Evolution of interstellar dust with Herschel

First results in the PDRs of NGC 7023

SPIRE ISM consortium

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Scientific goals of the Key project

Evolution of interstellar dust

Survey of the properties of interstellar dust with different conditions

Av, Illumination, Density, History, Star forming activity

Contribution of all processes acting on the dust particles …

Fragmentation / Coagulation / Condensation / Evaporation / Photo-processing

… for very diffuse regions to sites of star formation of our Galaxy

Selected targets in nearby galactic regions,

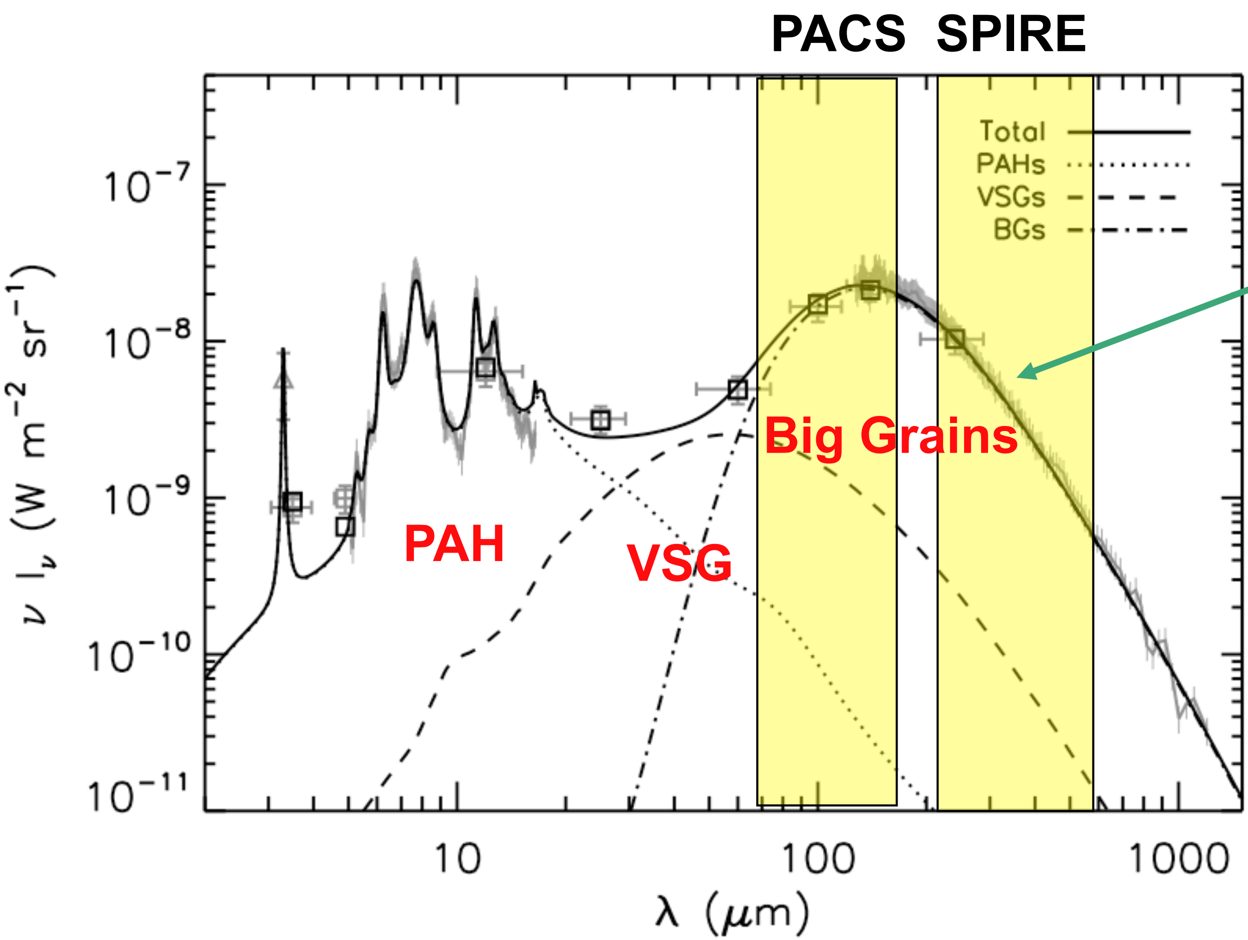
with precise and well understood physical conditions and geometry,
in order to derive the dust and gas properties from the observations

Combination of Mapping and Spectroscopy (SPIRE and PACS)

Dust SED: Continuum
Physical conditions : mainly CI, CII, OI, high-level lines of CO

Strong emphasis on the spatial information within individual objects

Full emission spectrum of interstellar dust



$$I_\lambda = \tau_{\lambda_0} \left(\frac{\lambda}{\lambda_0} \right)^{-\beta} B_\lambda(T)$$

Diffuse medium,
Compiègne et al. 2010

Models after Spitzer, before Herschel/Planck:

- Silicate + Graphite + PAH (e.g.,Draine & Li 2007)
- Silicate + Amorphous Carbon + PAH (e.g., Compiègne et al. 2010)
- with Silicate-cores / Carbonaceous mantles (e.g., Désert et al. 2010)
- with composite grains (e.g., Zubko et al. 2004)

Main questions to be addressed with Herschel

Emission properties of Big Grains:

Spectrum of the Big Grains ?

Variations of the emissivity index ? Dependence with the temperature ?

Absolute emissivity ? Dependence with the physical conditions ?

Nature and structure of Big Grains:

Separated populations of Carbonaceous and Silicate grains ?

Composite grains ? Aggregates ?

Evolution with :

- the physical conditions ?
- the smaller dust components ?

Structure of the ISM (diffuse clouds to dense cores) traced by the Big Grains emission (most of the dust mass)

Source	I_{100}[1]
Shock processed dust	
Spica H II	1-4
IVC G86.5+59.6	1-2
Cirrus to Molecular Clouds	
Ursa Major	4-8
Polaris flare	5-10
G300-17/Cham III	8-18
Taurus filament	10-20
PDRs	
NGC7023	1000
Horsehead	500
IC63	100
Ced201	100
ρ Oph filament	500
NGC7023 E	200
NGC2023	2000
IC59	100
Orion Bar	20,000
L1721	100
California	100
Hot PDRs with H II regions	
Sh2-104, Cygnus	
RCW 79	
RCW 82	
RCW120	
Pre-stellar cores	
L1544, Taurus	
L1521 E, Taurus	
L1521 F, Taurus	
L1689B, Ophiuchus	
Class 0 protostars	
IRAM04191, Taurus	
IRAS16293, Ophiuchus	
N1333-IRAS4, Perseus	
N6334I(N), NGC6334	
Class I protostars	
IRAS04191, Taurus	
L1489-IRS, Taurus	
EL29, Ophiuchus	
N6334I, NGC6334	

Sources and Observation Modes

Objects	Number	Observation Modes (SPIRE and PACS)
Galactic lines of sight	4	Spectroscopy
Very diffuse regions	2	Mapping
Cirrus/Molecular Clouds	4	Mapping
Classical PDRs	10	Mapping & Spectroscopy
Hot PDRs	4	Spectroscopy
Pre-stellar cores	4	Spectroscopy
Class-0 protostars	4	Spectroscopy
Class-1 protostars	4	Spectroscopy

(Large scale mapping of nearby molecular clouds in the Goult belt and HOBYS surveys, André et al., Motte et al.)

	Time (h)
SPIRE mapping alone	4.5
SPIRE + PACS // mapping	22.5
SPIRE Spectroscopy	85
PACS Mapping alone	20.3
PACS Spectroscopy	28
Total	163

Source	I_{100}[1]
Shock processed dust	
Spica H II	1-4
IVC G86.5+59.6	1-2
Cirrus to Molecular Clouds	
Ursa Major	4-8
Polaris flare	5-10
G300-17/Cham III	8-18
Taurus filament	10-20
PDRs	
NGC7023	1000
Horsehead	500
IC63	100
Ced201	100
ρ Oph filament	500
NGC7023 E	200
NGC2023	2000
IC59	100
Orion Bar	20,000
L1721	100
California	100
Hot PDRs with H II regions	
Sh2-104, Cygnus	
RCW 79	
RCW 82	
RCW120	
Pre-stellar cores	
L1544, Taurus	
L1521 E, Taurus	
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IRAS04191, Taurus	
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Used Observations

SPIRE and PACS mapping in the Science Demonstration Phase (SDP):

Cirrus/molecular cloud: Polaris (common field with the Gould belt KP)

Miville-Deschênes et al., Men'shchikov et al., Ward-Thompson et al.

