PACS Survey of Proto-planetary disks in Taurus/Auriga: Investigating the source of [OI]63 μm emission

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and the GASPS team

Grenoble, 22 March 2012

GAS in Protoplanetary Systems

* Systematic survey of atomic and molecular gas and dust in ~300 disks over range of masses, ages, and stellar types
  * Evolution of gas and dust in disks ~1-30Myr
  * Gas structure
  * Timescales of disk mass dispersal and broad overview of the transition from molecular to atomic to dusty composition

Taurus Sample

- Spectral types: Early G to early M
- Primarily class II sources
- Roughly coeval population (~1-3 Myr)
- Largest sample in GASPS project
  - ~70 linespec observations
  - ~40 rangespec observations
  - ~90 Photometry observations (70, 100, 160 μm)

PACS Spectroscopy

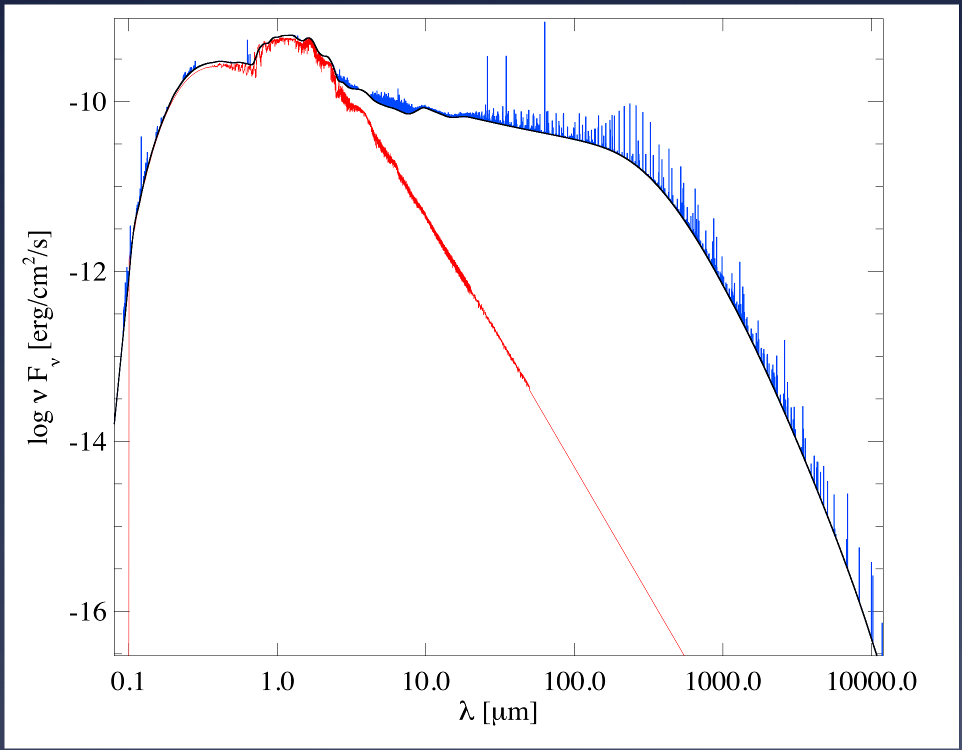
Winter 2010 – Fall 2011
LineSpec: 76 targets observed (1.25 – 7 ksec.)
RangeSpec: 38 targets observed (5-20 ksec.)

PACS SECTROSCOPY SETTINGS

Obs. Mode	Setting	Grating order	Camera	Observed Range (μm)	Species	Transition	Wavelength (μm)
LineSpec	A	3	Blue	62.68 – 63.68	**[OI]**	$\mathbf{^3P_1 \rightarrow ^3P_2}$	**63.184**
					o-H_2O	$8_{18} \rightarrow 7_{07}$	63.324
		1	Red	188.77 – 190.30	DCO^+	J=22-21	189.570
RangeSpec	B	2	Blue	72.00 – 73.05	CH^+	J=5-4	72.14
					CO	J=36-35	72.843
		1	Red	144 – 146.1	CO	J=18-17	144.784
					[OI]	$\mathbf{^3P_0 \rightarrow ^3P_1}$	**145.525**
	C	2	Blue	78.55 – 79.45	o-H_2O	$4_{23} \rightarrow 3_{12}$	78.741
					OH	1/2-3/2 hfs	79.11/79.18
					CO	J33-32	79.360
		1	Red	157.1 – 158.9	**[CII]**	$\mathbf{^2P_{3/2} \rightarrow ^2P_{1/2}}$	**157.741**
					p-H_2O	$3_{31} \rightarrow 4_{04}$	158.309
	D	2	Blue	89.45 – 90.50	p-H_2O	$3_{22} \rightarrow 2_{11}$	89.988
					CH+	J=4-3	90.02
					CO	J=29-28	90.163
		1	Red	178.9 – 181.0	o-H_2O	$2_{12} \rightarrow 1_{01}$	179.527
					CH+	J=2-1	179.610
					o-H_2O	$2_{21} \rightarrow 2_{12}$	180.488

•o-H_2O Riviere-Marichalar et al., A&A 538 L3 (2012)
•Podio et al. 2012, in prep.

