

High Mass Star Formation Revealed by Herschel PACS Spectroscopy

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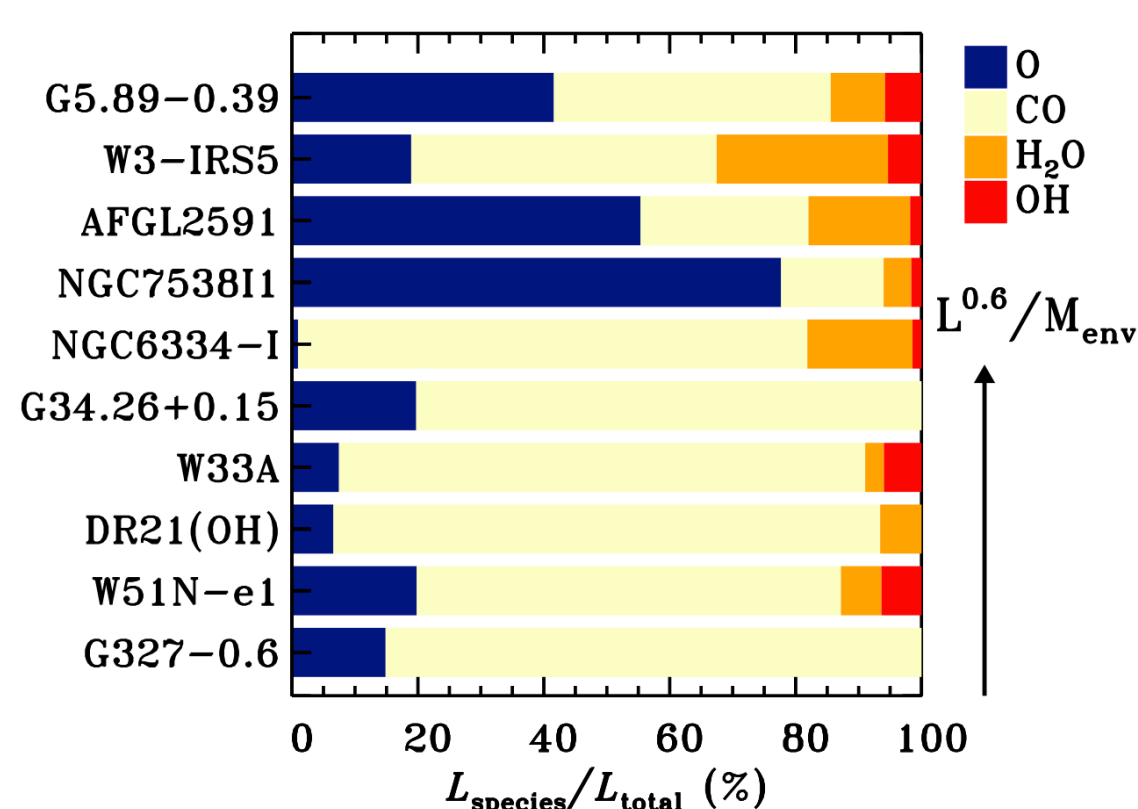
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1. INTRODUCTION

We present preliminary results of Herschel PACS range spectroscopy data toward 10 high mass young stellar objects (YSOs), taken as part of the key program Water in Star-forming Regions with Herschel (WISH, van Dishoeck et al. 2011). We attempt to find evolutionary trends of physical/chemical properties in high mass star formation.

High mass YSOs are expected to have a high accretion rate ($\sim 10^{-3} M_{\odot}/\text{year}$) or small cores merged. They become a main sequence star as still embedded in a cloud, which results in a HII region developed around (e.g., Zinnecker & Yorke 2007, Beuther et al. 2006).



Using the same data sets presented here but focusing on the centers only, our team has studied far-IR atomic/molecular line cooling for high mass YSOs (Karska et al. 2013). The results include that CO takes a larger role in line cooling for high mass YSOs than low mass and for earlier stages than later.