Classical PDR: NGC 7023 Abergel et al.,

Hot PDRs: RCW120, SH2-104 Anderson et al., Rodon et al.

SPIRE/FTS (single pointings) spectroscopy in the SDP :

SH2-104**:** Rodon et al.

+ SPIRE/FTS (single pointings) in the Performance Verification Phase:

Orion Bar: Habart et al., Naylor et al, Dartois et al.

DR21, Rosette: White et al.

Compact HII regions: G29.96-0.0, G32.80+0.19 Kirk et al., Dartois et al.

Pre-stellar core B133: Ward-Thompson et al.

Less than 10 % of the total observing time

No PACS spectroscopy

No full sampling SPIRE/FTS observation

Mapping of NGC 7023
Observations & Data processing

SPIRE :

2 perpendicular 8’ X 8’ maps (nominal scan speed , R=4), total time= 1765 s

Level-2 naive maps delivered by the HSC (standard corrections)

Overall absolute flux accuracy: 15 %

PACS :

2 perpendicular 10’ X 10’ maps (medium scan speed), total time= 5166 s

HIPE 2.3.1: Simple projection with second level deglitching

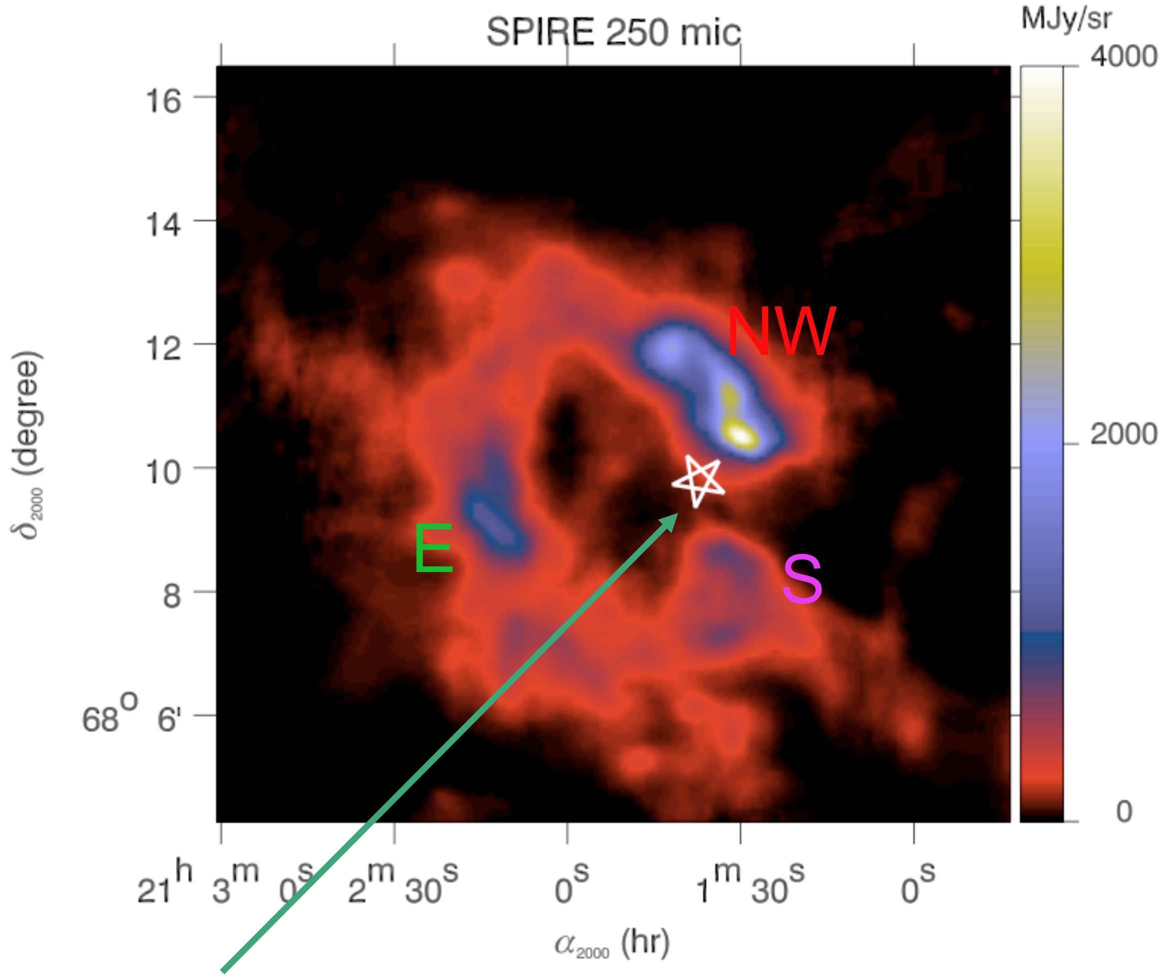
High pass filtering to remove the 1/f noise

Artefacts around bright structures

Preliminary

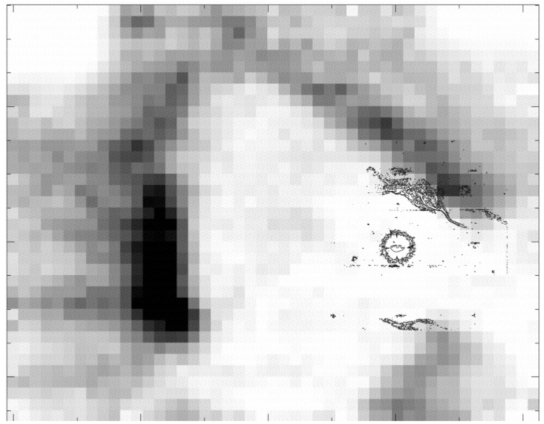
Overall absolute flux accuracy: 10% and 20% in the blue and red bands, resp.

