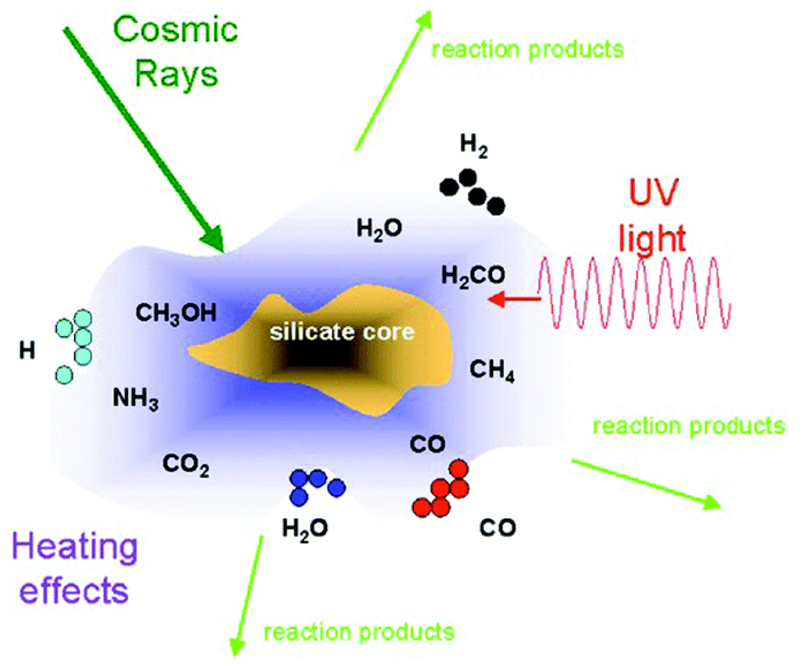
Temperatures of dust & gas in the S 140 high–mass star–forming region.

E. Koumpia[1], P.M. Harvey[2], V. Ossenkopf[3], F.F.S. van der Tak[1], B. Mookerjea[4]; e-mail: e.koumpia@sron.nl

50 Years Dutch Space Research

1. Motivation

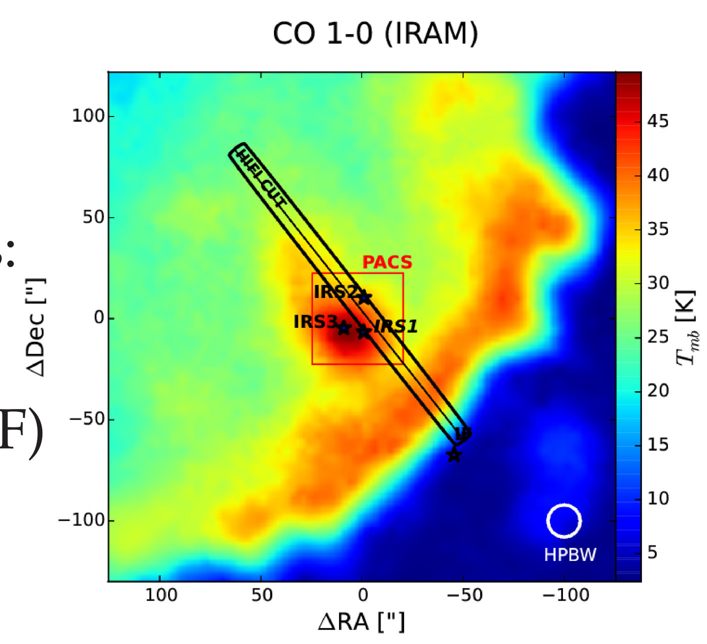
In theory, in ***dense*** parts of molecular clouds, where $n_{H_2} \geq 10^{4.5}$ cm^{-3} $\Longrightarrow T_{dust} \sim T_{gas}$ (Goldsmith 2001).



Is this universal? We investigate the thermal balance between gas & dust in a high–mass star–forming region clumpy region.

