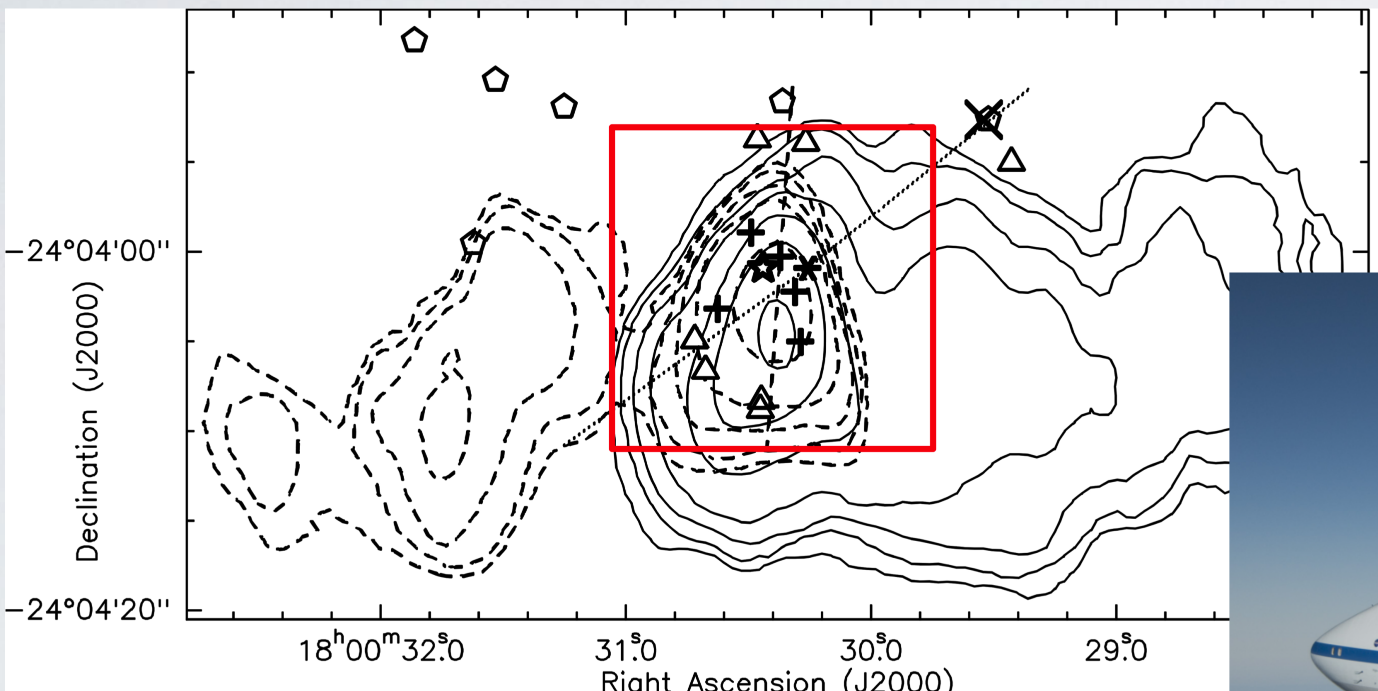
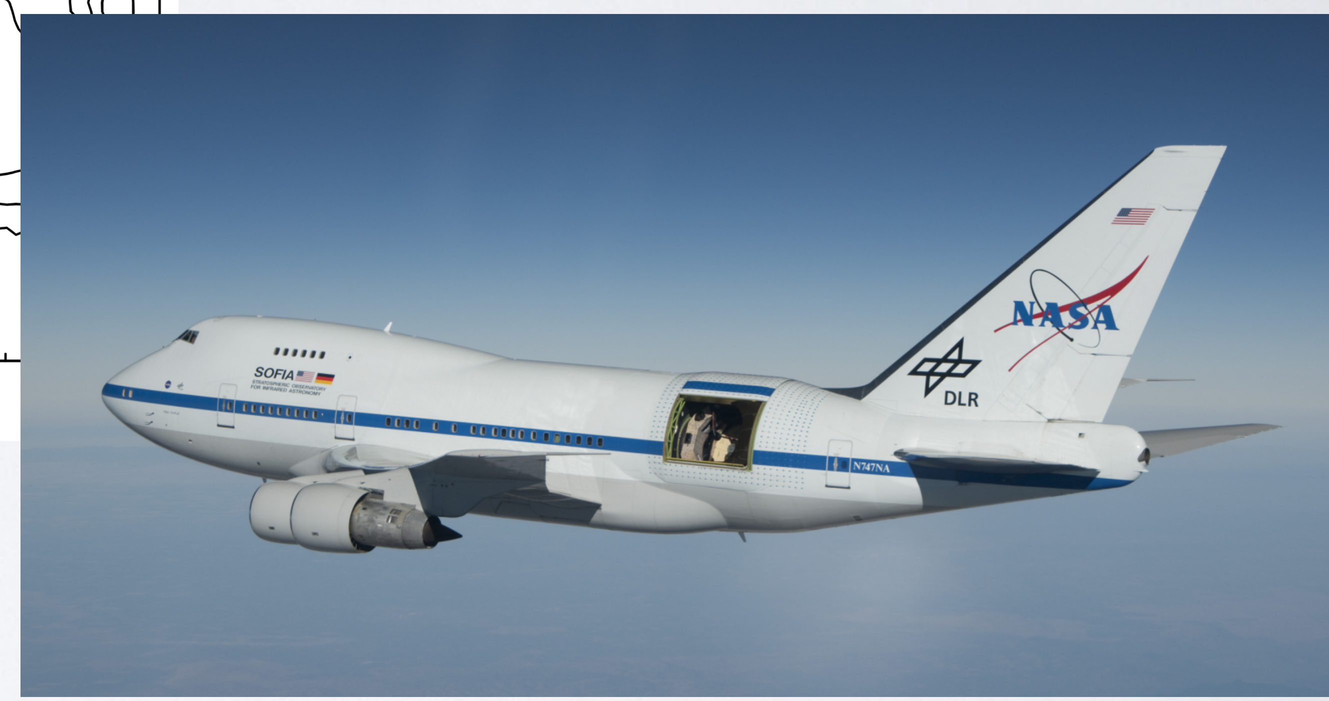
[OI] 63μm GREAT observations in massive star forming region: G5.89-0.39