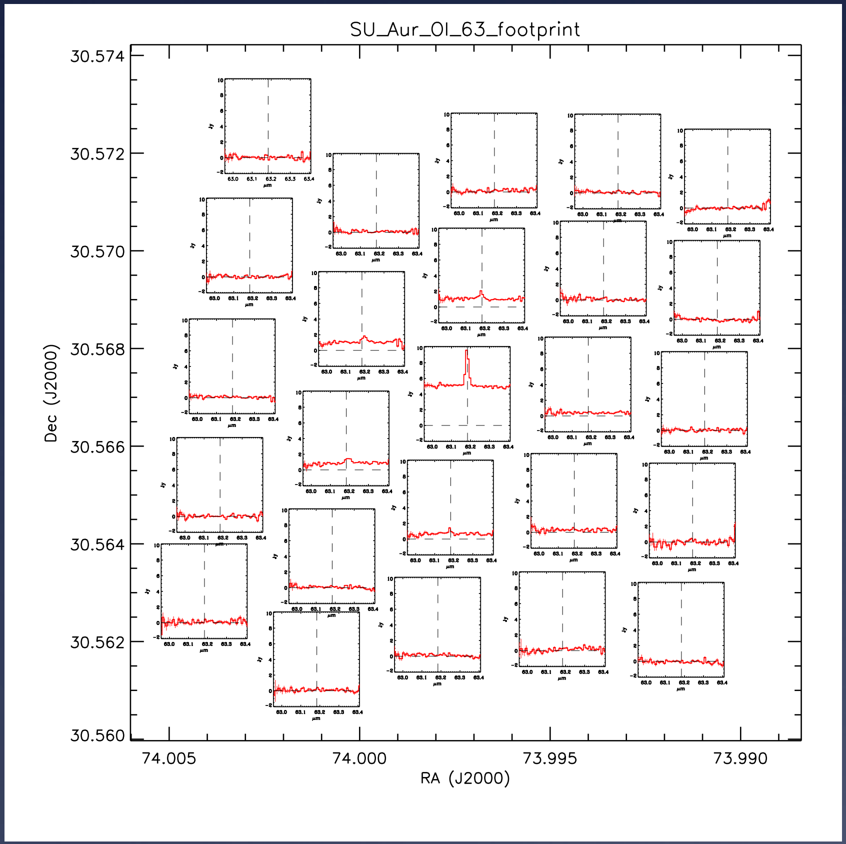
[OI]63

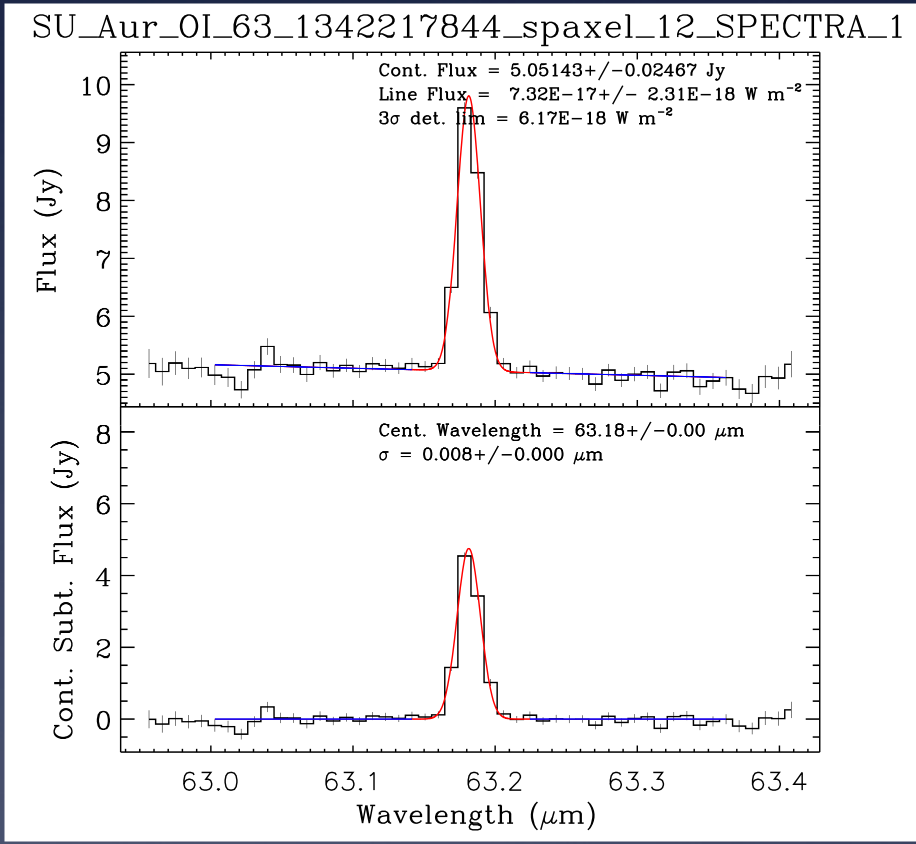


- [OI] 63 strongest FIR line in the PACS range
  - Primary cooling line in protoplanetary disks
  - Traces warm surface layer of the disk down to A_V~3
  - Additional measurement of [OI]145 & [CII]158 can yield information on temperature, density, characteristics of emission region

•Measurement of [OI] can constrain current models of disk structure:
•What is gas/dust structure/location?
•Gas/Dust ratio?
•Gas & dust coupled?