2. Source – S 140

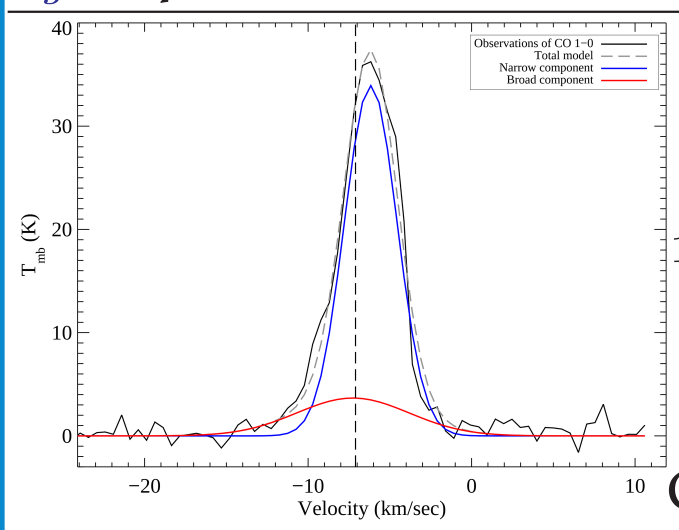
- L$\sim 10^4$L$_\odot$
- D = 746 pc
- FIR sources: IRS 1–3
- $\chi \sim 10^2$ (ISRF)
- M$\sim$840 M$_\odot$