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Motivations

[OI] 63 μm is

1. Major coolant in PDRs (e.g., Tielens & Dalgarno 1985) ⇒ tracer of physics of the gas;

2. Major coolant in jets from YSOs ⇒ direct tracer of mass-loss rates (Hollenbach 1985);

3. Important PDR cooling line in external galaxies (e.g., Malhotra et al. 2001; Coppin et al. 2012) not affected by extinction ⇒ potentially a powerful tracer of star-formation rates in galaxies even at high red-shifts (e.g, De Looze et al. 2014).

Motivations

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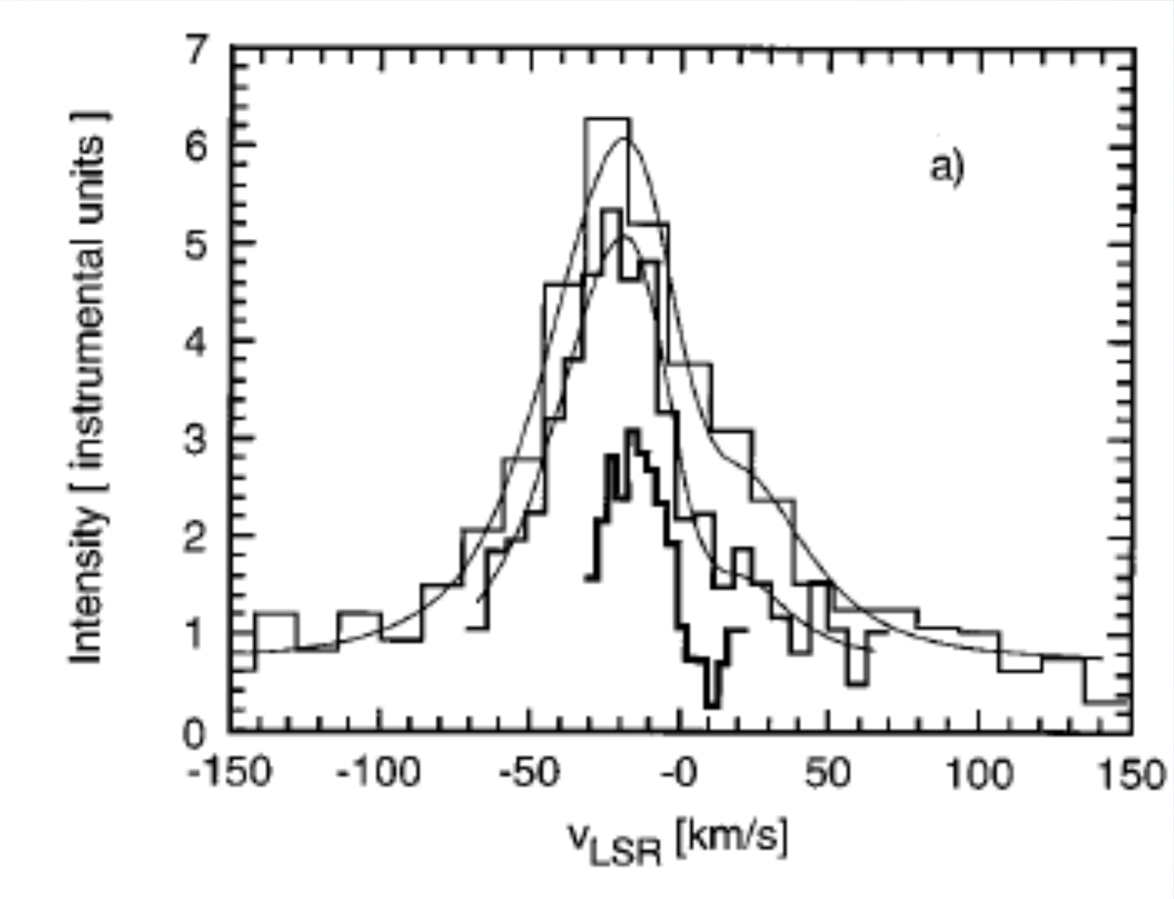
BUT