Observations





Line Sensitivities: ~ 0.5 – 10^{-17} W m^{-2}

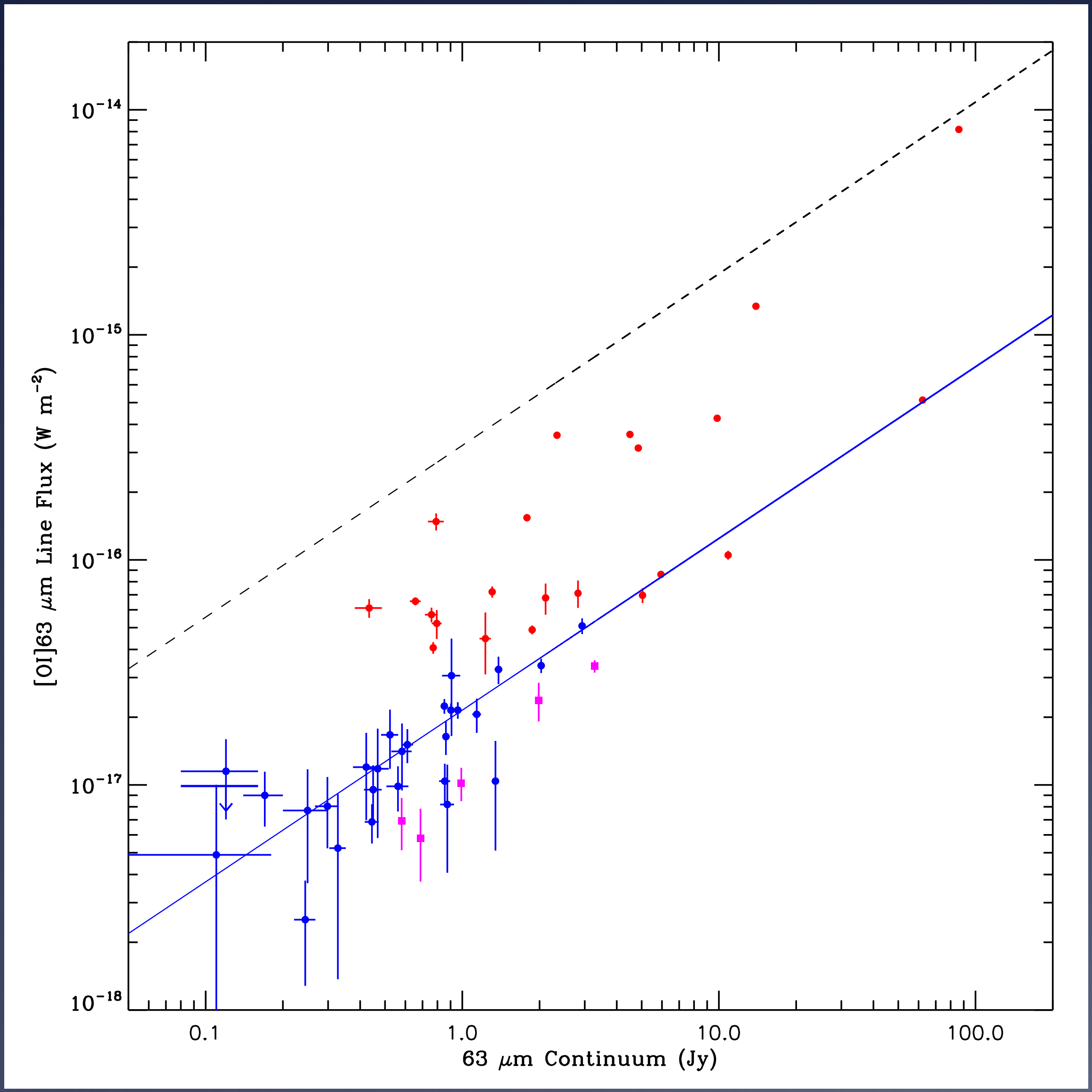
Continuum Sensitivities: ~100 mJy, better in photometry

[OI]63 : 52/76 (68%)

[OI]145 : 21/38 (55%)