50 " –> 0.2 pc

3. Method-Data

T_{gas} (quiescent): CO lines-Narrow component

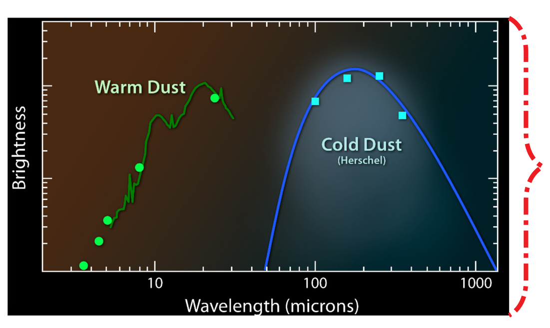


- **IRAM 4′×4′**

CO 1–0, CO 2–1, ^{13}CO 1–0, C^{18}O 1–0

- **HIFI cuts**

CO 9–8, ^{13}CO 10–9



T_{dust}: Continuum

- **PACS** ~1′×1′

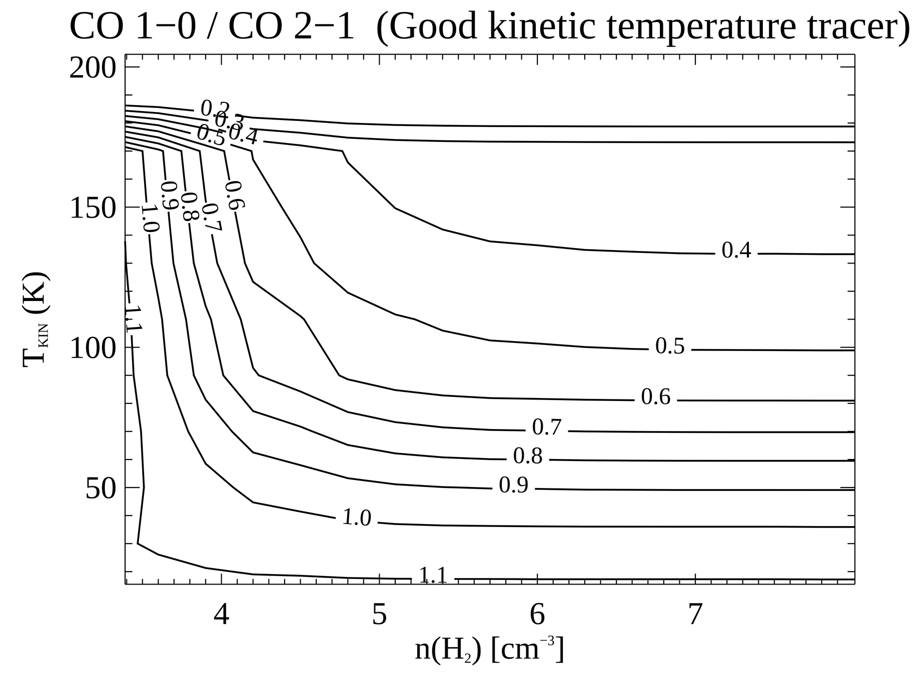
73–187 μm

- **SOFIA** 11–37 μm, **SCUBA** 450 μm

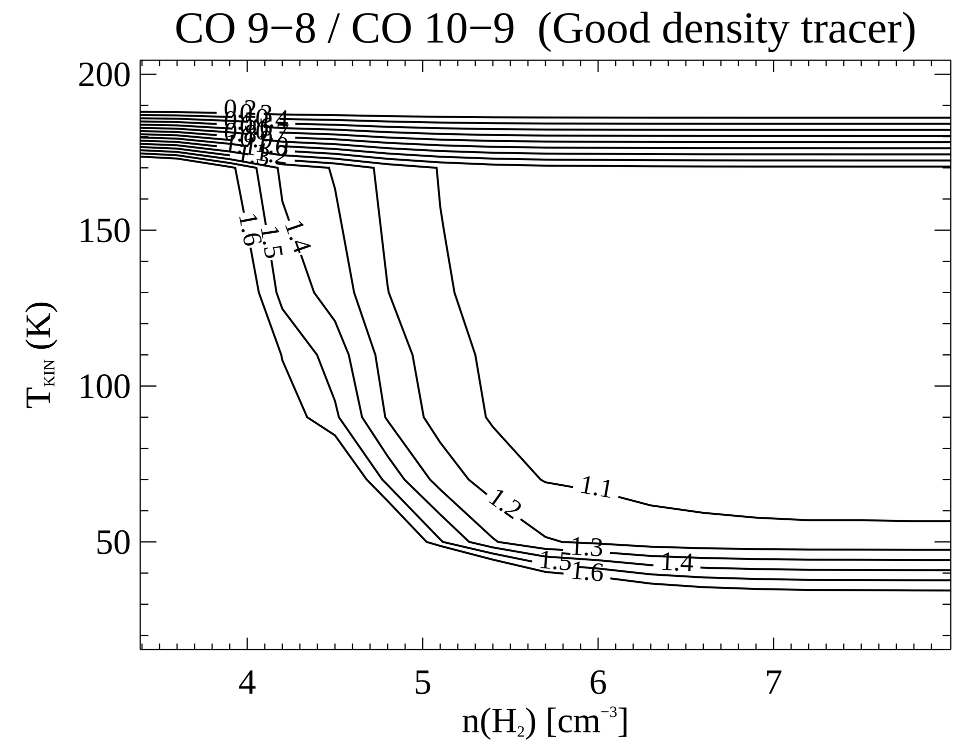
! Our data trace both cold & warm medium.

4a. Gas Analysis

CO 1–0/2–1 appears to be a ***good tracer*** **of T_{kin} for $n_{H_2} \geq 10^5$ cm^{-3} (RADEX).**



CO 9–8/10–9 $\Longrightarrow$ ***good tracer*** of **densities**.