NGC 7023



HD 200775

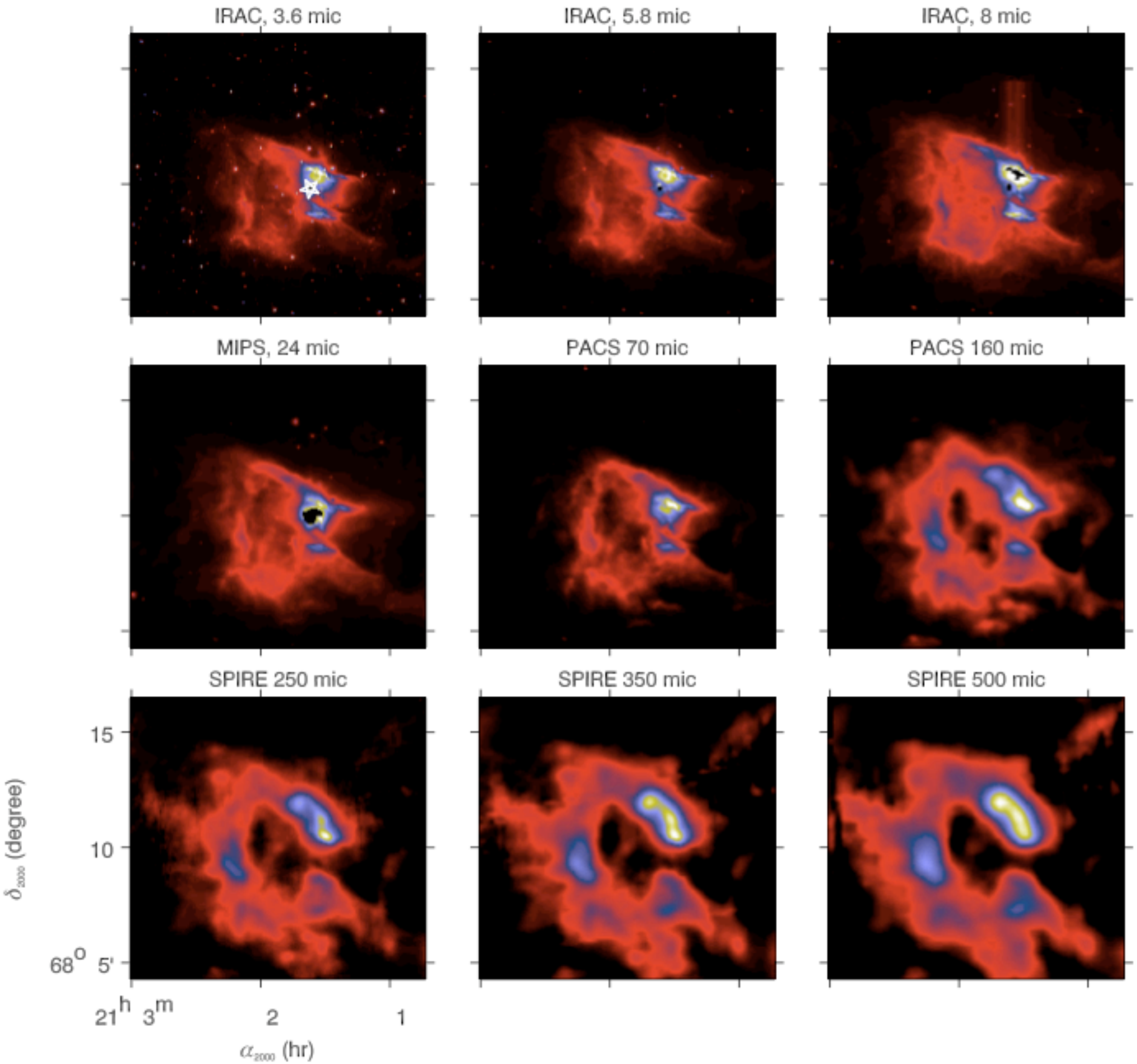
^{13}CO (3-2) emission



Gerin et al. 1998

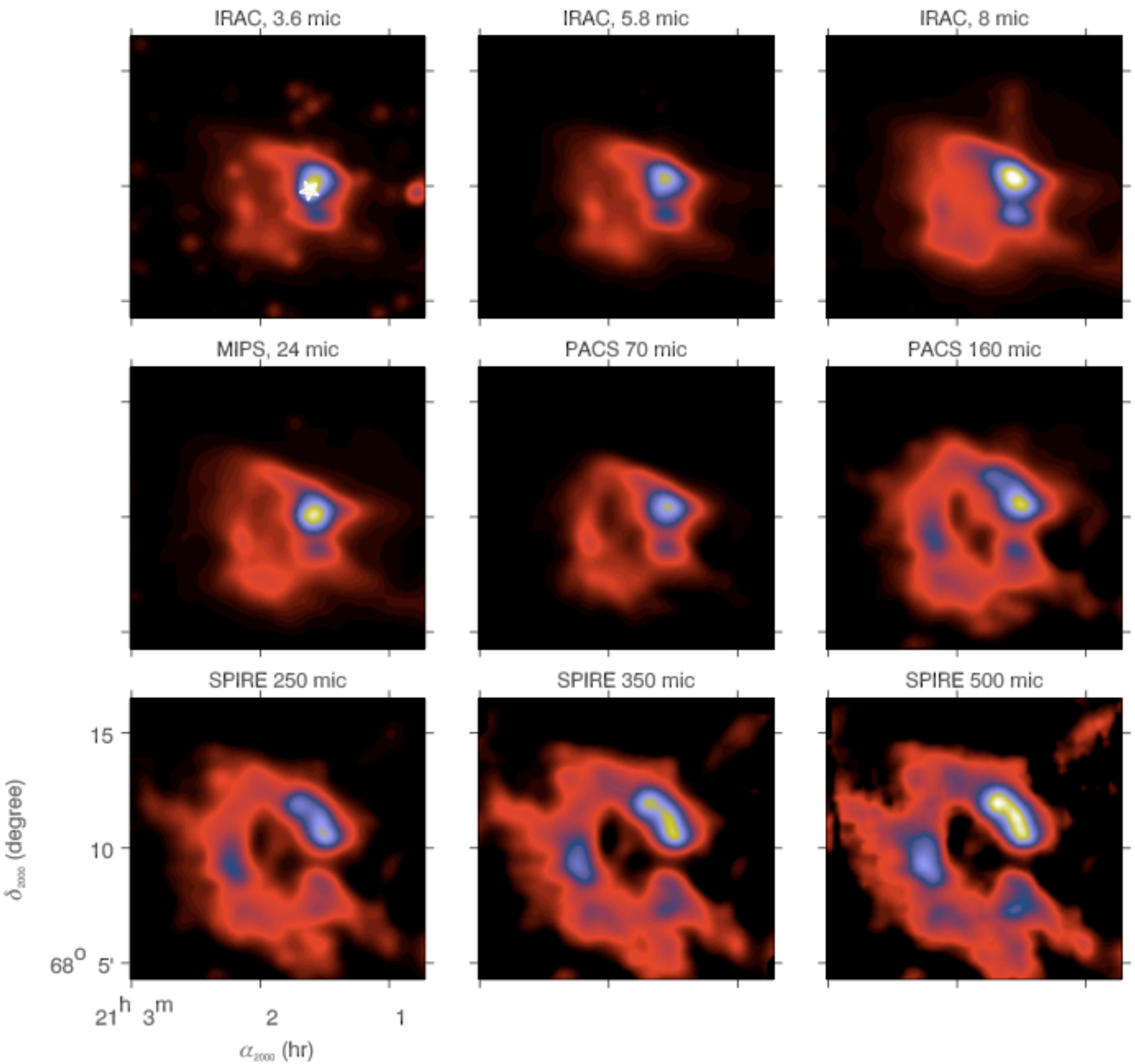
3 PDRs viewed approximately edge-on

NGC 7023: Spitzer + Herschel



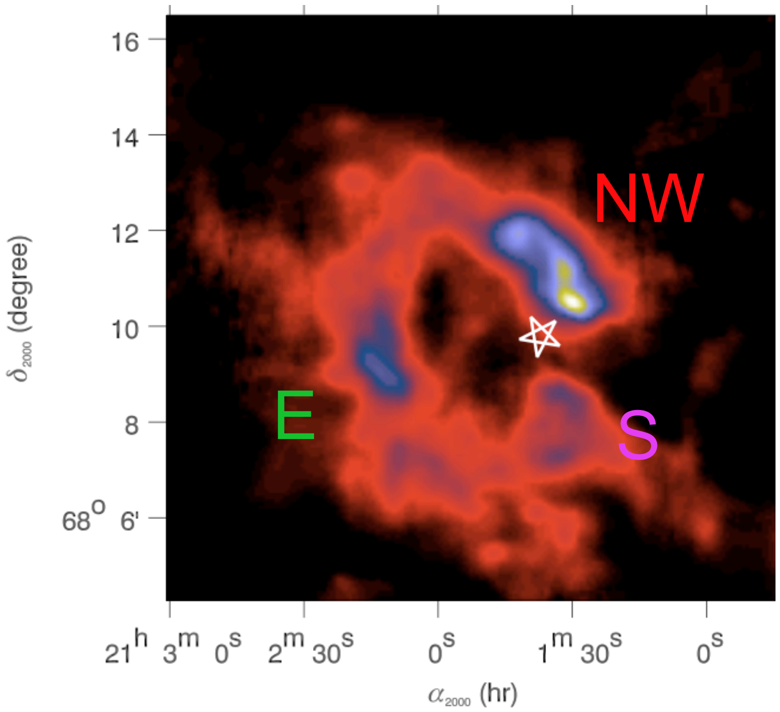
NGC 7023: Spitzer + Herschel

Angular resolution of SPIRE at 500 µm assuming gaussian beams Preliminary

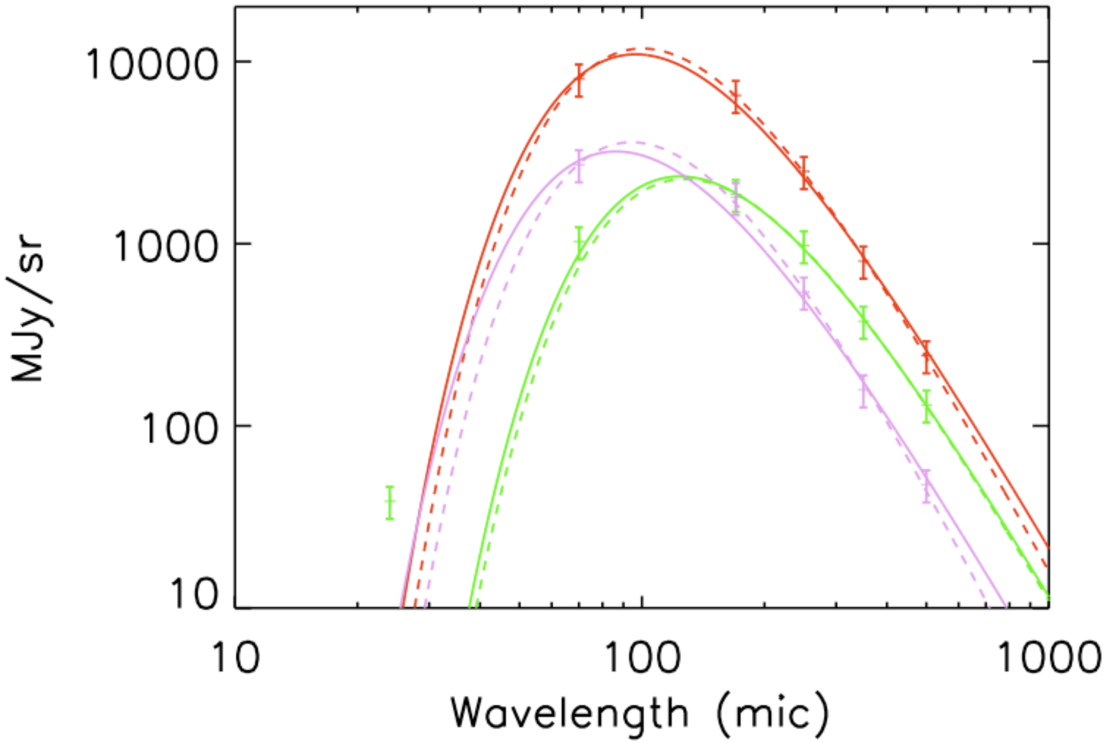


NGC 7023: SED at the peak 250 μm positions

SPIRE 250 μm



PACS SPIRE

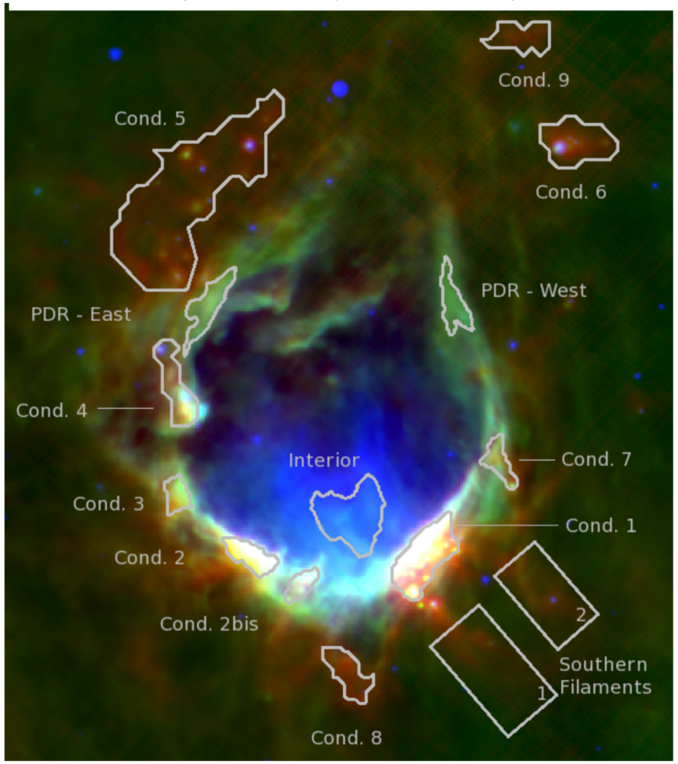