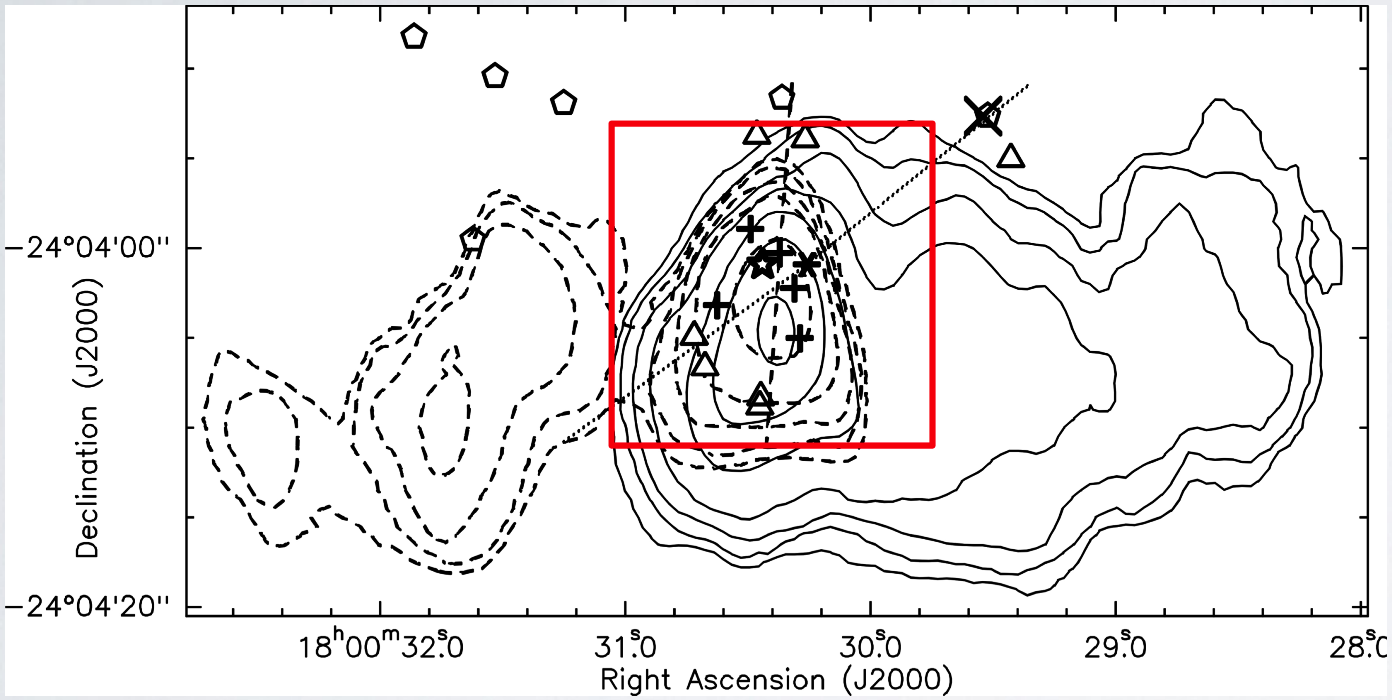
absorption from foreground clouds and self-absorption can contaminate the profile and mine the diagnostic power of [OI] (e.g., Poglitsch et al. 1996; Liseau et al. 2006)

⇒ ***spectroscopically resolved observations of the [OI] 63 μm line are fundamental to exploit its full potential***

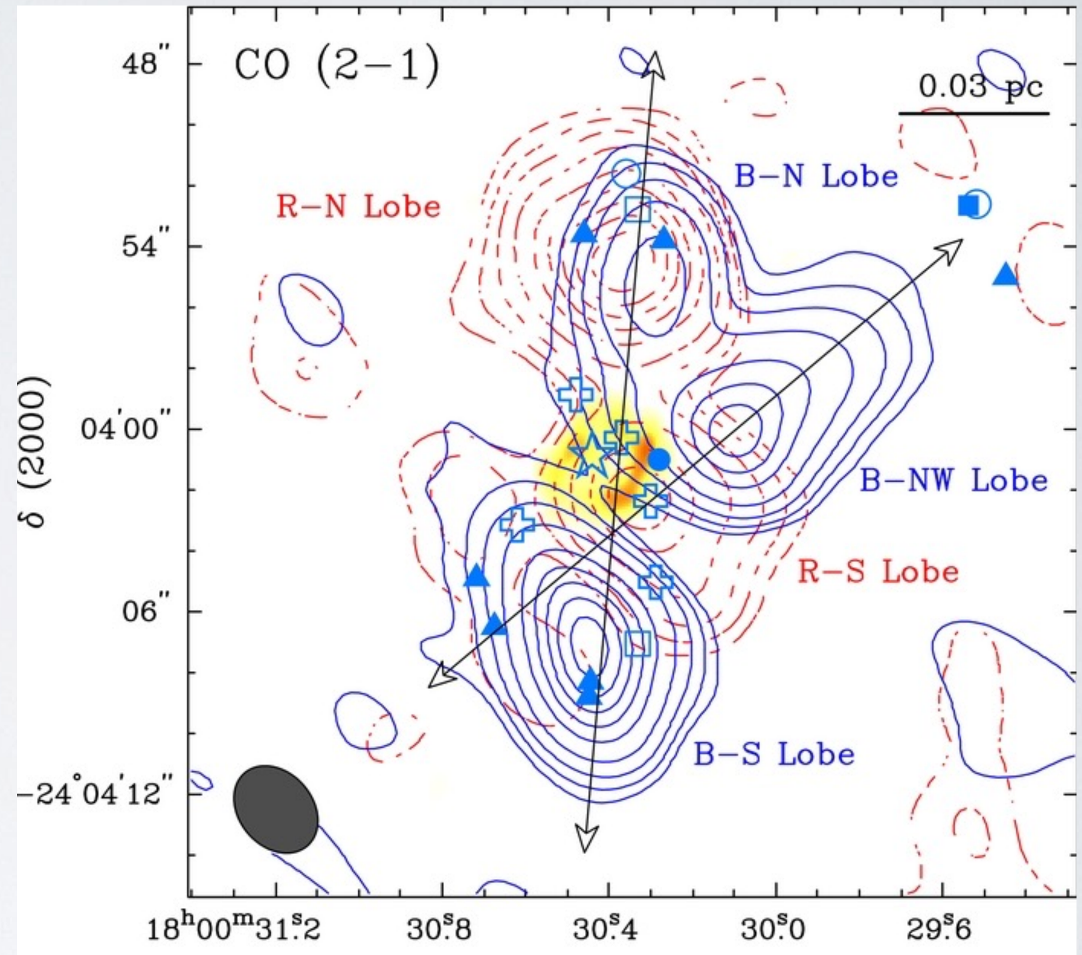


DR21OH [OI] 63 μm spectrum KAO (Poglitsch et al. 1996)