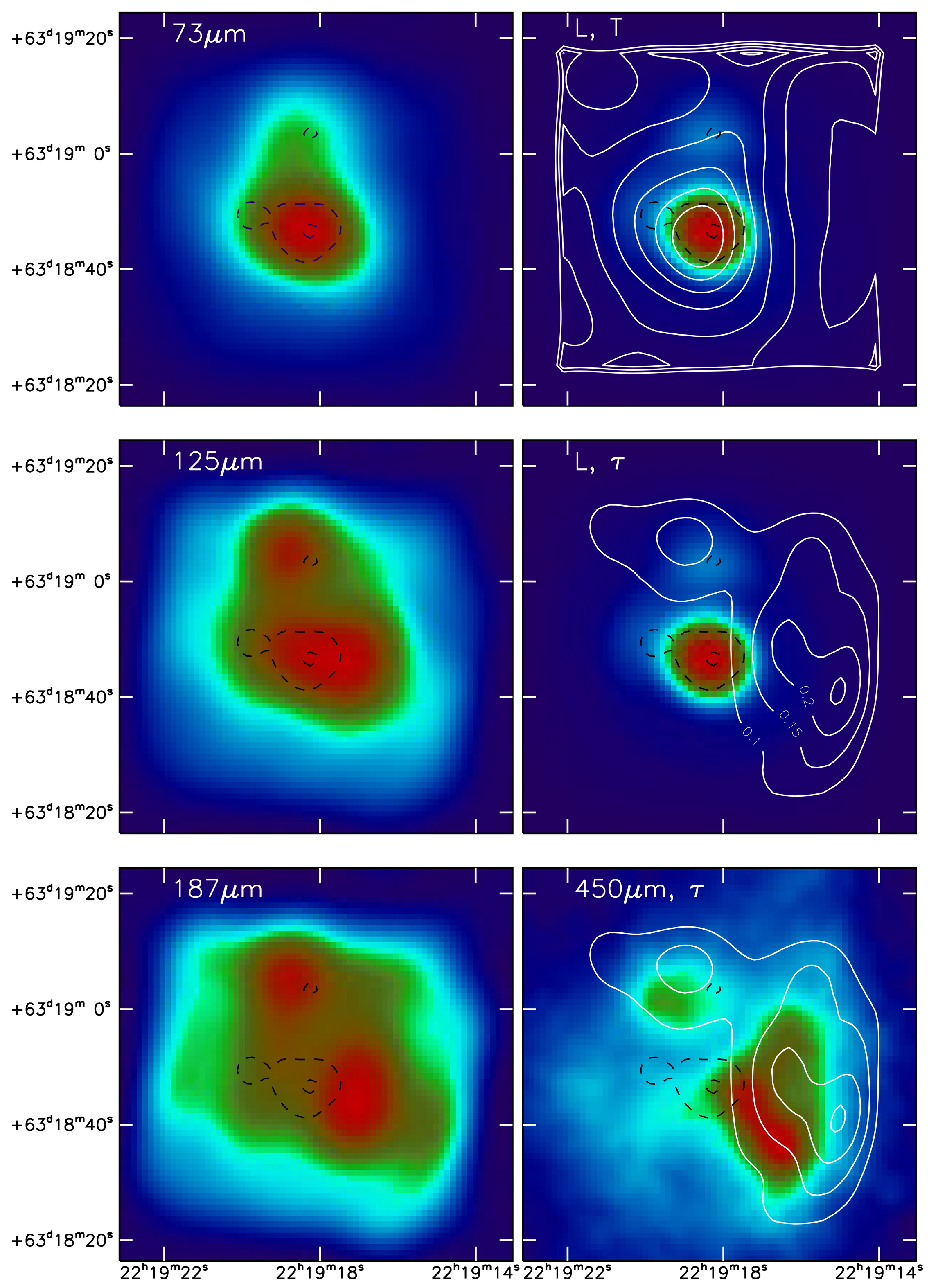
χ^2 fit: observed & synthetic (RADEX) intensities of CO & isotopologues at:

HIFI cuts: low & high -J lines $\Longrightarrow$ **$n_{H_2} \geq 10^5$ cm^{-3}** along the **entire** cut.

IRAM maps: low-J lines $\Longrightarrow$ for 4″×4″ spatial points $\Longrightarrow$ **Kinetic Temperature & CO column density** maps for a **fix $n_{H_2} = 10^5$ cm^{-3}.**

4b. Dust Analysis

Greybody fit at each 1″×1″ spatial points.



Smoothed ~ 1′×1′ **PACS** images (left)

