

Radiation Diagnostics for Protostellar Winds and Disks

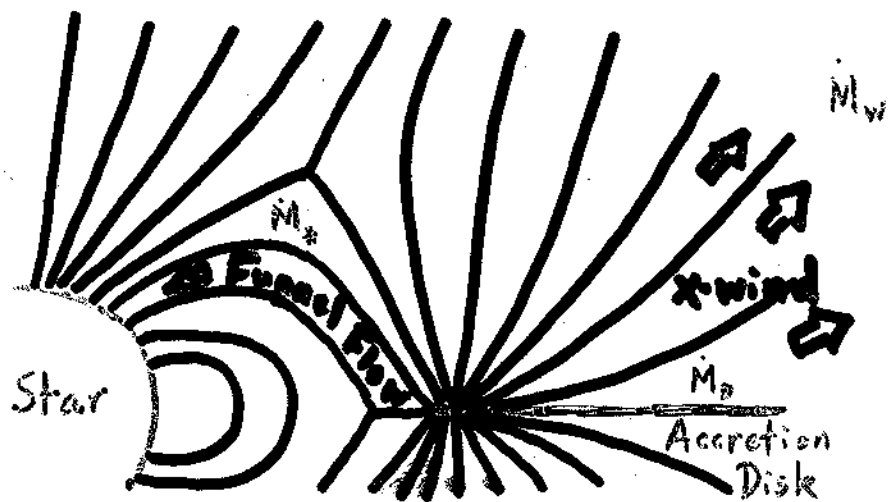
A. Glassgold, S. Lizano, J. Najita, H. Shang, F. Shu

Outline of Talk

- Low-Mass Protostars and Their Radiation Diagnostics
- Mechanical and Thermal Models of Protostellar Winds and Jets
- Diagnostics at High Spectral Resolution but Low Spatial Resolution
- Chemistry of Disk Atmospheres
- Diagnostics at High Spectral Resolution but Low Spatial Resolution