SOFIA GREAT observations G5.89-0.39



d=1.28 kpc (Motogi+2011)



G5.89-0.39 hosts

- a UCHII from a O8 star (Feldt+2003)
- one of the most extreme massive outflows (Harvey & Forveille 1988)
- compact EHV N-S and NW-SE outflows associated with HV H_2 emission (Puga+2006; Hunter+2008; Su+2012)

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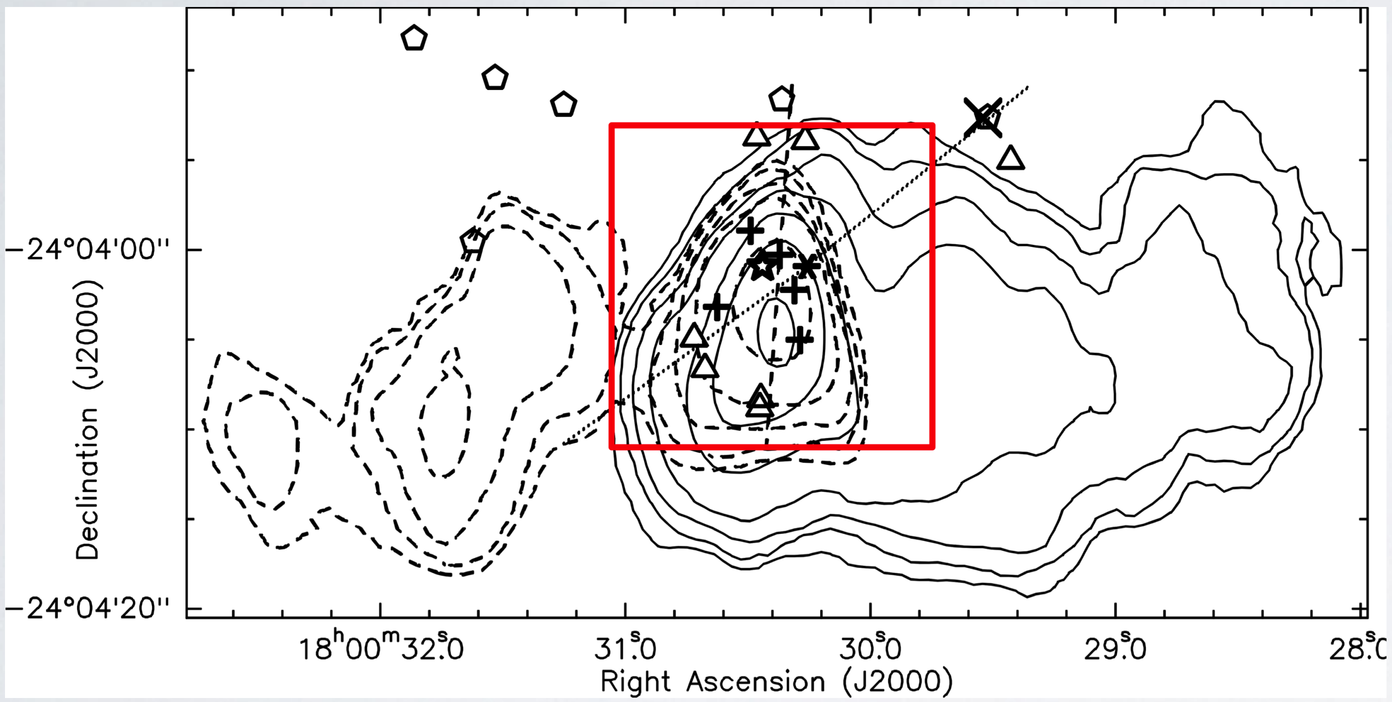
SOFIA GREAT observations
G5.89-0.39