2. OBJECTS/OBSERVATIONS

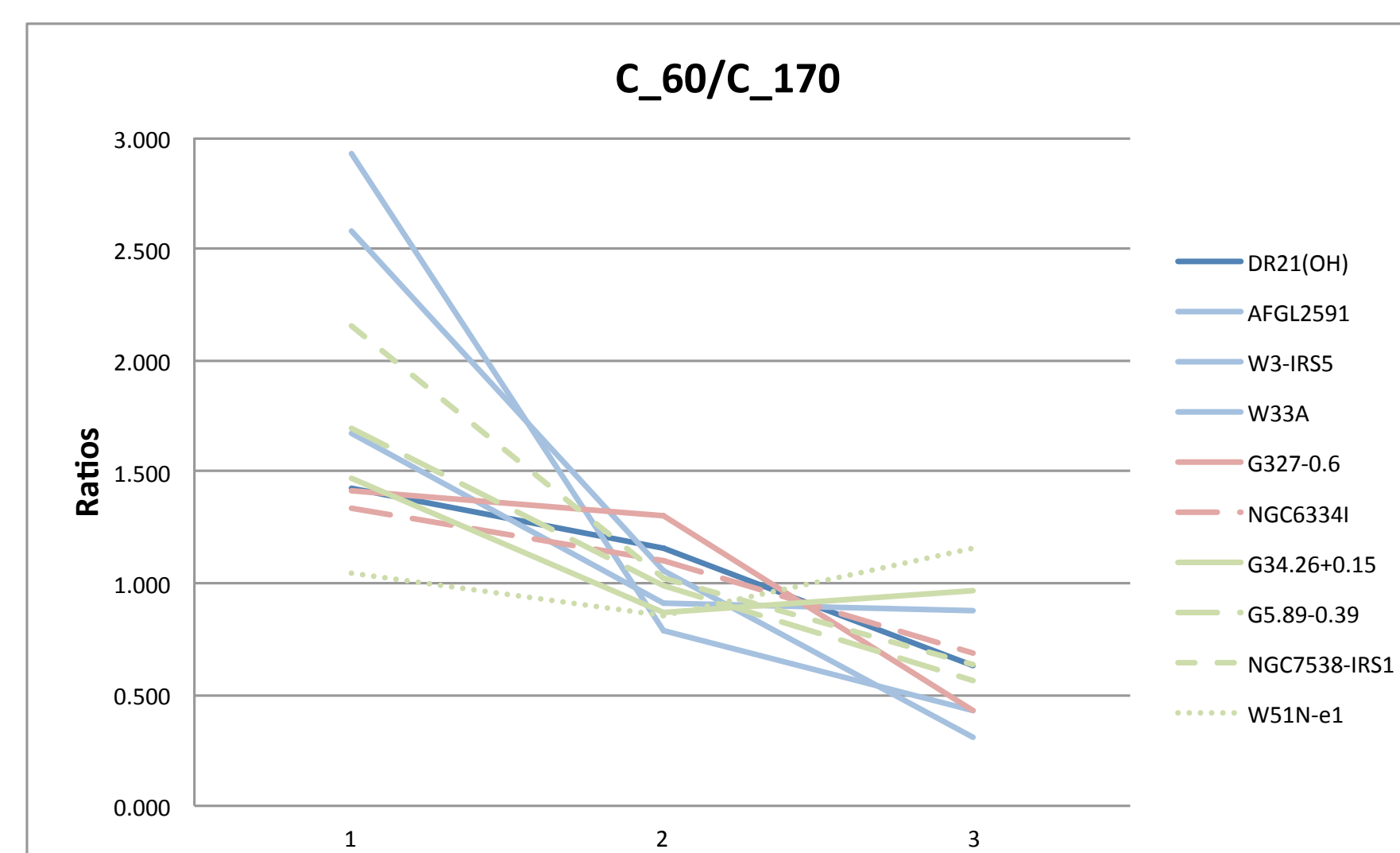
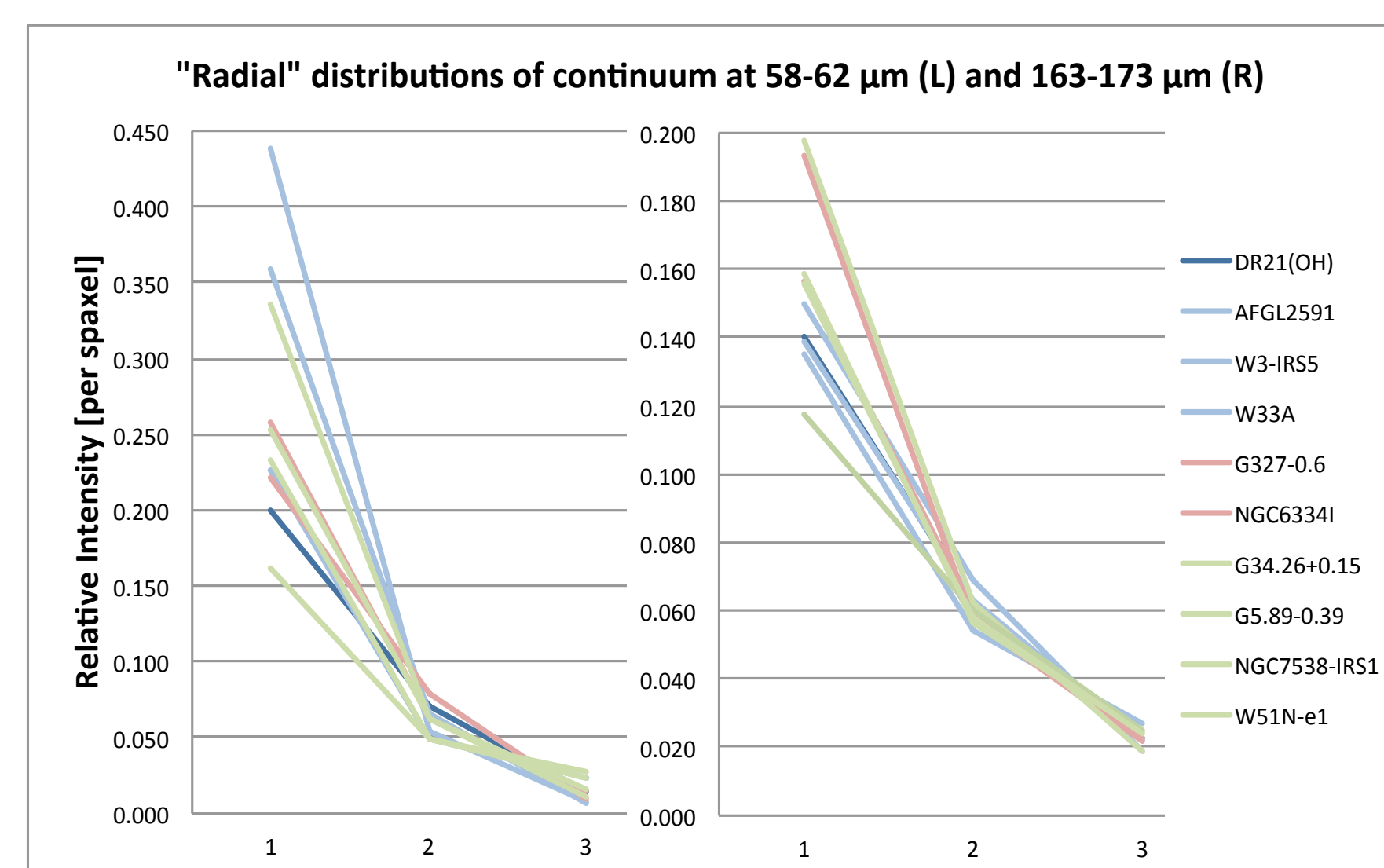
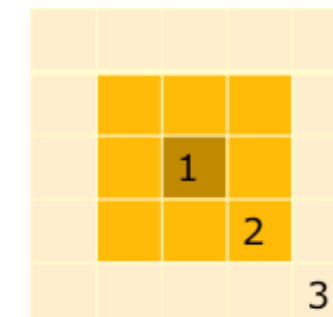
- Herschel Space Observatory (2009-2013)
3.5 m primary; PACS, HIFI, SPIRE
- Photodetector Array Camera & Spectrometer (PACS)
Spectrometer
- Red 57-105 μm and blue 105-210 μm cameras
5x5 spaxels (9.4 arcsec x 9.4 arcsec spatial pixels)
 $R = \lambda/\Delta\lambda = 1000-5000$