Line Radiation from Protostars

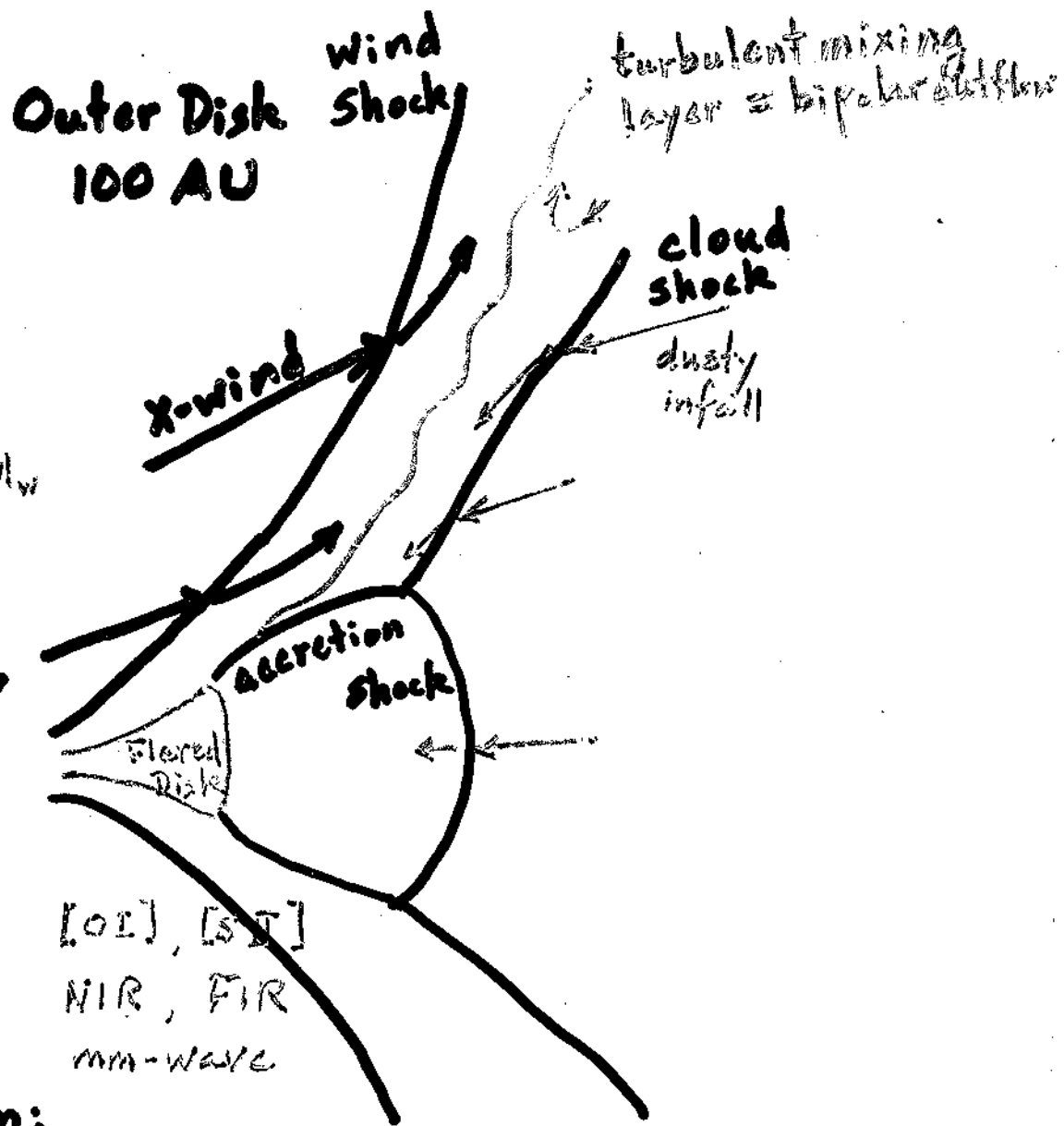
Central Machine
0.1 AU



X-rays, Optical, NIR, Radio

Examples of FIR Line Emission:

Atomic Fine-Structure : [OI] $63\mu\text{m}$, $145\mu\text{m}$
 Molecular Rotational : H_2 , CO



[OI], [SI]
 NIR, FIR
 mm-wave

Ceccarelli et al. (1997)