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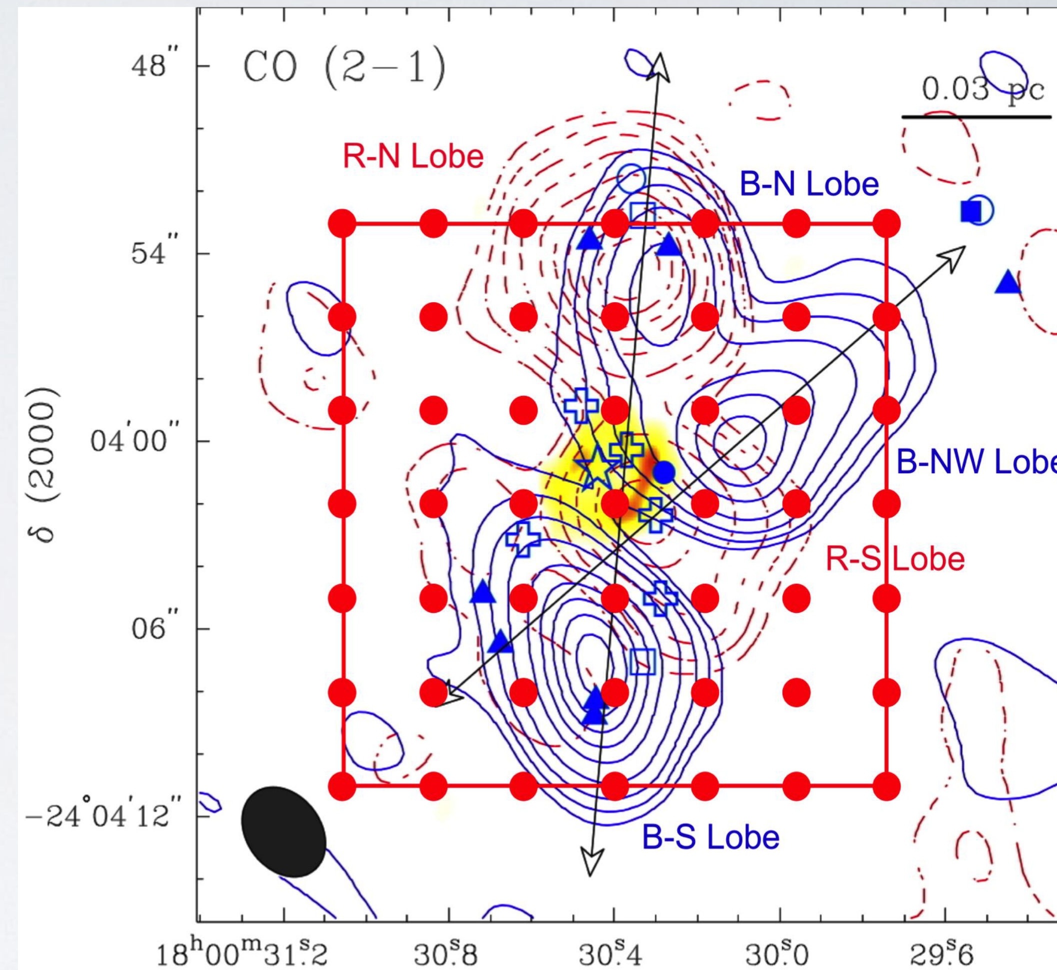

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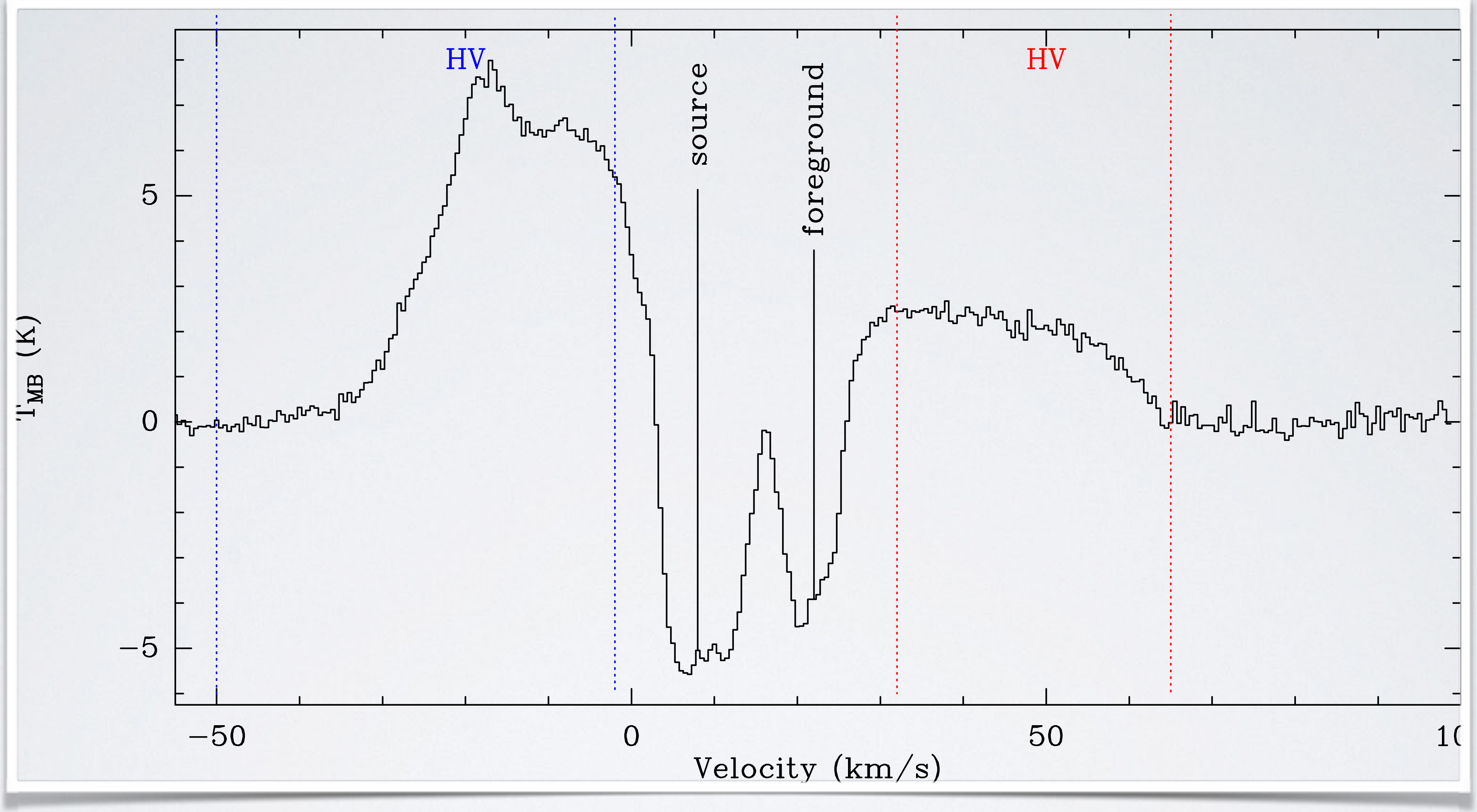
SOFIA GREAT observations G5.89-0.39