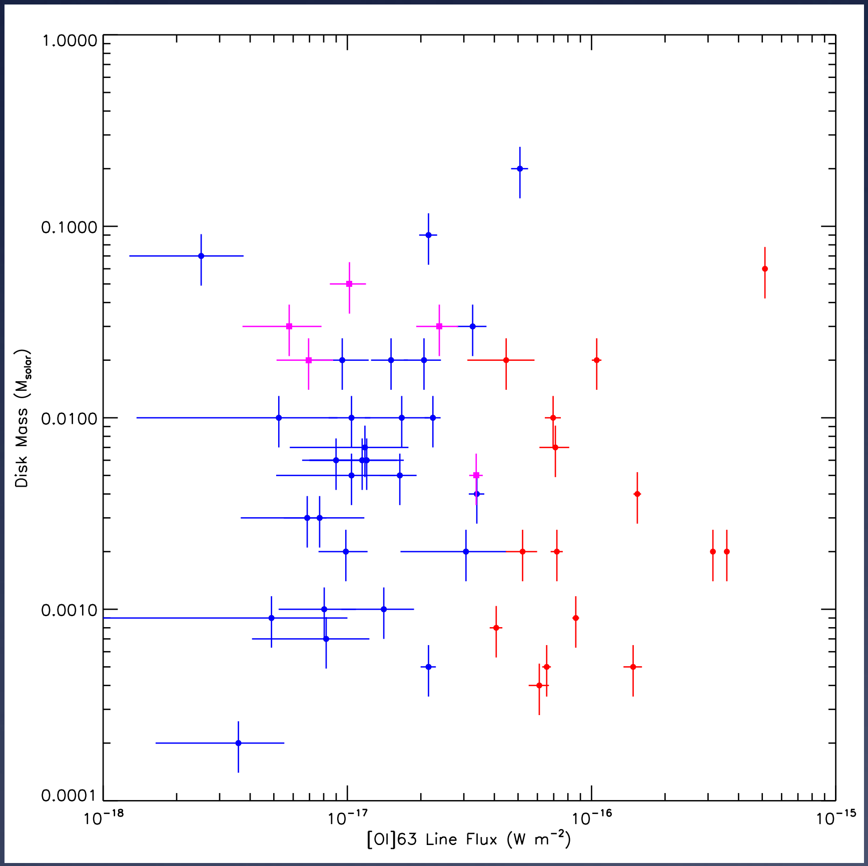
[CII]158 : 18/38 (47%)

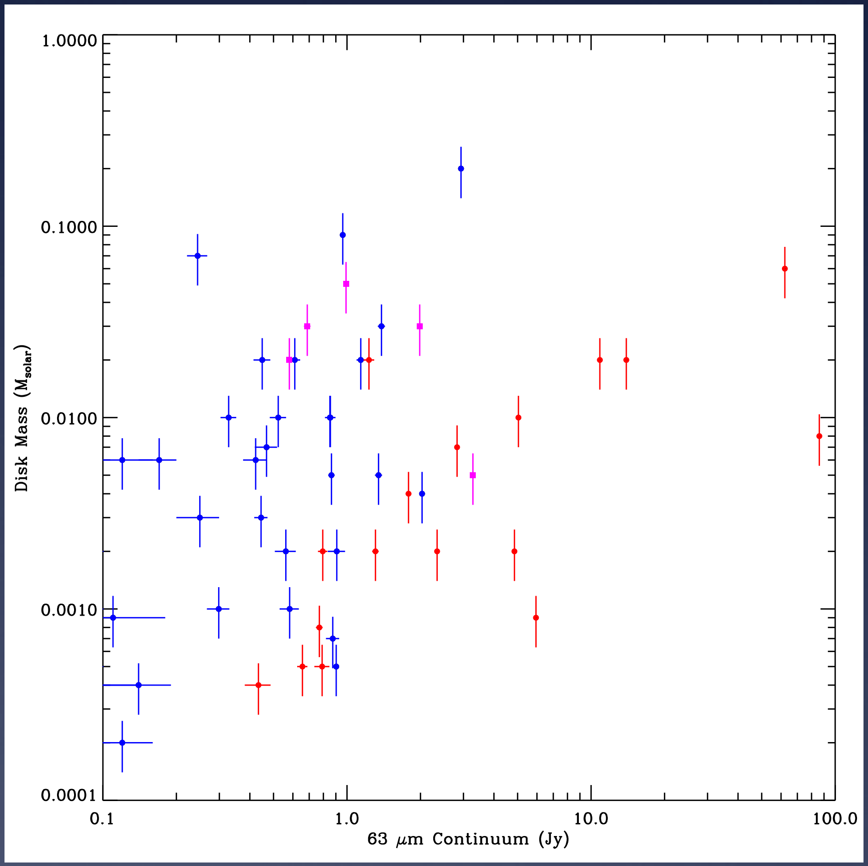
[OI]63 vs. 63 μm Continuum



- Tight correlation between [OI]63 line emission and 63 μm continuum flux for non-outflow sources
- The [OI] 63 μm line emission in outflow sources is dominated by the outflow, and can be up to 15 times stronger than the emission from the disk. Several outflow sources show extended [OI] (Podio et al. 2012, in prep)
- Known transition disks are ~2x lower in [OI]63 flux compared to classical T Tauri disks

Disk Mass





No correlation with disk mass (as expected):