ISO-LWS observations of IRAS16293-2422

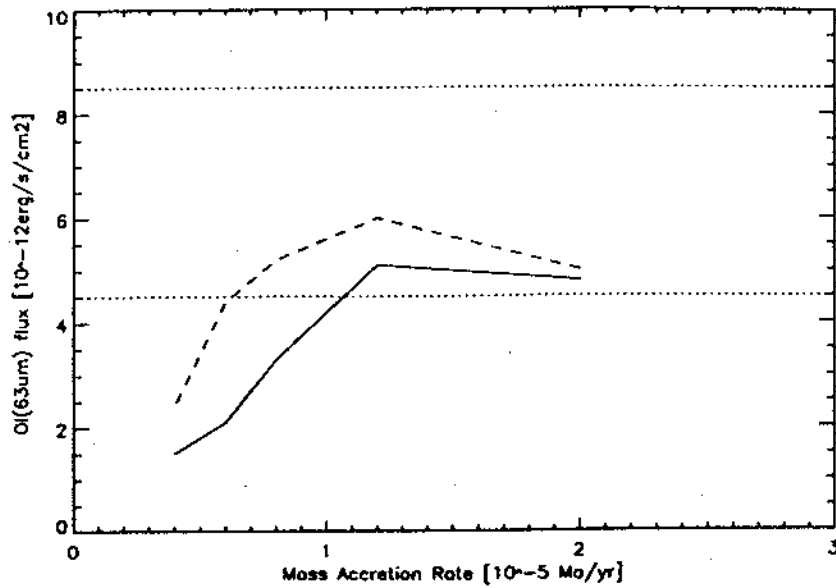