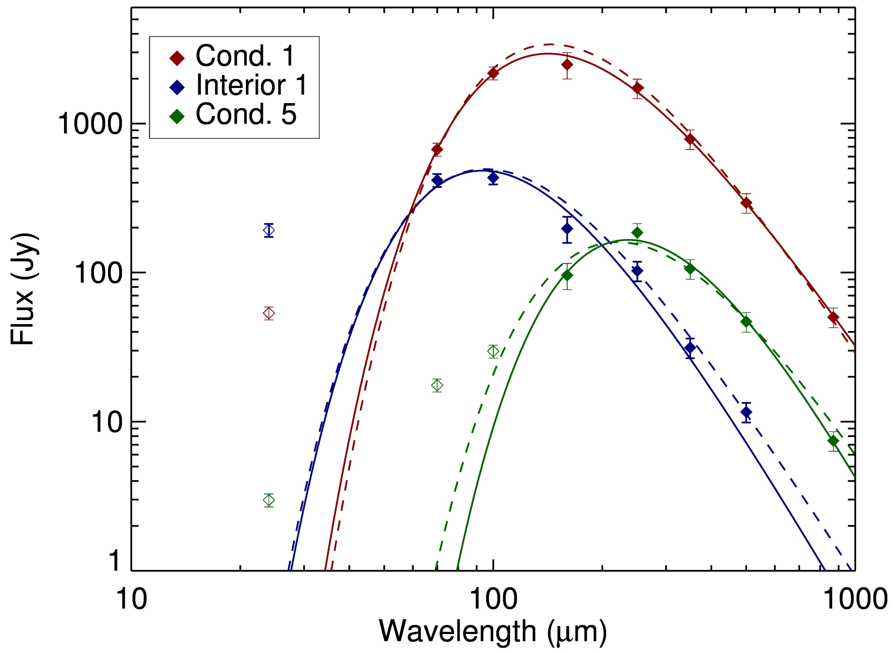
Solid lines : β = 2, *T* = 30.0, 33.5, 23.3 K.
Dashed lines : Free values of β = 2.3, 2.6 & 2.1 with *T* = 27.1, 27.2 K, 22.1 K

Taking into account the overall uncertainties: compatible with β = 2

RCW 120 hot PDR

24 µm, 70 µm, 250 µm





From Anderson et al. (submitted to A&A):

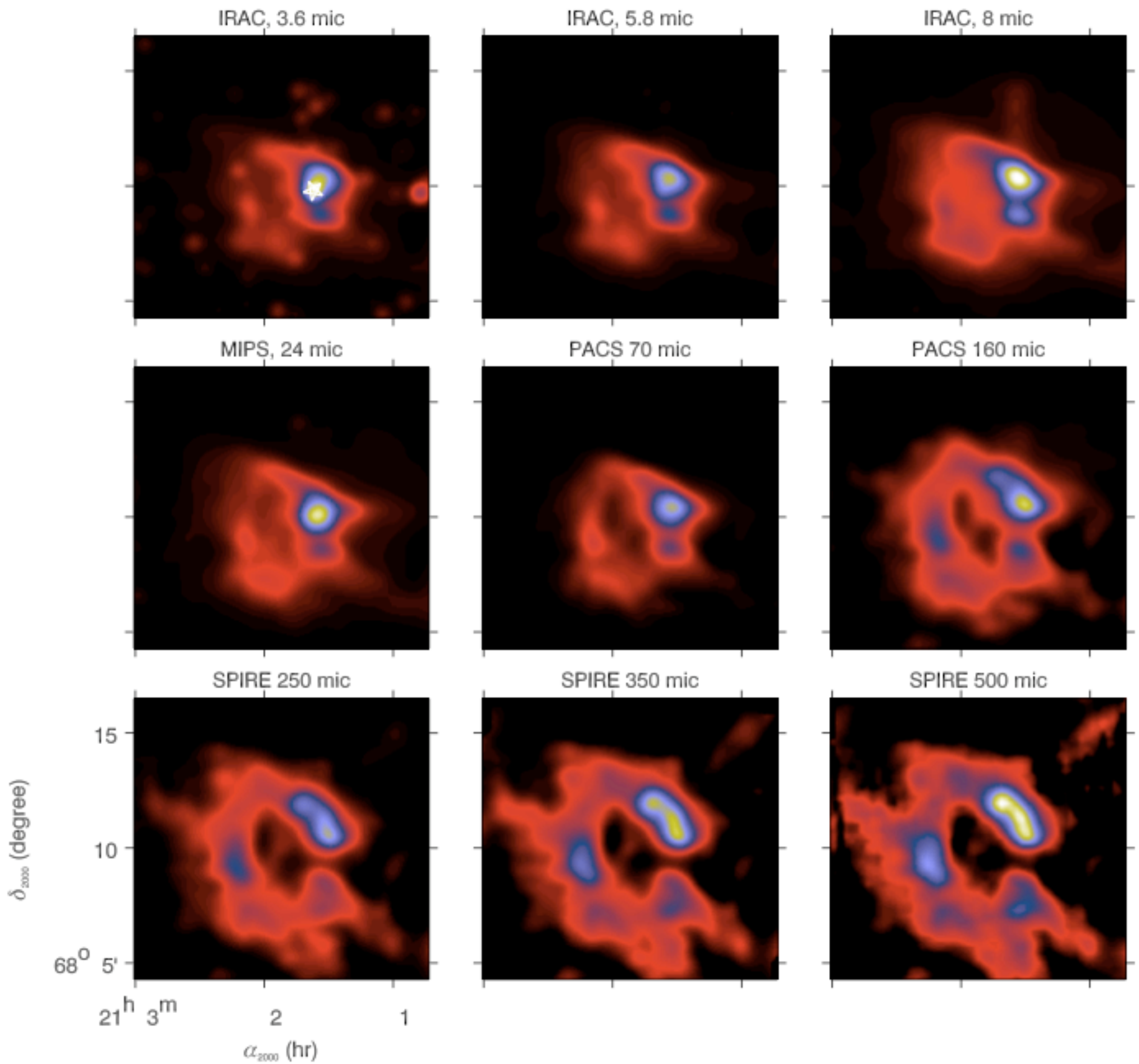
- Peak positions: spectra compatible with β = 2
- Indication of increasing value of β with decreasing temperature (T around 10 K)