- [OI] 63 µm 18”×18” **map**
- CO(16-15) 18”×18” **map**
- OH triplets **single pointings** at 2514 GHz, 1838 GHz and 1834 GHz

Complementary data

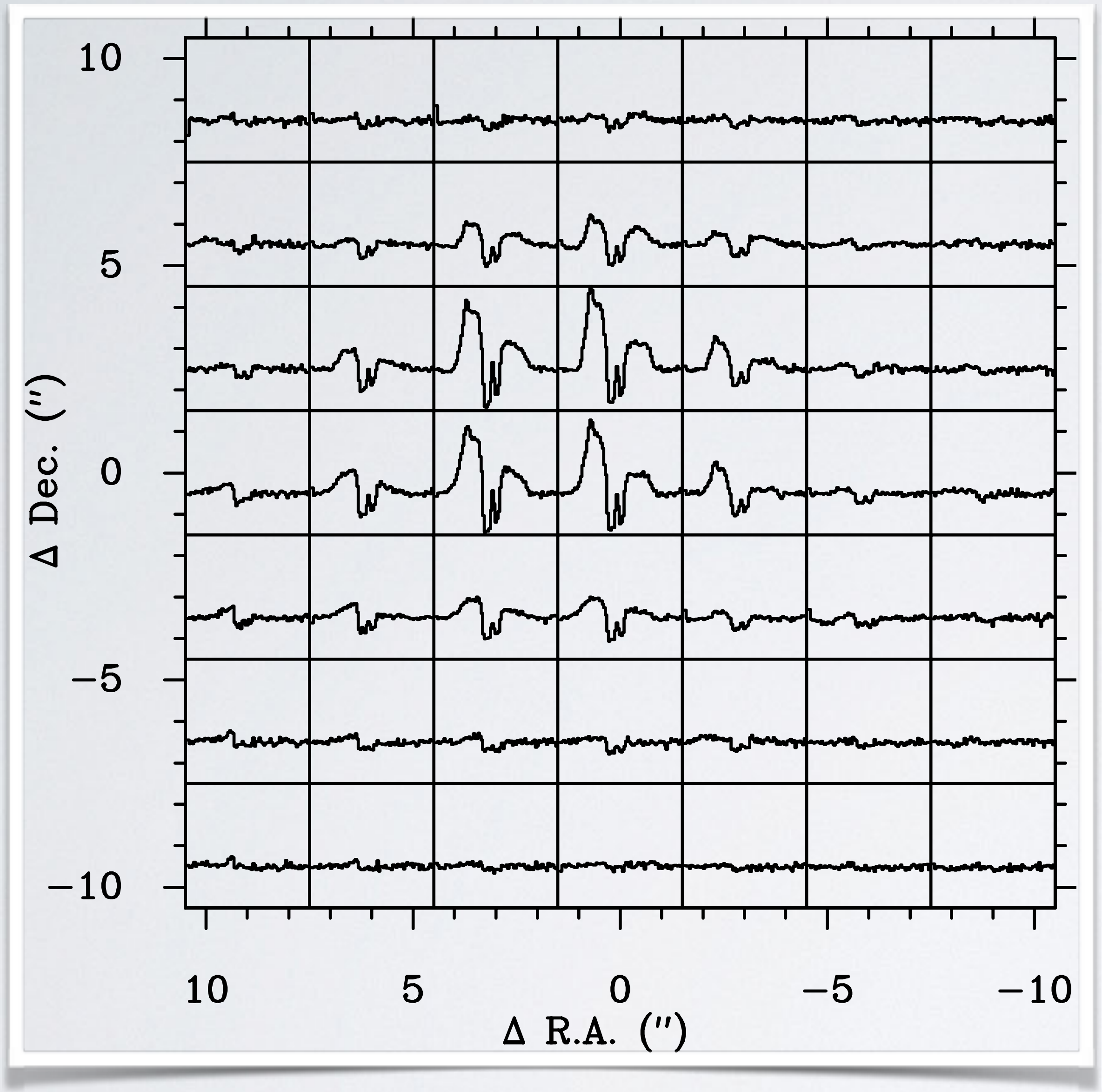
- APEX CO(6-5)/(7-6) maps (Gusdorf +2015)
- *Herschel* HIFI H_2O (752 GHz, 987 GHz, 1113 GHz, 1661 GHz, 1669 GHz) (Gusdorf+2015, van der Tak+2013)