Objects (van der Tak et al. 2013)
Mid-IR-quiet and mid-IR-bright objects (MIRQ/B)
Hot molecular cores (HMC)
Ultra compact HII regions (UCHII)

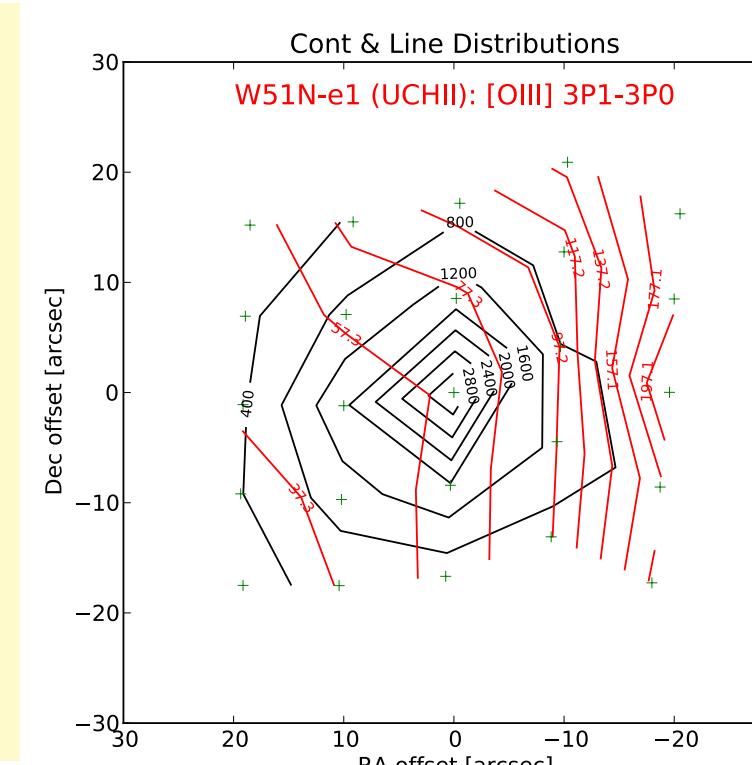
	RA (J2000)	Dec	V_{LSR}	L_{bol}	d
	h m s	° ' "	km/s	L_{\odot}	kpc
DR21(OH)	20 39 00.8	+42 22 48	-4.5	1.3×10^4	1.5
AFGL 2591	20 29 24.7	+40 11 19	-5.5	2.2×10^5	3.3
W3-IRS5	02 25 40.6	+62 05 51	-38.4	1.7×10^5	2.0
W33A	18 14 39.1	-17 52 07	+37.5	4.4×10^4	2.4
G327-0.6	15 53 08.8	-54 37 01	-45.0	5.0×10^4	3.3
NGC6334-I	17 20 53.3	-35 47 00	-7.7	2.6×10^5	1.7
G34.26+0.15	18 53 18.6	+01 14 58	+57.2	3.2×10^5	3.3
G5.89-0.39 (W28A)	18 00 30.4	-24 04 02	+10.0	5.1×10^4	1.3
NGC7538-IRS1	23 13 45.3	+61 28 10	-57.4	1.3×10^5	2.7
W51N-e1	19 23 43.8	+14 30 26	+59.5	1.0×10^5	5.1

3. CONTINUUM

- Spectral energy distributions (SEDs) over 60-200 μm
- Radial distributions
peak – intermediate – boundary spaxel
- Targets different in fluxes and angular sizes
Normalized by total fluxes
Concentration ratios
e.g., C_{60}/C_{170} , where $C = (\text{peak flux}) / (\text{total flux})$