See also Rodon et al. (poster) for Sh2-104

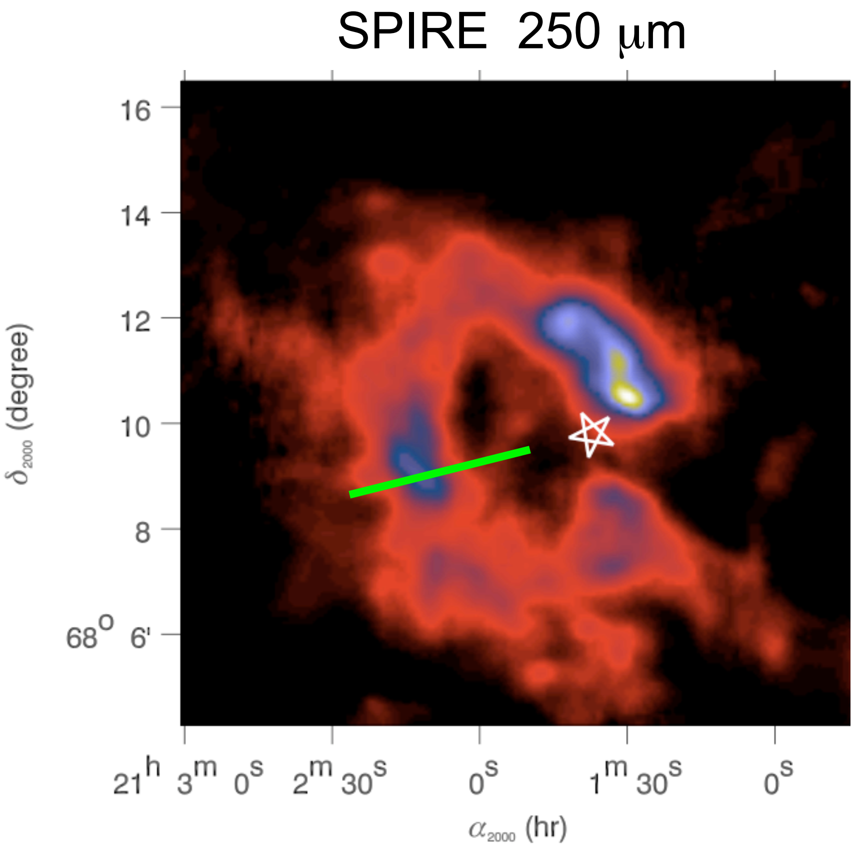
Name	T (K) $\beta = 2$	T (K) β free	β
Interior	30.4 ± 0.9	28.9 ± 2.0	2.4 ± 0.2
PDR - West	27.1 ± 0.6	20.5 ± 1.0	2.9 ± 0.2
PDR - East	23.1 ± 0.7	22.9 ± 2.1	2.1 ± 0.2
Cond. 1	20.1 ± 0.3	21.6 ± 1.1	1.7 ± 0.2
Cond. 2	22.2 ± 0.4	22.1 ± 1.2	2.1 ± 0.2
Cond. 3	21.5 ± 0.3	22.2 ± 1.2	2.0 ± 0.2
Cond. 4	21.0 ± 0.4	23.0 ± 1.2	1.8 ± 0.2
Cond. 5 (IRDC)	12.6 ± 0.5	9.2 ± 0.9	3.2 ± 0.4
Cond. 6 (IRDC)	13.1 ± 0.5	10.5 ± 1.2	2.8 ± 0.4
Cond. 7	21.8 ± 0.4	22.7 ± 1.2	1.9 ± 0.2
Cond. 8	14.3 ± 0.6	9.9 ± 1.0	3.3 ± 0.4
Cond. 9 (IRDC)	12.8 ± 0.5	10.2 ± 1.1	2.9 ± 0.4
Cond. 10	23.5 ± 0.7	25.9 ± 2.8	1.9 ± 0.2
Southern Filaments 1	14.6 ± 0.7	10.7 ± 1.3	3.0 ± 0.4
Southern Filaments 2	13.5 ± 0.6	9.6 ± 1.0	3.2 ± 0.4