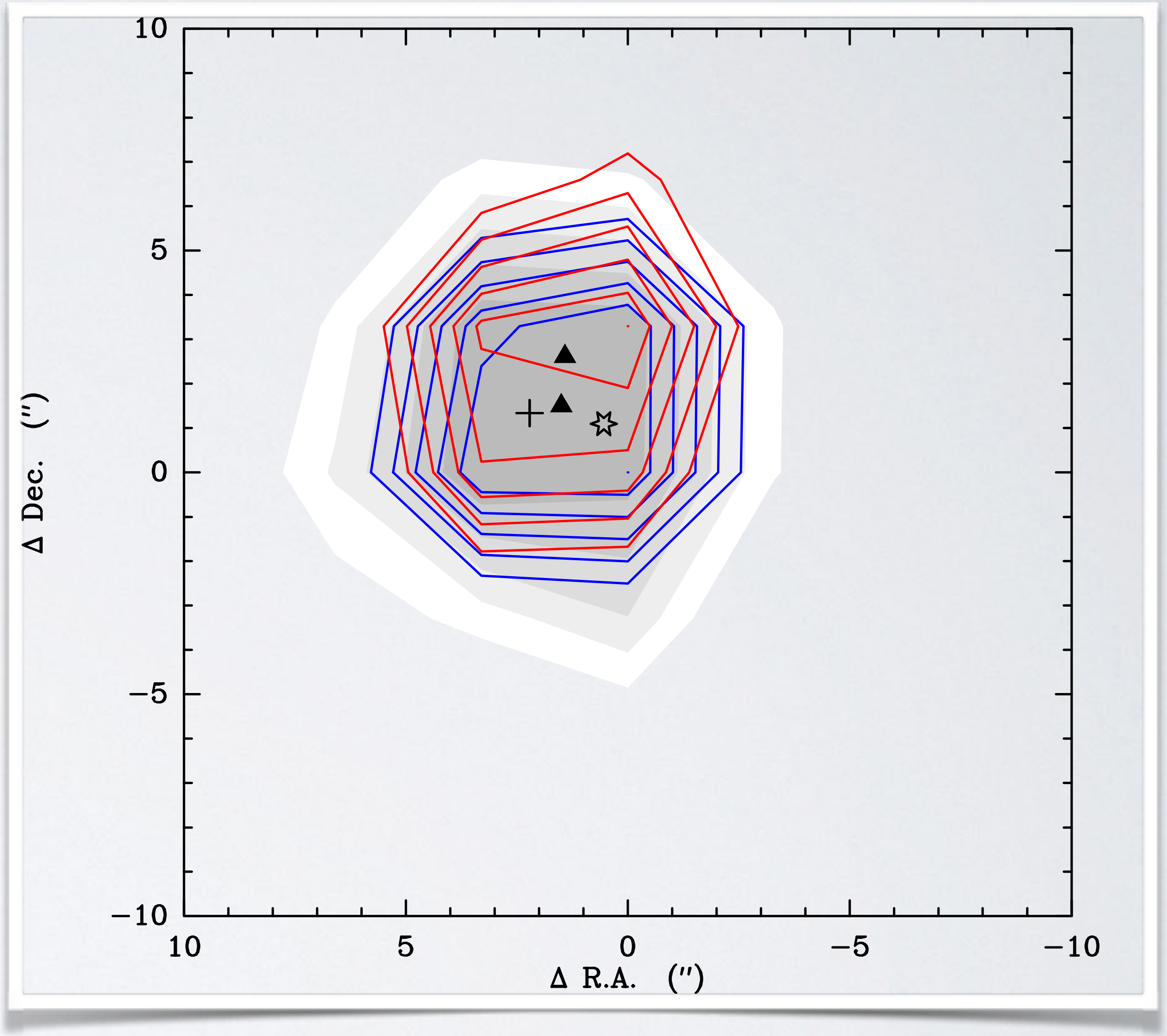
[OI] distribution in G5.89-0.39



- HV emission (| v_{max}-v_{lsr} | ≃70 km s^{-1})
- deep absorptions from the source and from different line of sight clouds;

[OI] distribution in G5.89-0.39





- ✦ HV emission distributes along the north-south as CO
- ✦ HV emission arises from the inner region of EHV outflows in CO(3-2) (Su+2012)
- ✦ HV emission is more compact (<6”.6 beam) than EHV CO outflows

SOFIA Stratospheric Observatory for Infrared Astronomy
GREAT
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Outflow parameters

	Blue	Red
$N\,(10^{21}\,\mathrm{cm^{-2}})$	3.2	
$M\,(M_\odot)$	0.05	
$\Delta v_{max}\,(\mathrm{km\,s^{-1}})$	50	58
$t_d\,(\mathrm{yr})$	400	350
$P\,(M_\odot\,\mathrm{km\,s^{-1}})$	2.4	
$F_m\,(M_\odot\,\mathrm{km\,s^{-1}\,yr^{-1}})$	0.006	
$E_k\,(10^{45}\,\mathrm{erg})$	1.2	
$L_{mech}\,(L_\odot)$	24	

Mass-loss rate estimate:

I. from Hollenbach 1985

$$\frac{\dot{M}}{M_\odot yr^{-1}} = 10^{-4}\frac{L_{[OI]\,63\,\mu m}}{L_\odot}$$

$\simeq$ 2.5 10^{-4} $M_\odot yr^{-1}$

II. from simple geometry assumptions

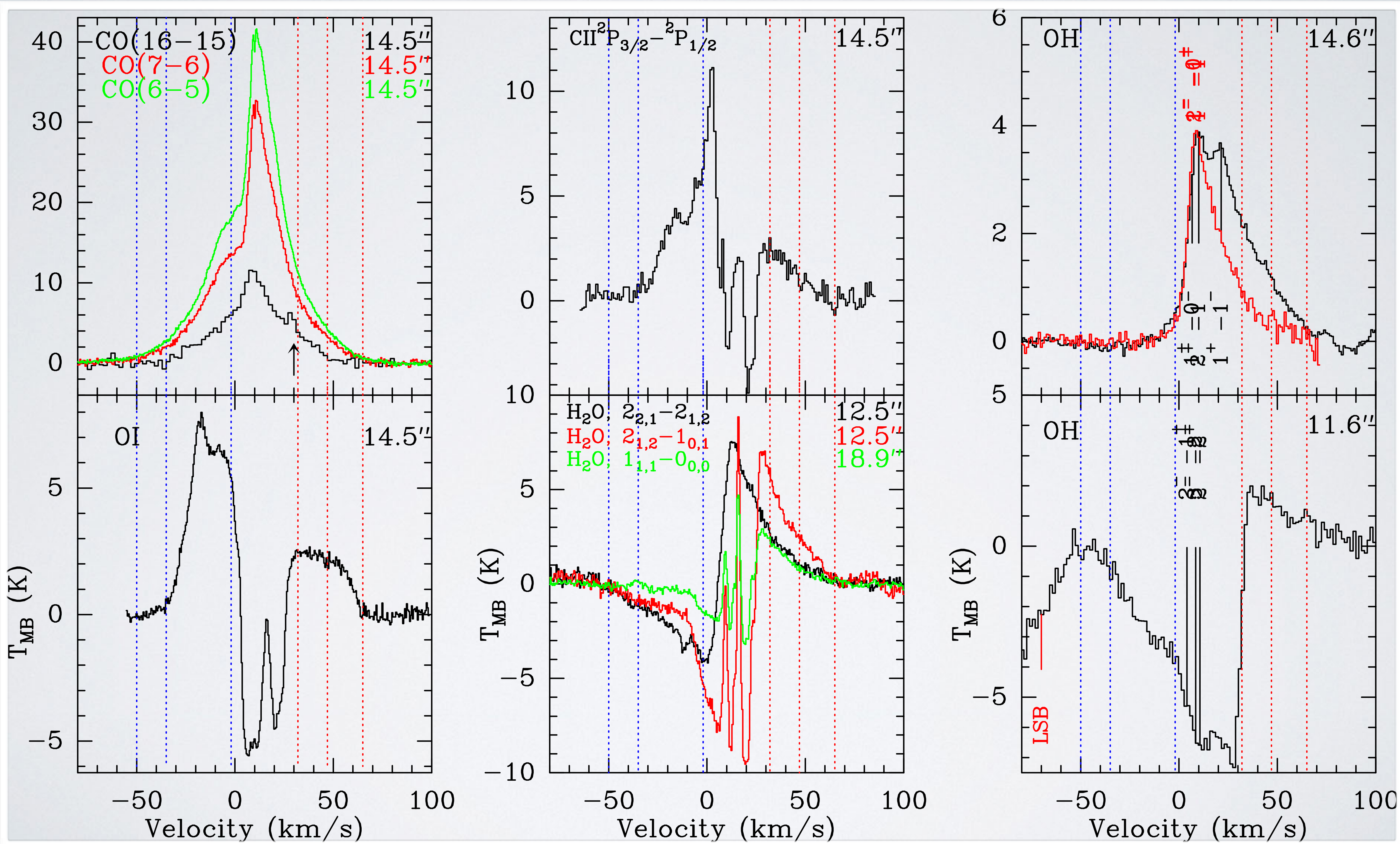
$$\dot{M} = \frac{M}{t_d}$$

> 0.9 10^{-4} $M_\odot yr^{-1}$

in good agreement with each other and with estimates from CO (Gusdorf+2015)

⇒ **the molecular outflow in G5.89-0.39 is likely driven by the [OI] atomic jet**

Atomic and molecular spectra



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Far-IR line luminosity

I. **Over the whole profile** [OI] contributes ≃50% to the total line L_{FIR} together with CO
II. **At HV**, [OI] is the main contributor (5.1 $L_\odot$) to the line L_{FIR} followed by CO (≃1.3 $L_\odot$)
III. H_2O is not a significant contributor even at HV

This work (14″.5 beam)						
Velocity range	$L_{CO(16-15)}$ ($L_\odot$)	L_{OH}[a] ($L_\odot$)	L_{H_2O}[b] ($L_\odot$)	$L_{OI\,63\mu m}$ ($L_\odot$)	L_{CII} ($L_\odot$)	L_{FIRL} ($L_\odot$)
total profile	0.65	0.44	–	5.6	0.42	7.15
HV-red	–	0.08	0.03	0.85	0.02	0.99
LV-red	0.06	0.13	0.09	1.15	0.06	1.5
green	0.42	0.12	0.08[c]	–	0.1	0.72
HV-blue	–	–	–	0.04	–	0.04
LV-blue	0.17	–	–	5.13	0.2	5.5
Values from Karska et al. (2014) (9″.4 beam)						
Velocity range	L_{CO}[d]	L_{OH}[e]	L_{H_2O}[e]	$L_{OI\,63\mu m}$[f]		
total profile	3.9	0.5	0.8	3.7	–	8.8

Conclusions

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In G5.89-0.39:

- [OI] at 63 μm is **heavily contaminated by absorption** at low velocities;
- [OI] at 63 μm is characterised by **emission at HV in the same velocity range as mid- and high-J CO, H_2O, OH**;
- The **outflow(s) in G5.89-0.39 is likely driven by the atomic jet tr**aced in [OI];
- [OI] is the **major contributor to the line far-IR cooling budget at HV**

Future perspectives

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A larger **sample of massive YSOs** in different evolutionary phase: open time cycle 3 project on ATLASGAL sources+P.I. time project on W3(OH)/W3(H_2O))

ATLASGAL sources