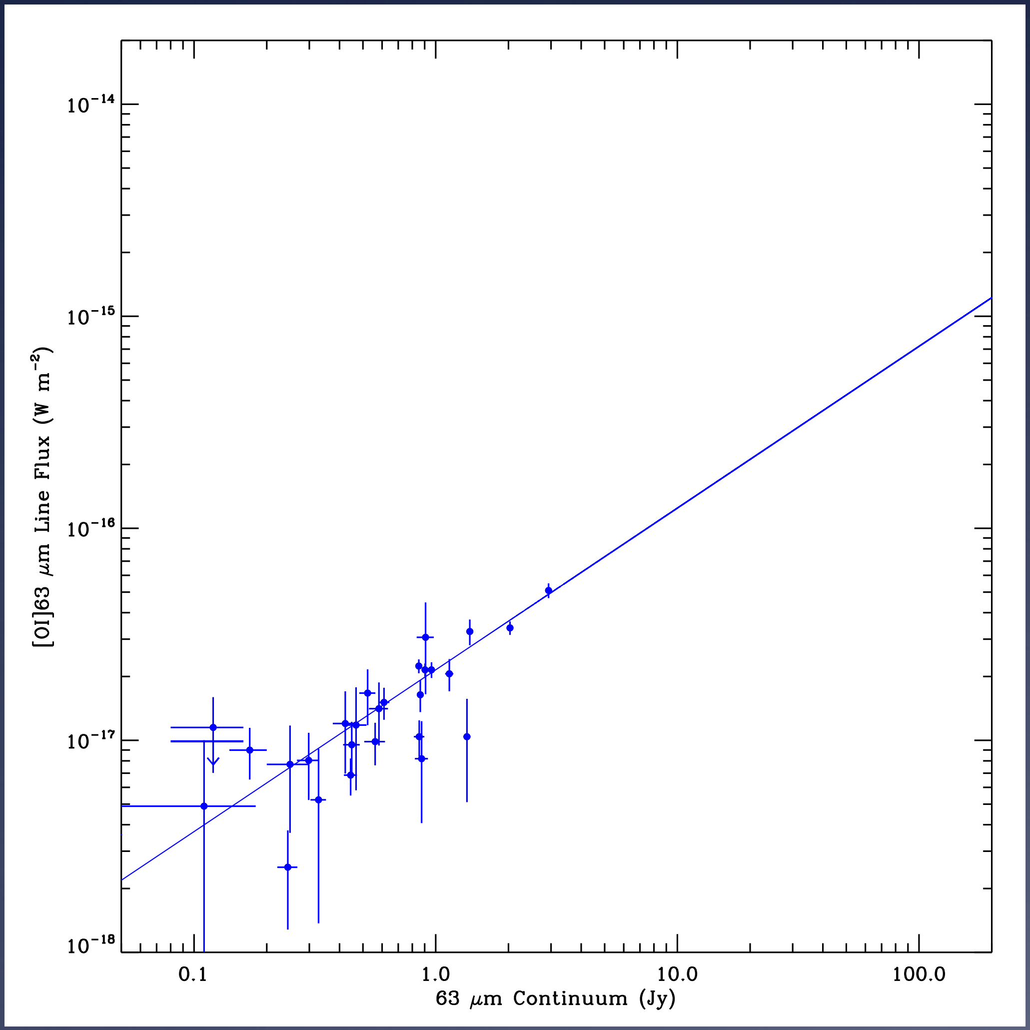
•[OI]63 probes only surface layer

•Bulk of 63 μm continuum comes from the warm the inner ~20 AU of the disk

•No correlation with accretion rate

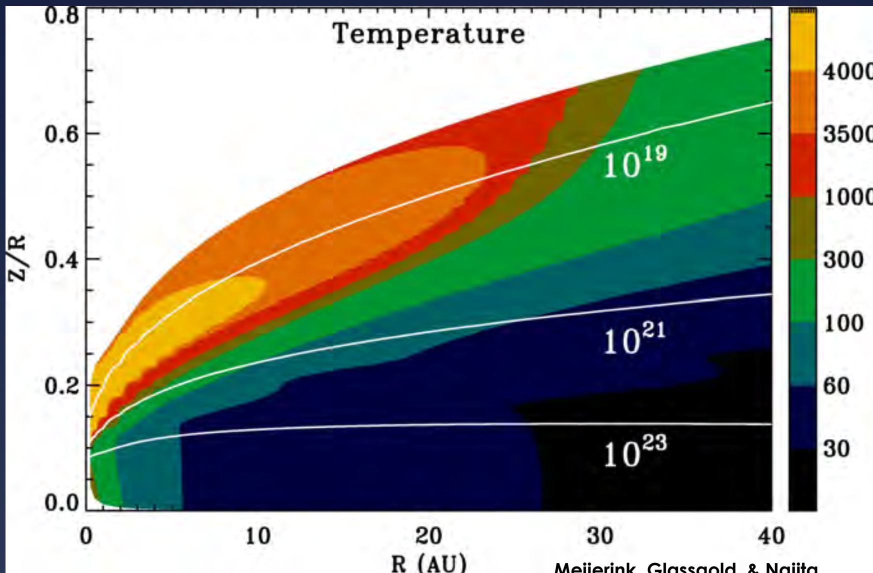
•No correlation with x-ray luminosity (see poster by Giambattista Aresu)