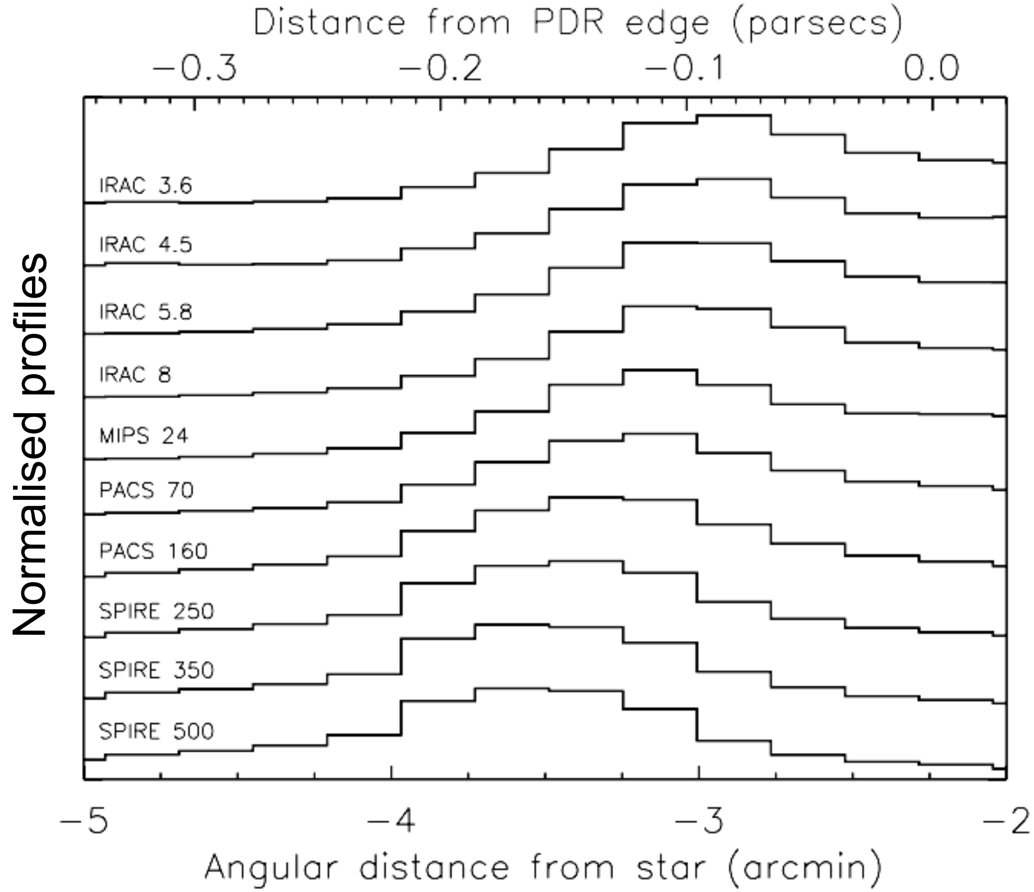
NGC 7023: Spitzer + Herschel

Angular resolution of SPIRE at 500 µm assuming gaussian beams Preliminary



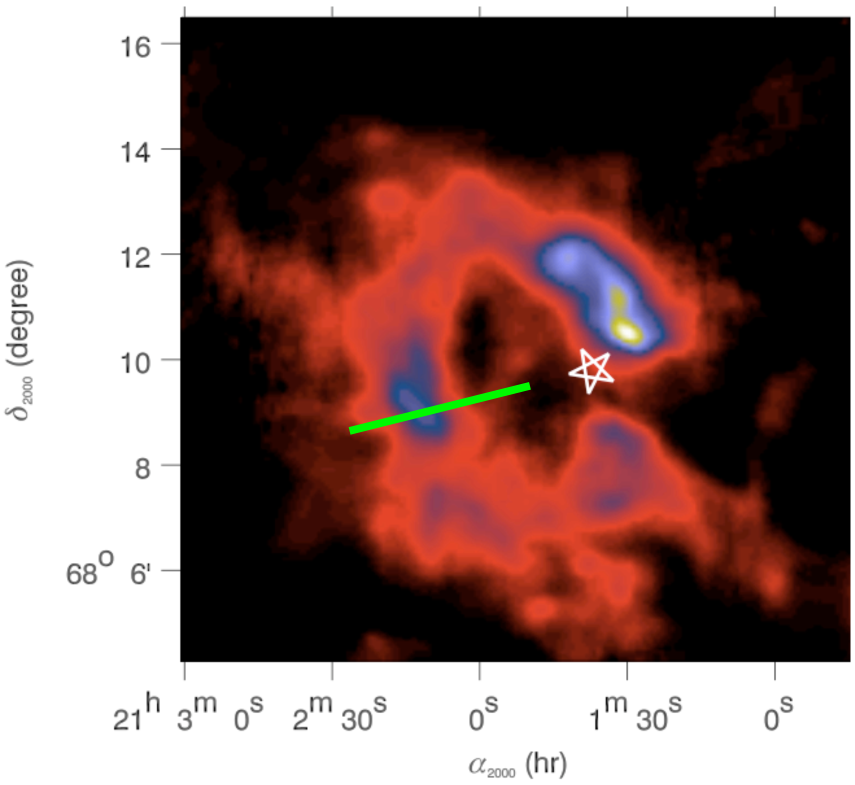
Brightness profiles across the East PDR

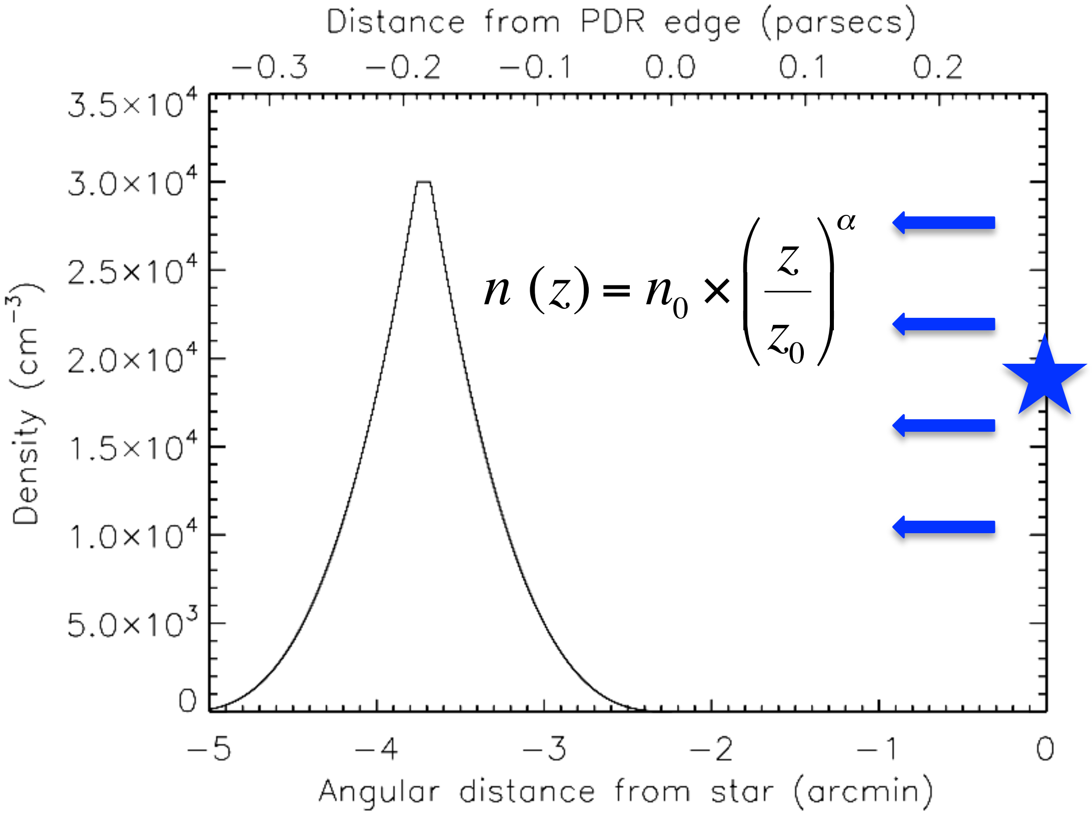




Modelling of the East PDR: 1. Density profile

SPIRE 250 μm

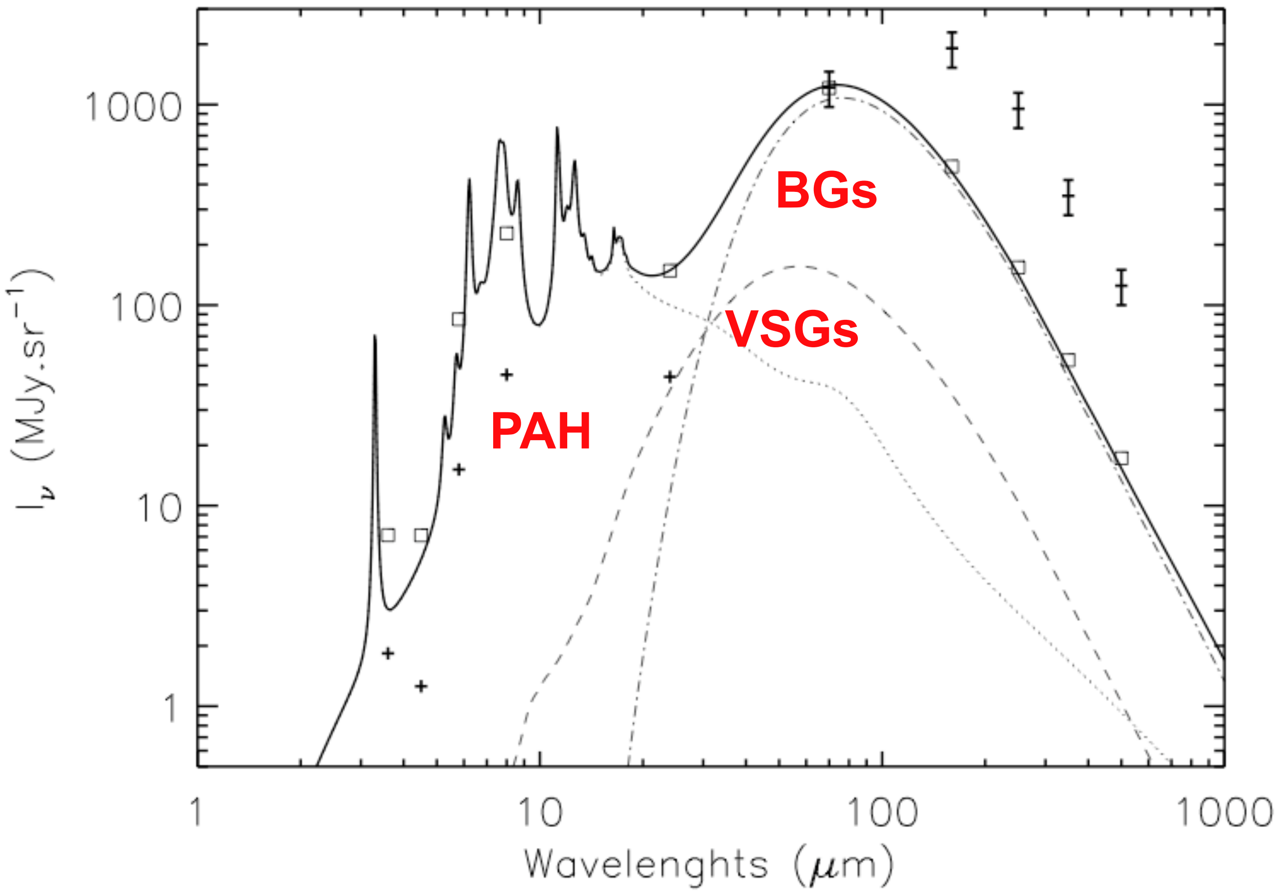