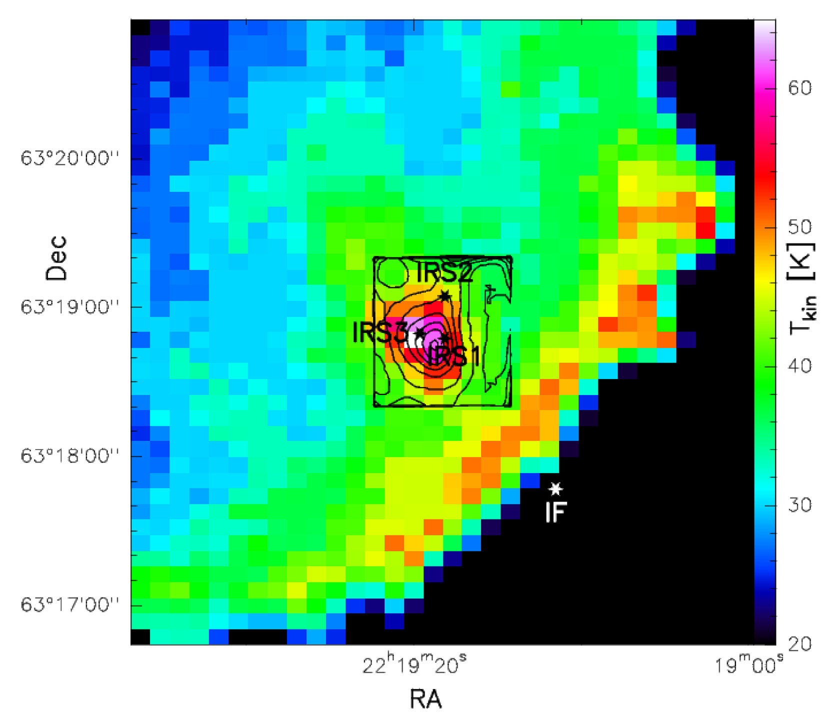
37 μm (**FORECAST**) emission (black contours)

L_{tot} (11-187μm) overplotted with: T_{dust} contours at 70, 65, 60 ...K (up) τ at 0.1, 0.15, 0.2 & 0.25 (middle)

450μm **SCUBA** - τ contours (bottom).

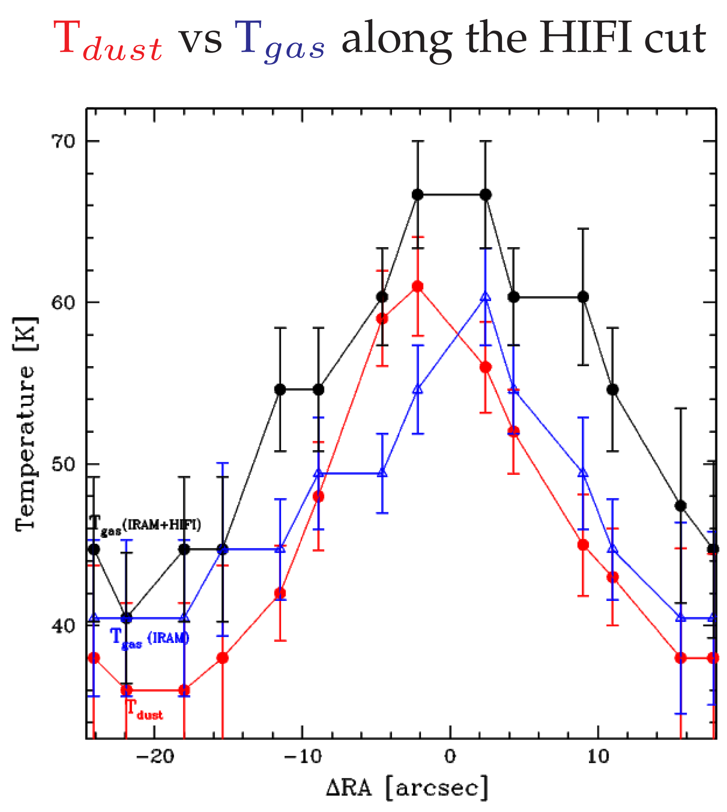
5. T_{dust} vs T_{gas} – Results

Kinetic temperature map



T_{dust} **contours**: 70 K (inner)–35 K (outer)

