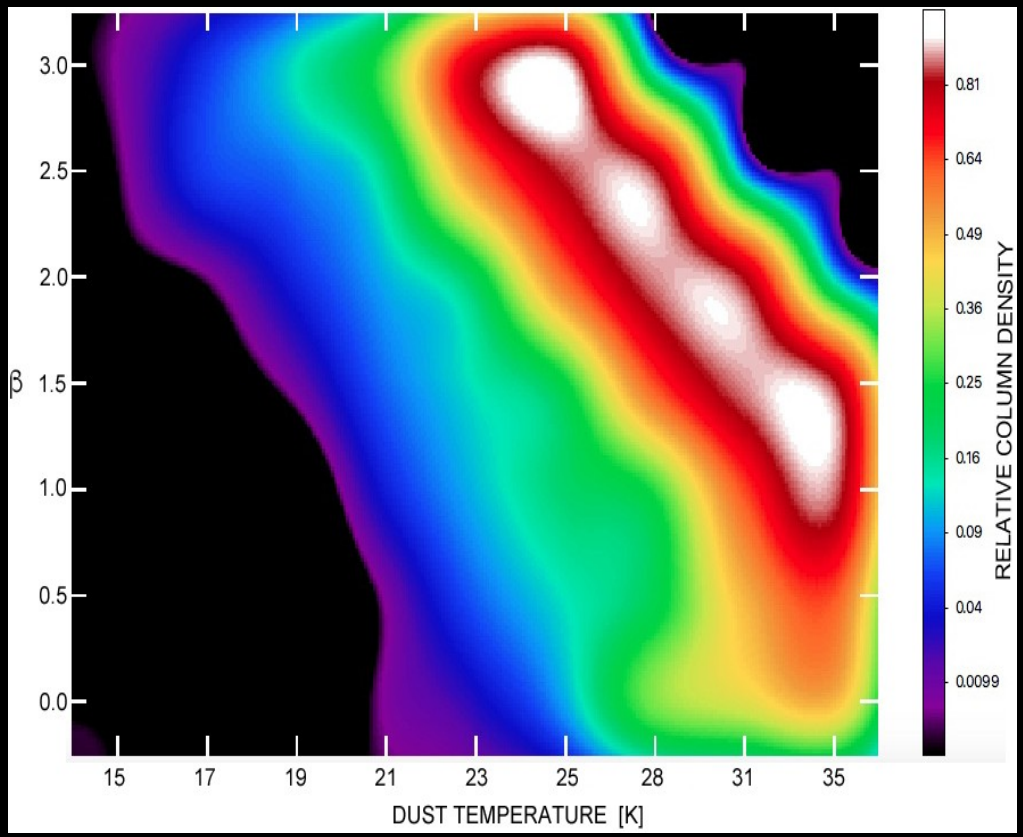
- Increase image noise until there is no information
- Decrease noise in steps
- Update knowledge about building block temperature and emissivity at each step

Ref: PPMAP, Marsh et al. 2015, 2017

# PPMAP degeneracy – G11.2-0.3




Applying a Gaussian prior to the distribution of mass across emissivity index




No prior for the distribution of mass across emissivity index