3 parameters : n_0, z_0 , α

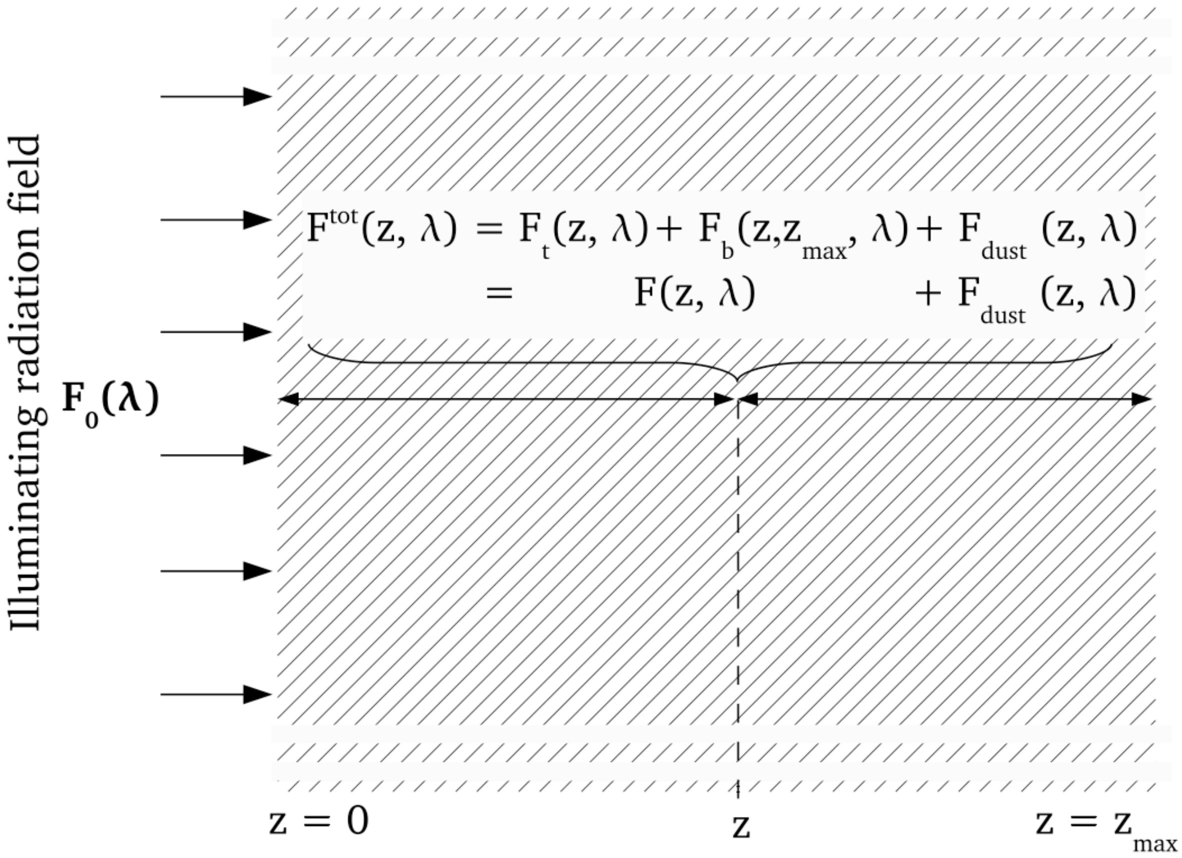
Modelling of the East PDR: 2. Dust Model

"DUSTEM" Compiegne et al. 2010 : Silicate + Amorphous Carbon + PAH, with dust properties and abundances corresponding to the diffuse ISM and G_0= 250 (from the distance star-illuminated edge):



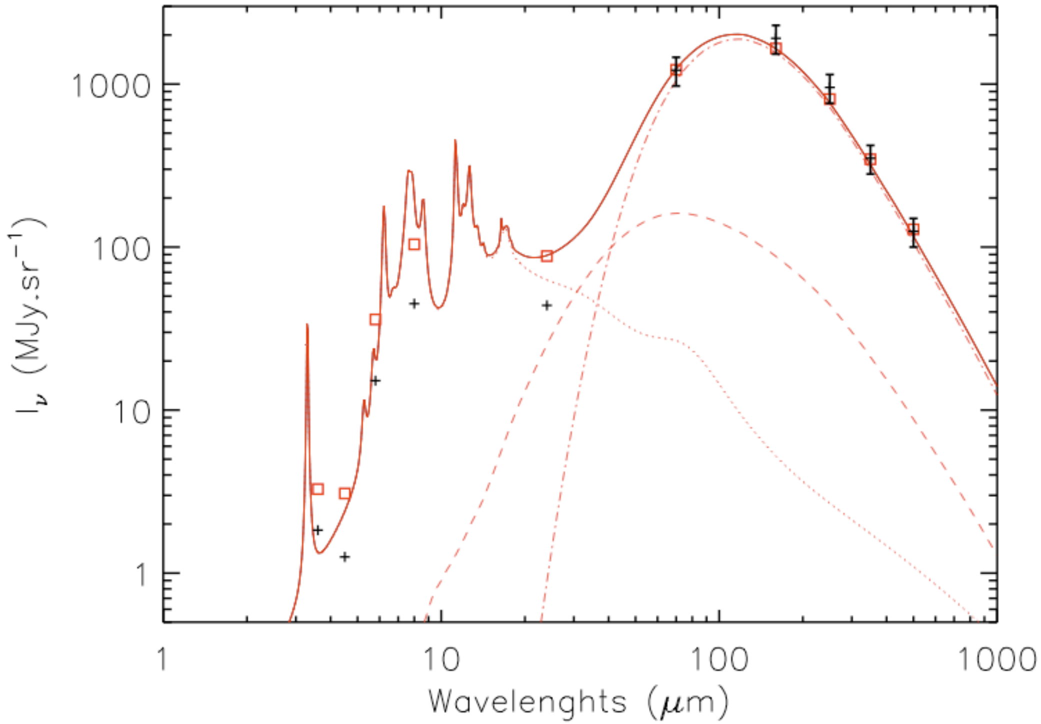
Modelling of the East PDR: 3. Radiative Transfer