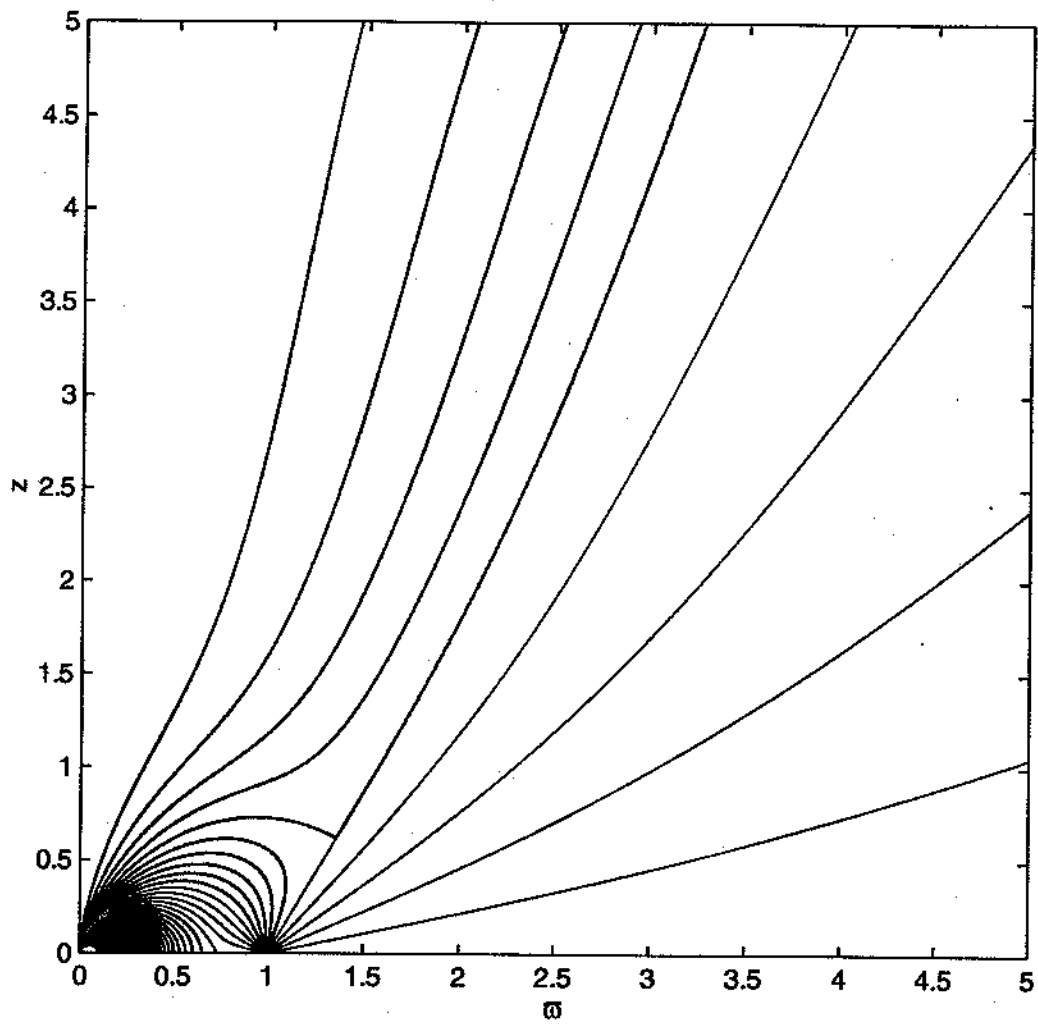
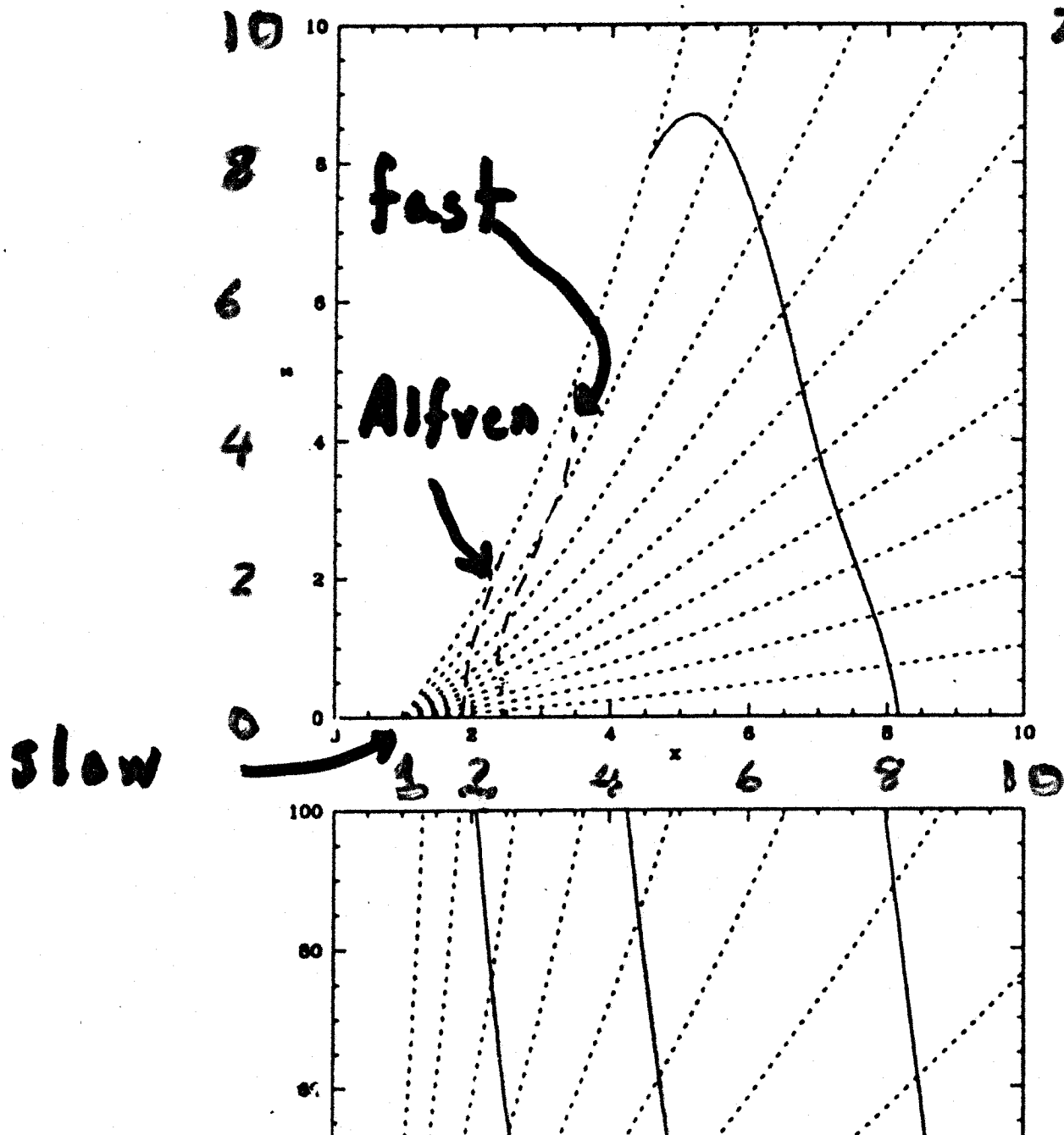