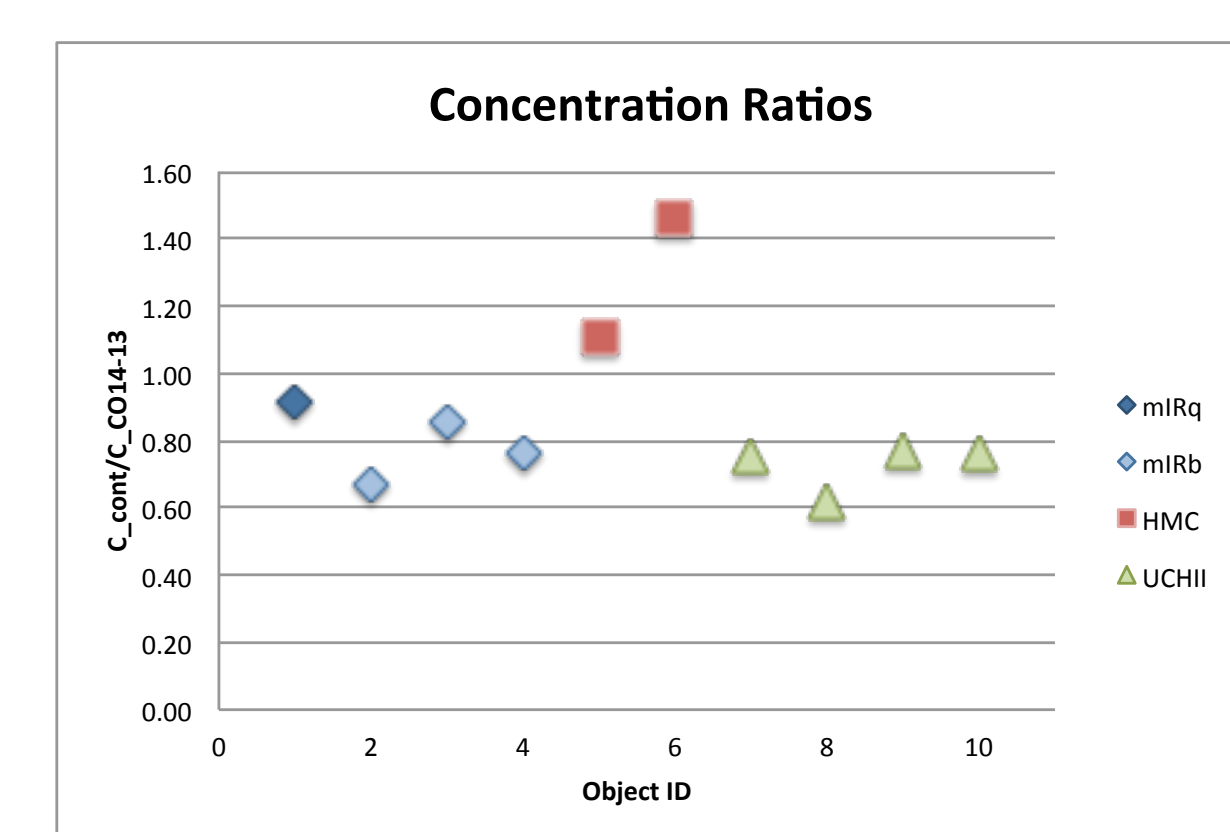
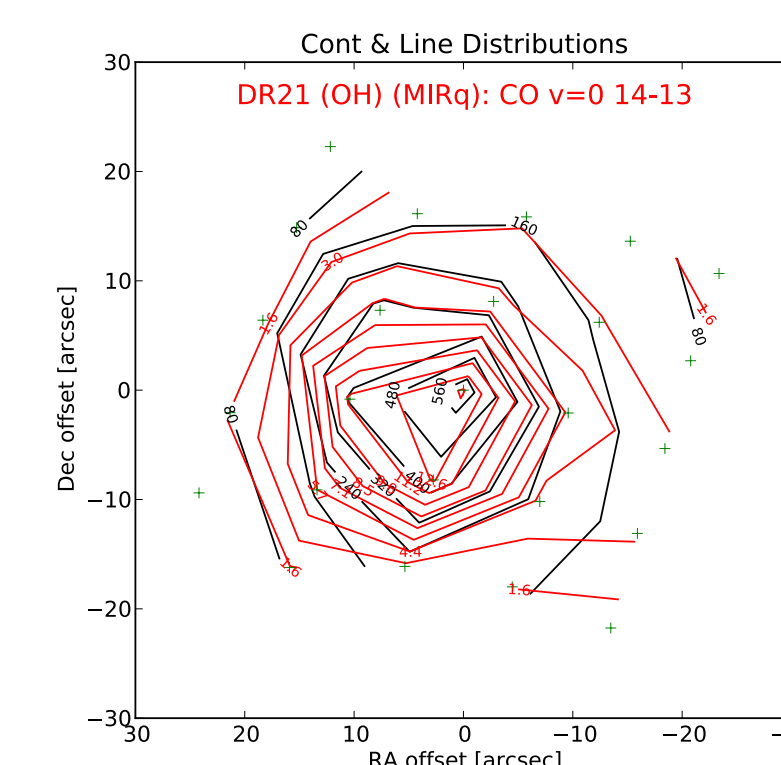
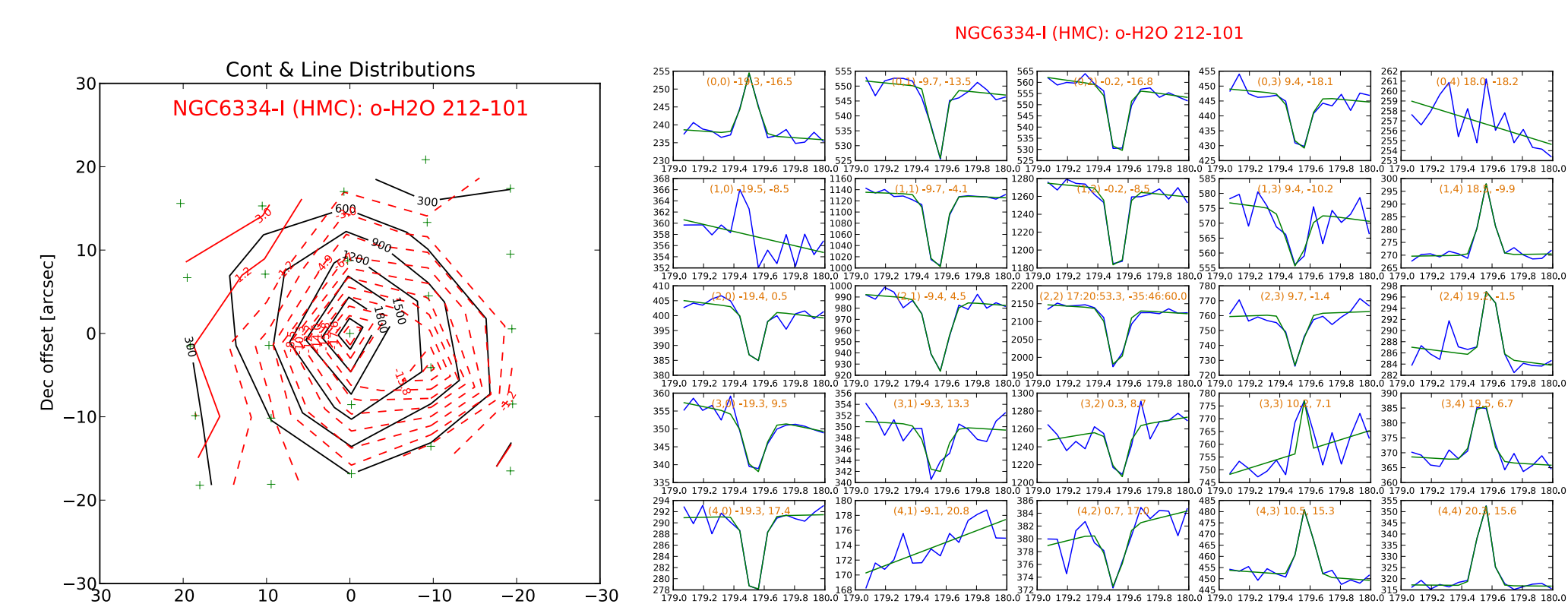
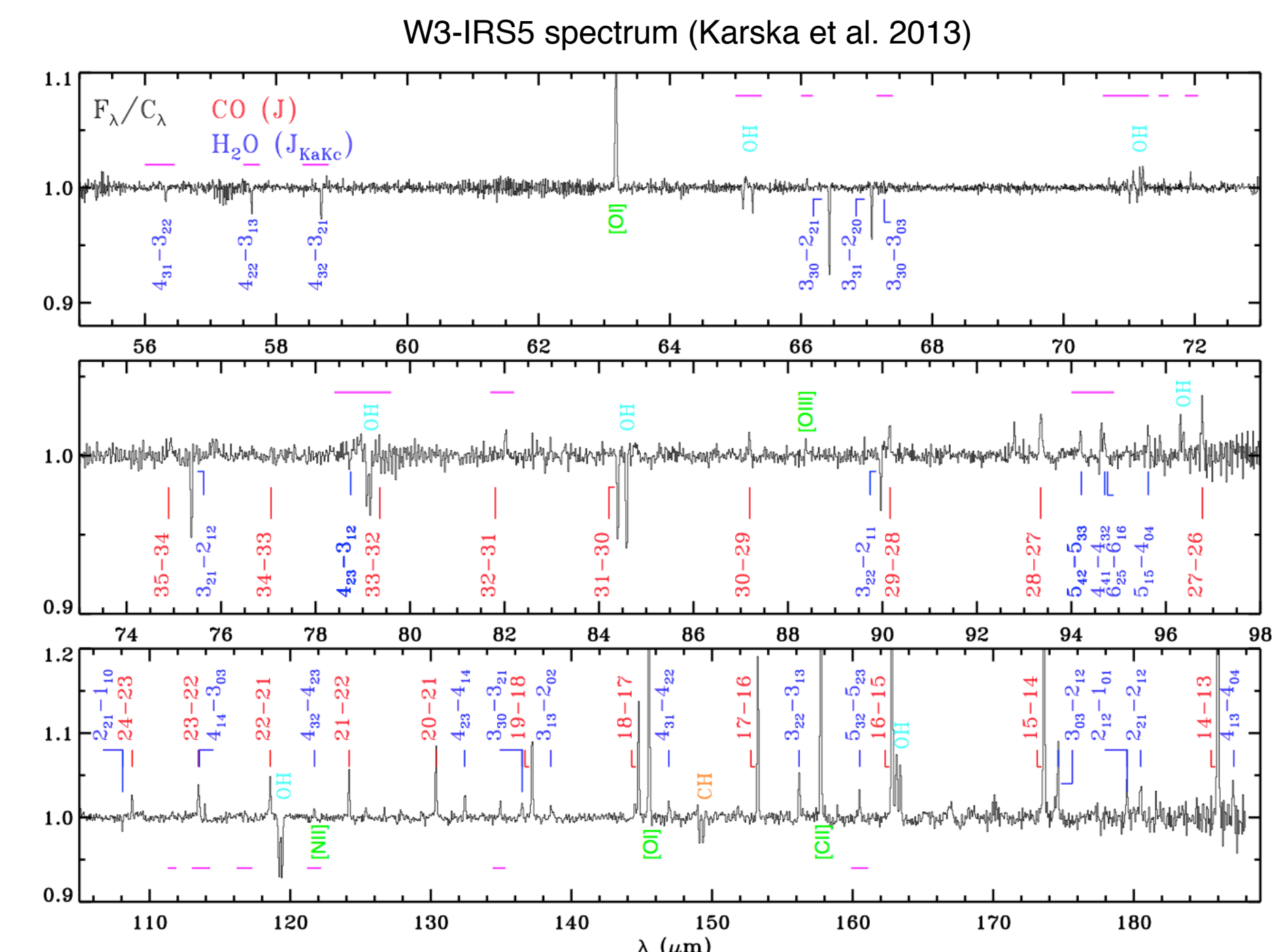


- HMCs and MIRQ have the concentration ratios close to 1 and shallow-steep patterns, which suggest higher extinction even in FIR. Note that W51N-e1 shows an overturn pattern, which is consistent to a strong [OIII] peak off the continuum peak.



4. MOLECULAR/ATOMIC LINES

- Water lines in absorption and emission
- CO lines all in emission
 $J=22-21$ (118.581 μm) \rightarrow $J=13-12$ (200.271 μm)
- OH lines in absorption/emission
- CH lines all in absorption
- [OI], [CII], [NII], [OIII] lines: absorption/emission but not fully checked for off-position contamination



- HMCs (and MIRQ) have the highest concentration ratios of continuum to CO 14-13. It indicates that HMCs have a relatively lower CO flux and/or a relatively strong continuum at the center, which suggest a high extinction. The strong continuum might also be due to a high accretion luminosity (e.g., Osorio et al. 1999).

5. CONCLUSIONS

Based on the concentration ratios between MIR and FIR and between continuum and CO, HMCs appear to have higher extinction. It suggests that HMCs could be the earlier stage than MIRQ/B objects, rather than between MIRQ/B and UCHII. Further investigations with more molecular lines and modeling will be carried out.

REFERENCES

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