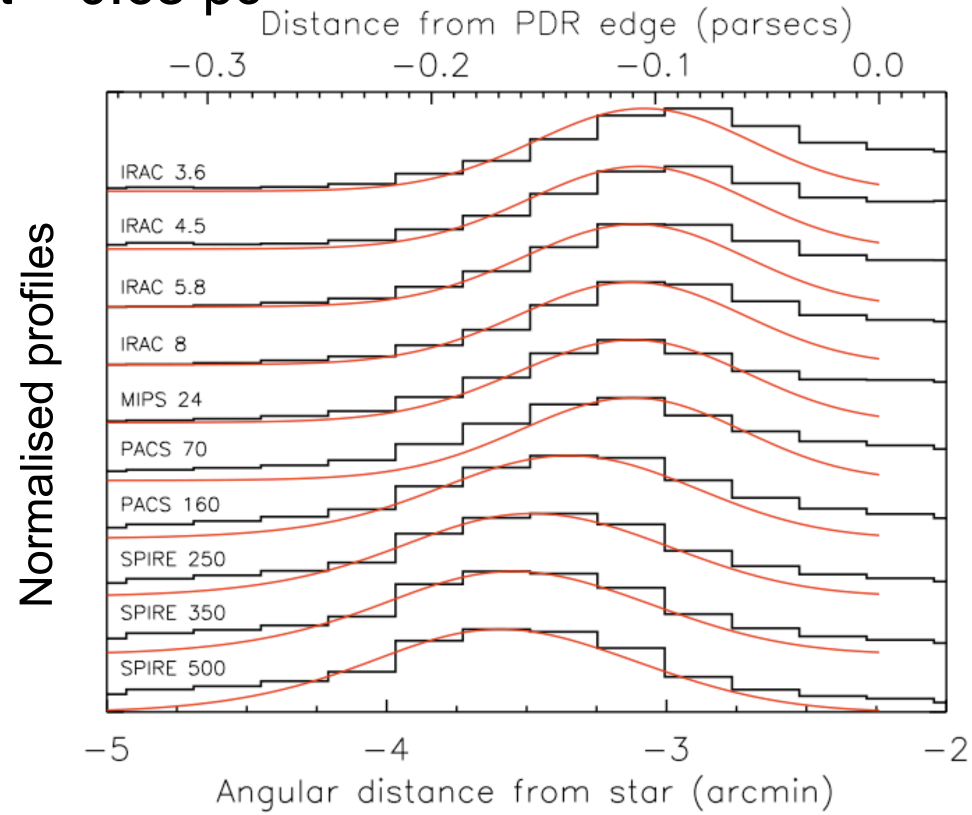
Plan-parallel model (Compiègne et al. 2008) :



Modelling of the East PDR: 4. Results

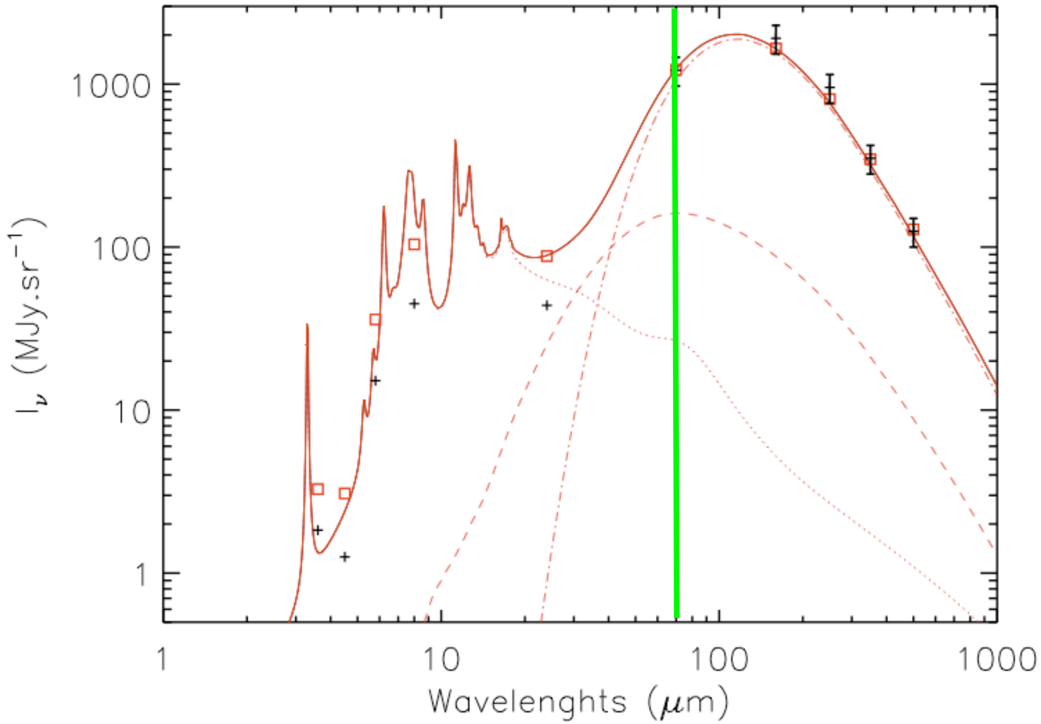
3 parameters of the density profile: $n_0 = 3\ 10^4\ cm^{-3}$, $z_0 = 0.18$ pc, $\alpha = 2.8$
Length of the PDR along the line of sight = 0.65 pc

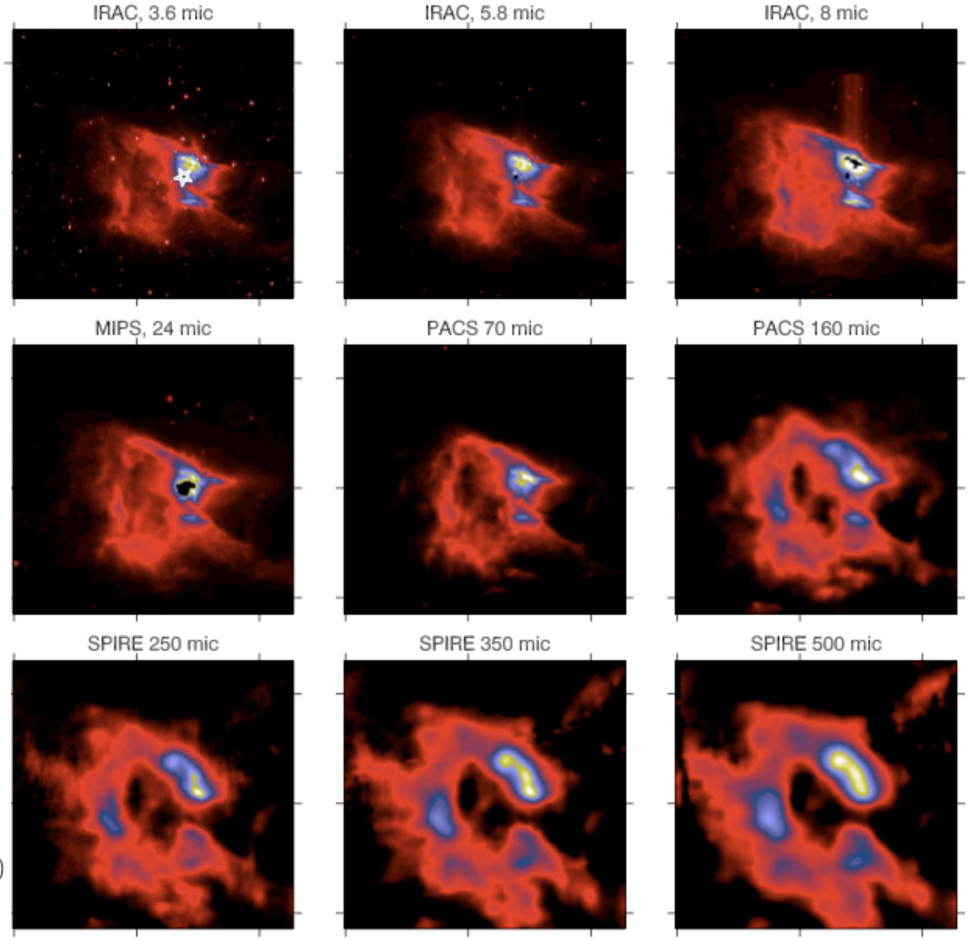




PAHs and VSGs emissions over-estimated by a factor 2
Decrease of the relative abundances
Or the absolute emissivity of the Big Grains is increased

Modelling of the East PDR: Consequence





- The 70 μm emission is comparable to smaller wavengths maps, since it is more sensitive to the radiation field than the longer wavelength emission (as the PAHs and the VSGs emissions)
- The 160 μm emission is comparable to longer wavengths maps

First Conclusions

SPIRE and PACS data allow us to use the Big Grain emission are a tracer of the interstellar matter

At the peak positions of the PDRs, the SED of Big Grains measured with SPIRE and PACS can be adjusted with a modified black-body with $\beta = 2$

Improvement in the data processing still necessary to conclude firmly for a dependence of β with the temperature

Dust and radiative transfer models allow us to derive, from SPIRE and PACS, data quantitative informations on the dust properties

Next step: Combination with spectroscopic observations

See presentations/posters in SPIRE spectroscopy by Dartois et al., Habart et al.,, White et al., Rodon et al.,, Ward-Thompson et al.

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