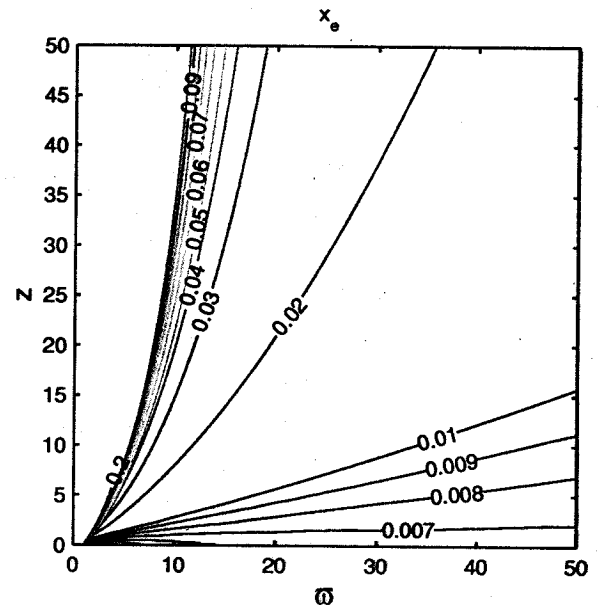
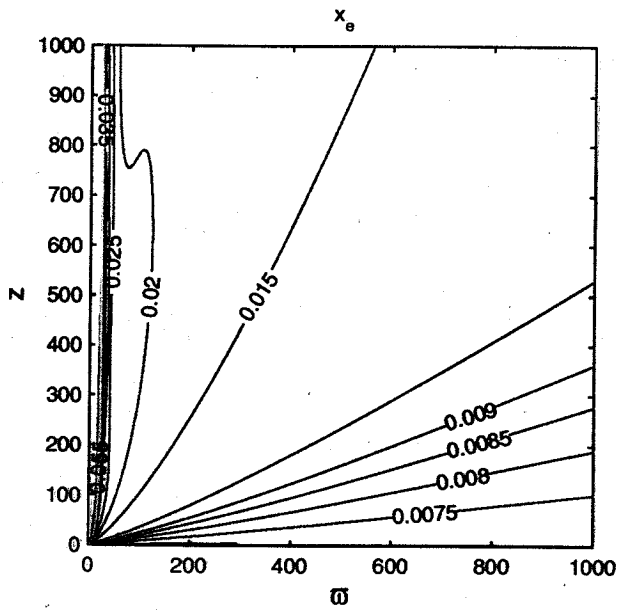
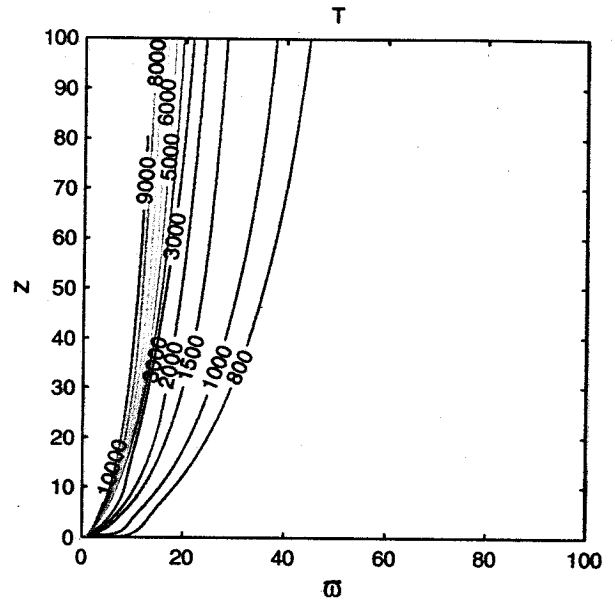
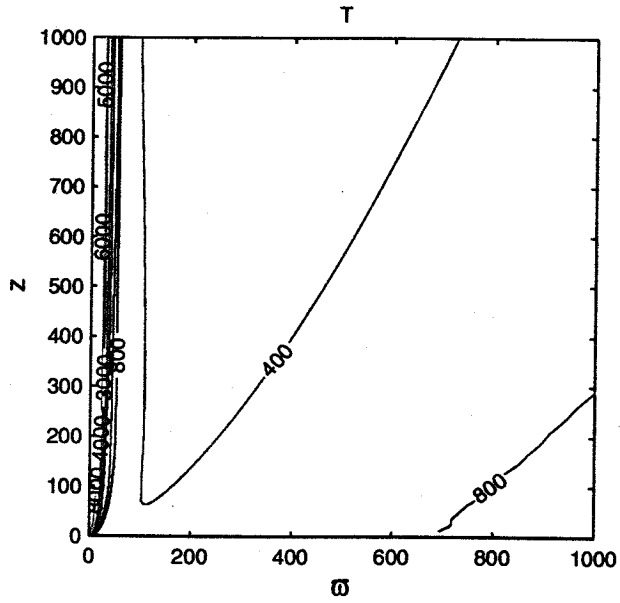
Fig. 4.— OI(63μm) line flux versus mass accretion rate.