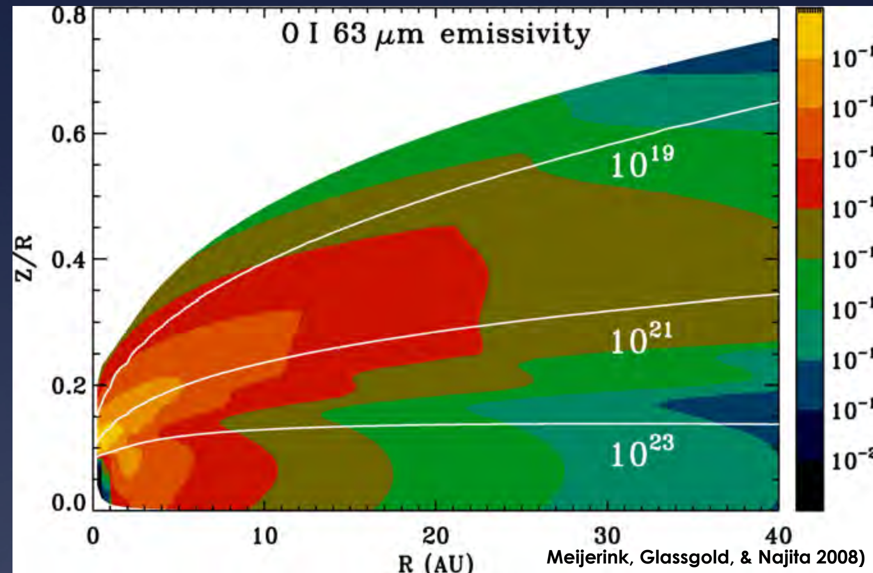
[OI]63 emission origin

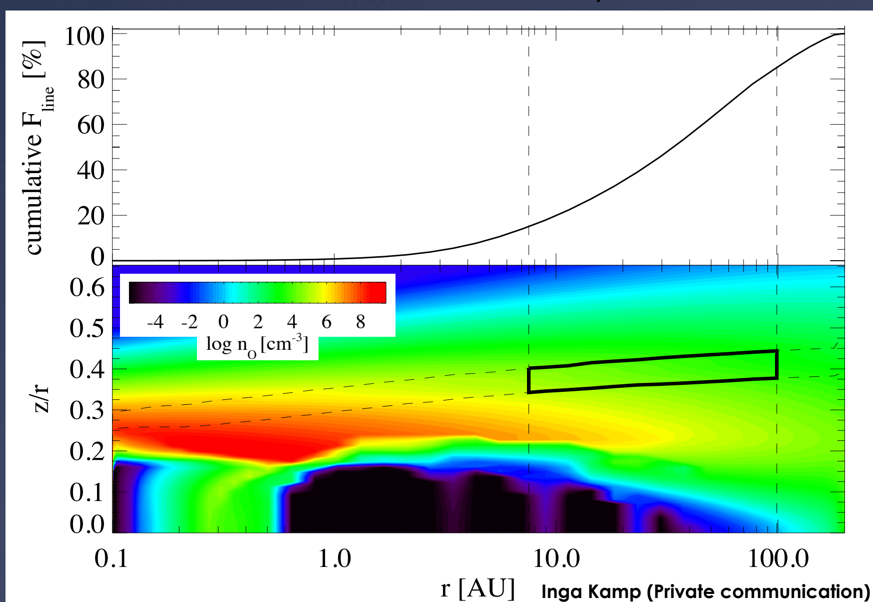


- Bulk of 63 μm continuum emission comes from inner ~20 AU of disk
- Correlation suggests the [OI] 63 line primarily probes the same region of the disk (along with some contribution from the outer disk).
- However.....