T_{dust} vs T_{gas} along the HIFI cut

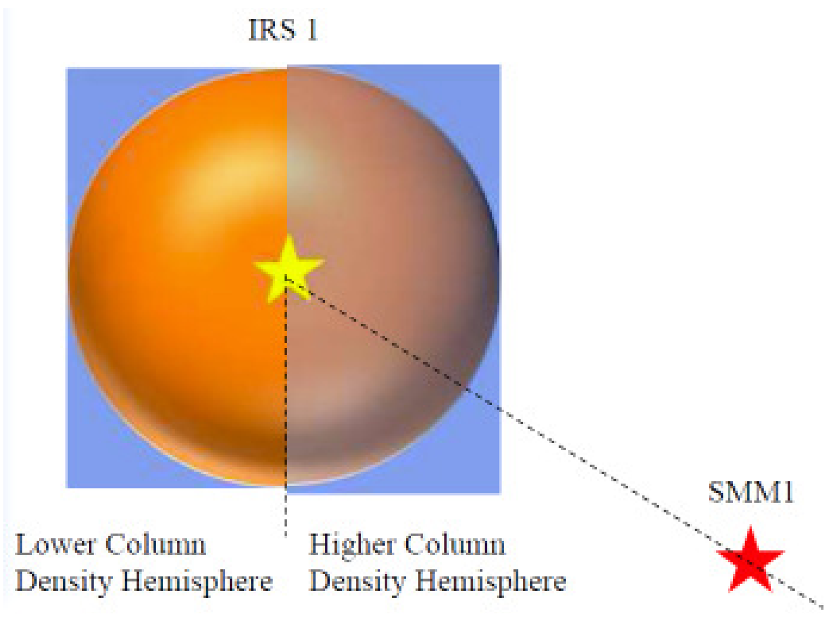


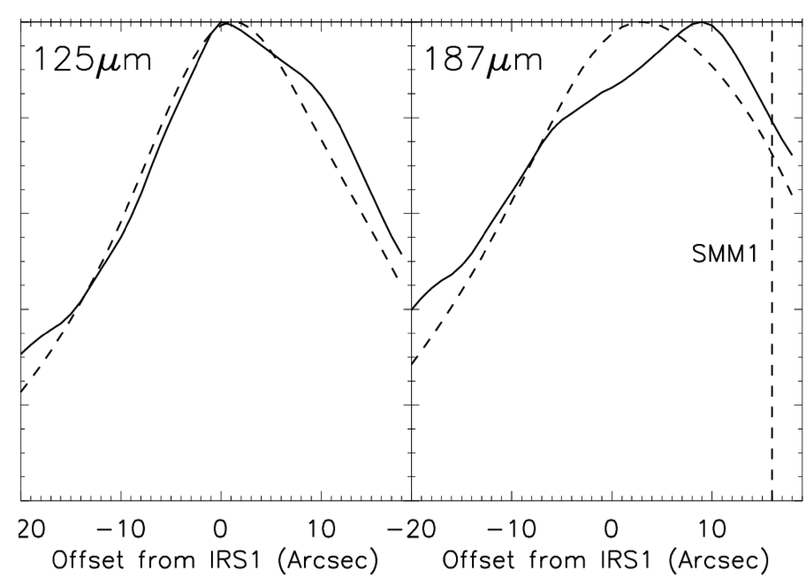
- Low-J analysis $\Longrightarrow$ lower limit of T_{gas}
- Low & high-J analysis $T_{gas} > T_{dust}$ (by 5-12 K)

Result-Interpretation

More **efficient gas heating** mechanism ***even*** at $n_{H_2} \geq 10^{4.5}$ cm^{-3} $\Longrightarrow$ Deep **UV** penetration from the embedded sources in a ***clumpy*** medium.

6. Density gradients & multiple sources–Dusty Code





Best fit parameters:

$\rho \propto r^{-0.4}$
$A_V \sim 40$
$R_{outer}/R_{inner} \sim 1500$

Good fit between modelled & observed SED+profiles (right).

Best fit: 2–hemisphere model, ***including*** the internal source at **sub–mm peak** (10^2 L$_\odot$).

7. A future direction

- Test our dust models $\Longrightarrow$ synthetic intensities of CO towards IRS1–3 (i.e. RATRAN) $\Longrightarrow$ compare observations.
- Use larger dust fields (e.g. HiGal).
- Study similar sources (e.g. DR 21).

Institutes: [1]SRON Netherlands Institute for Space Research, [2]University of Texas at Austin, [3]I. Physikalisches Institut der Universität zu Köln, [4]Tata Institute of Fundamental Research