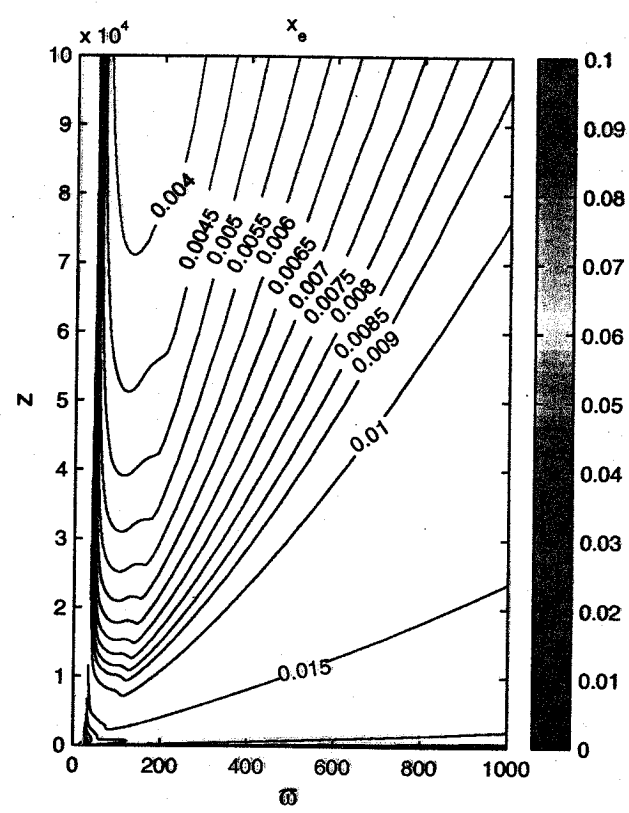
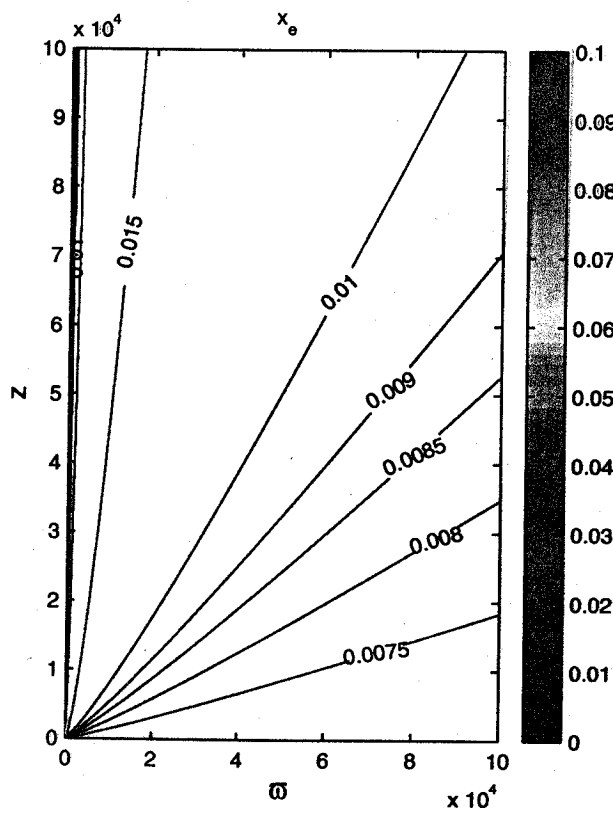