[OI]63 emission origin



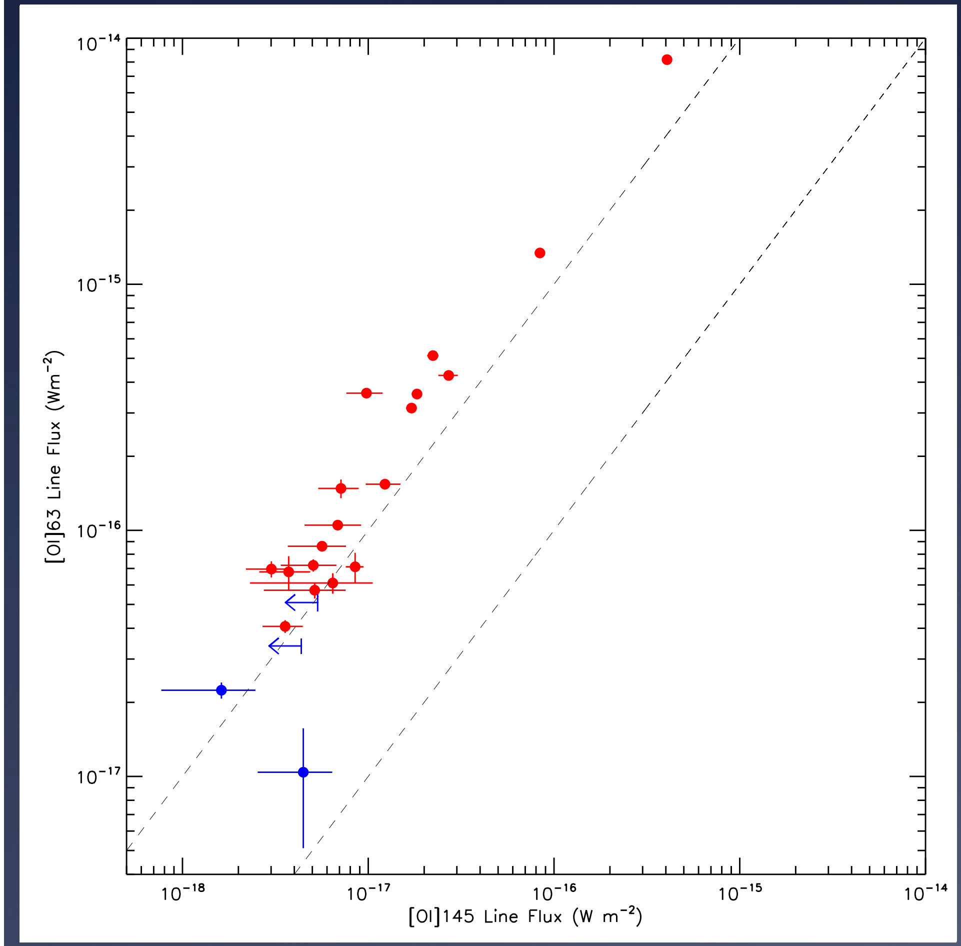




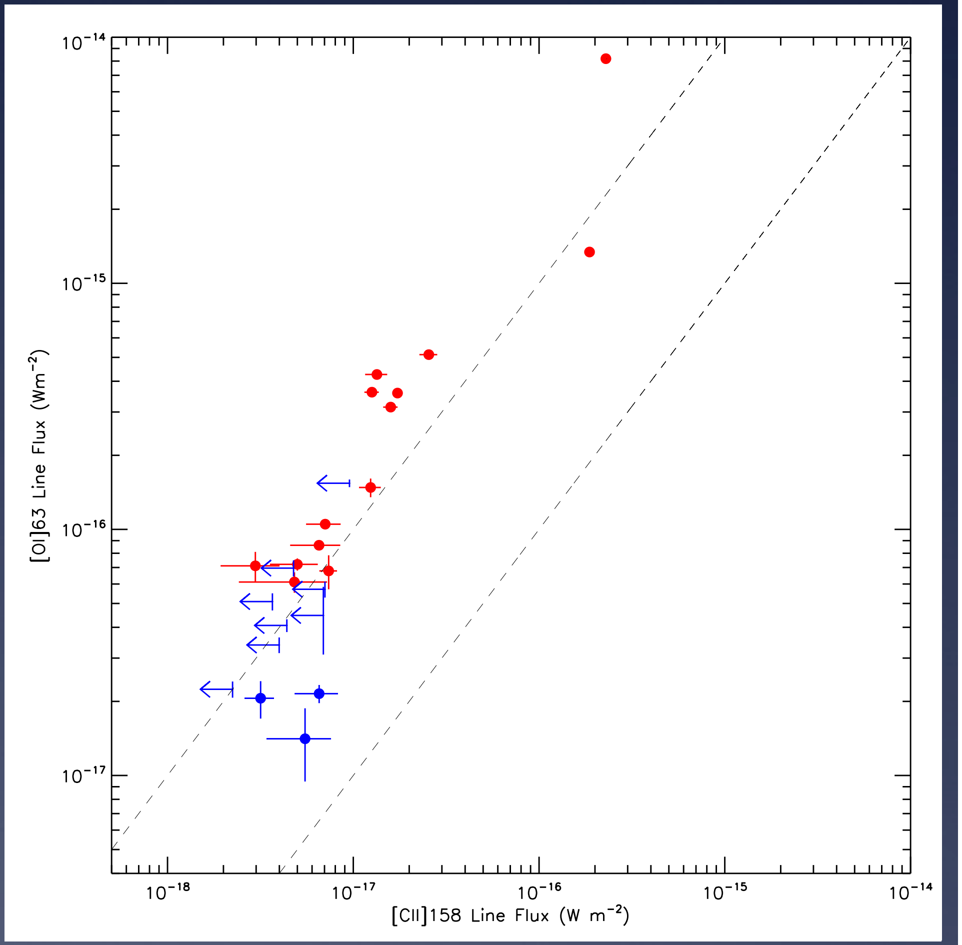
[OI]63 emissivity peaks at R < 20 AU, X-ray only (Meijerink, Glasgold, & Najita 2008).

Other models show > 50% of [OI]63 coming from R > 30 AU, UV only

Line Ratios

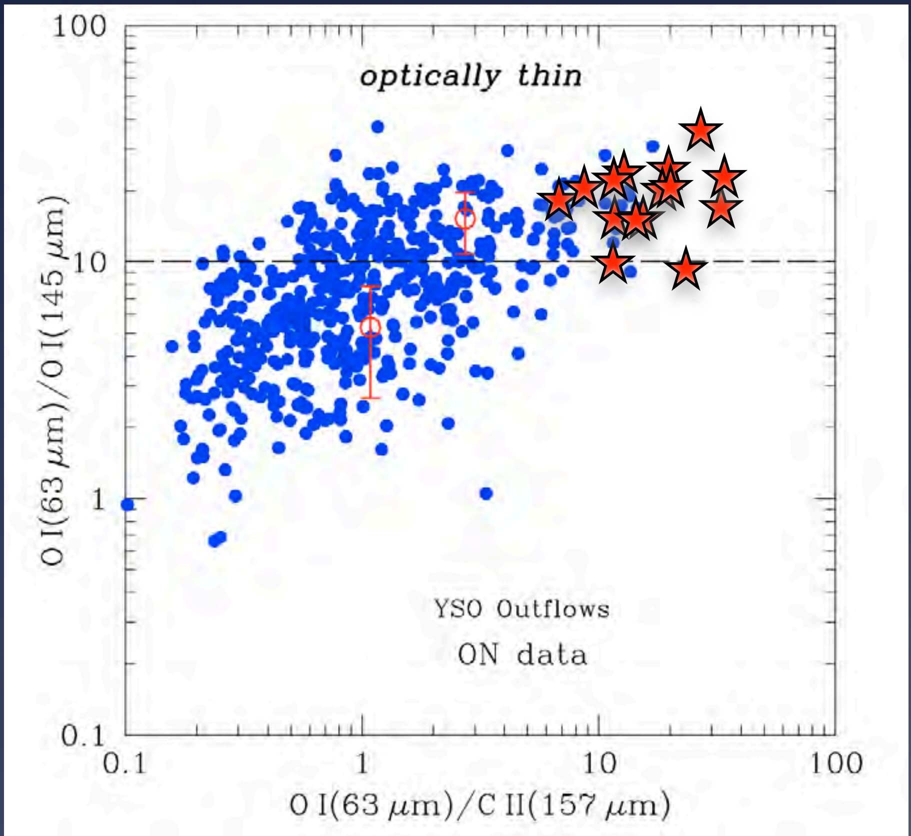


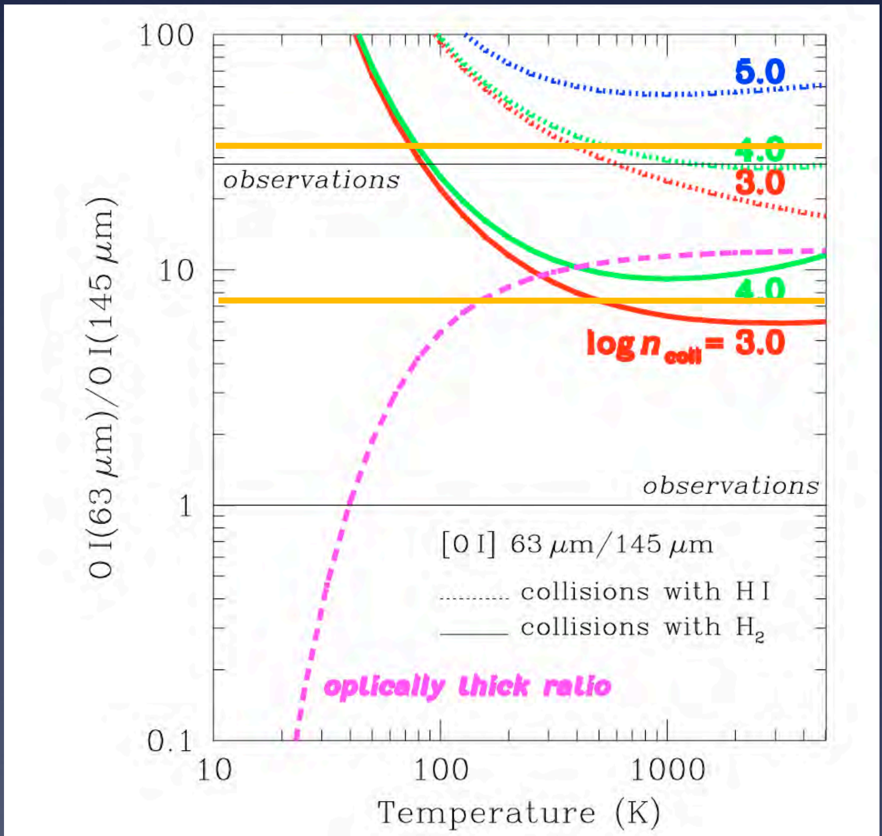
[OI] 63 / [OI] 145



[OI] 63 / [CII] 158

PDR Emission?





Liseau et al. 2006

T > ~200 K, n < 10^4, optically thin emission, ***if*** emission comes from the same region

Ongoing Work

- Contraints on the models (DENT grid, see Woitke et al. 2010MNRAS, astro-ph/1003.2323, 2010)

    - gas/dust ratio, UV flux, disk geometry, etc.

•Source of [OI]63 emission: majority of [OI]63 coming from inner ~20 AU (as observations suggest) or from further out in the disk (as models show)?

•Emission optically thin or thick?

Conclusions

* In strong outflow sources the emission from the outflow dominates the line intensity.
* Strong correlation with 63 μm continuum. Bulk of [OI]63 emission from the same region as continuum
* Known transition disks show a deficit of [OI]63 emission compared to classical T Tauri disks
* For sources with [OI]63, [OI]145, and [CII]158 detection, we find line ratios of ~10 – 20 (all outflow sources)
  * Suggests optically thin emission with T~200 K and n <10^4 PDR dominated?