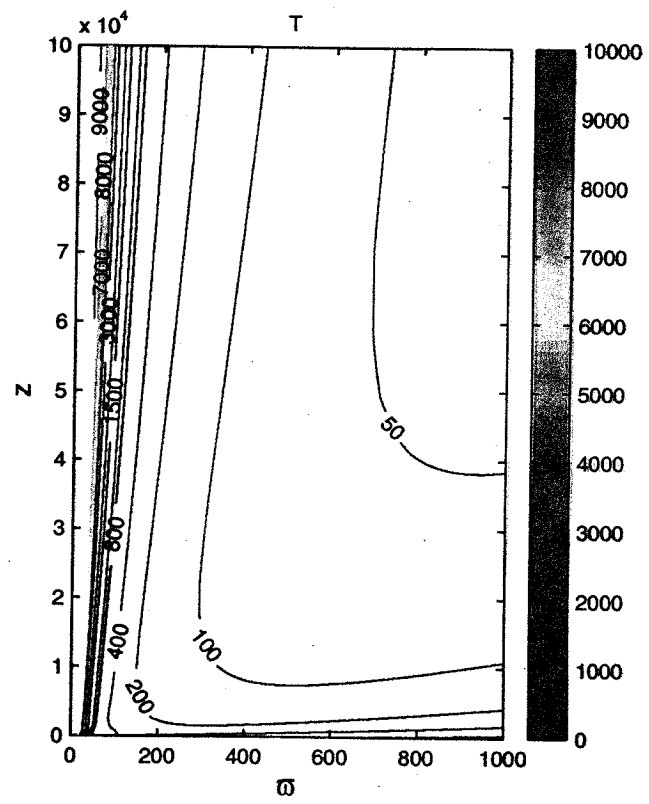
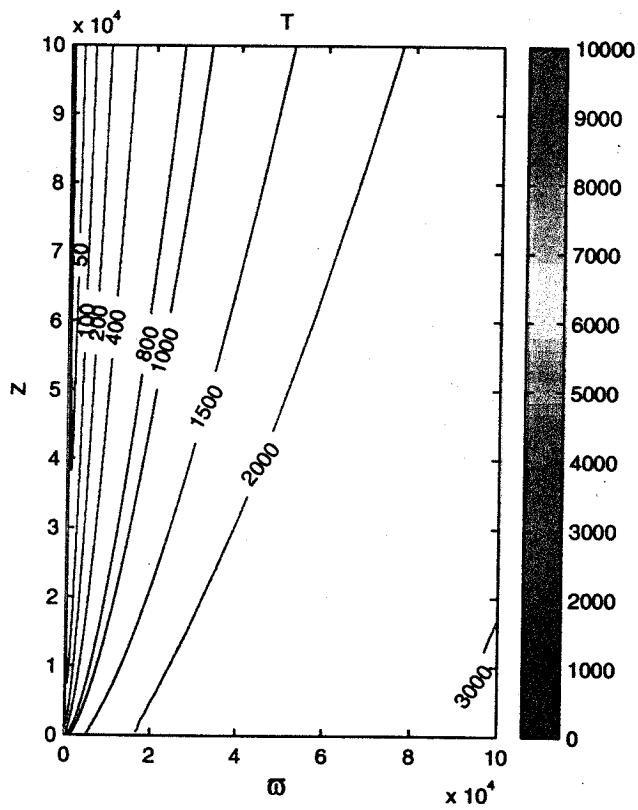
Shu, Najita, Ostriker
Shang + Shu



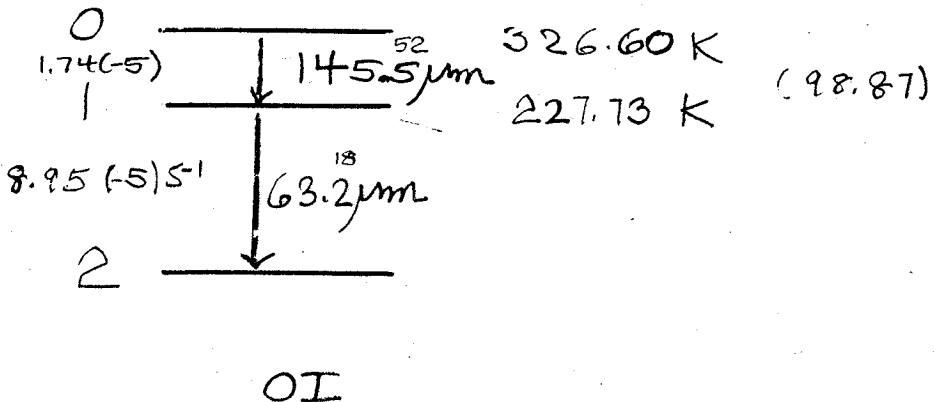
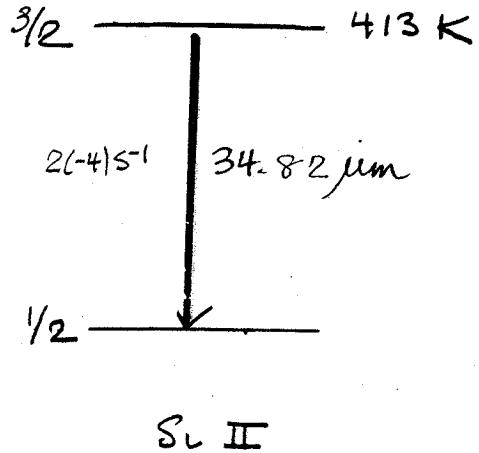
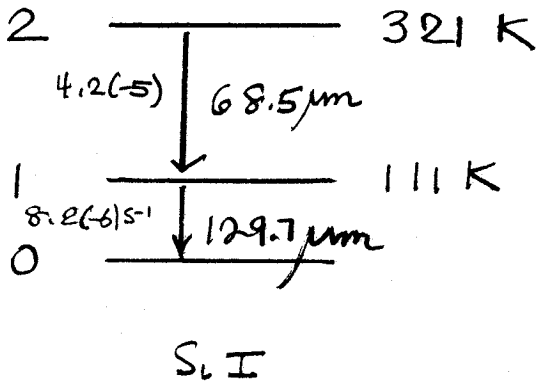
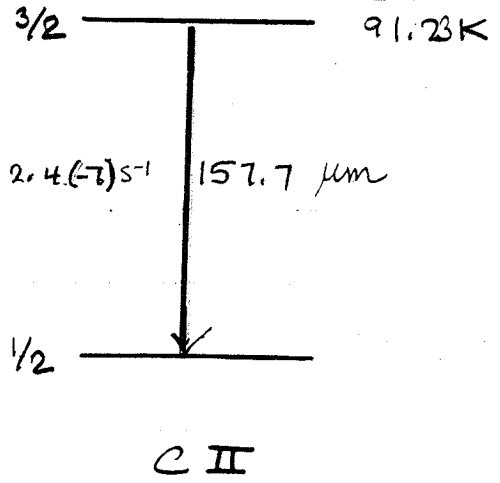
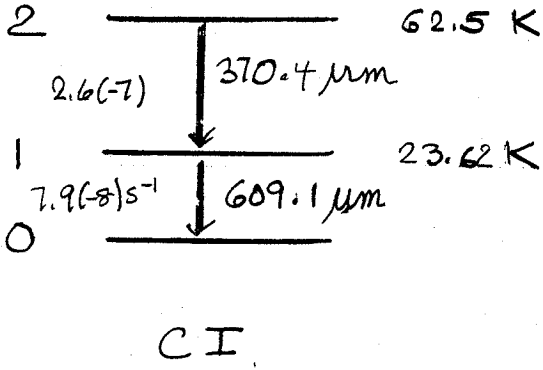
T-Tau
 $3 \times 10^{-8} \text{ uoy}$



T Tauri
 $3 \times 10^8 M_{\odot}$



Carbon, Oxygen, and Silicon Fine Structure

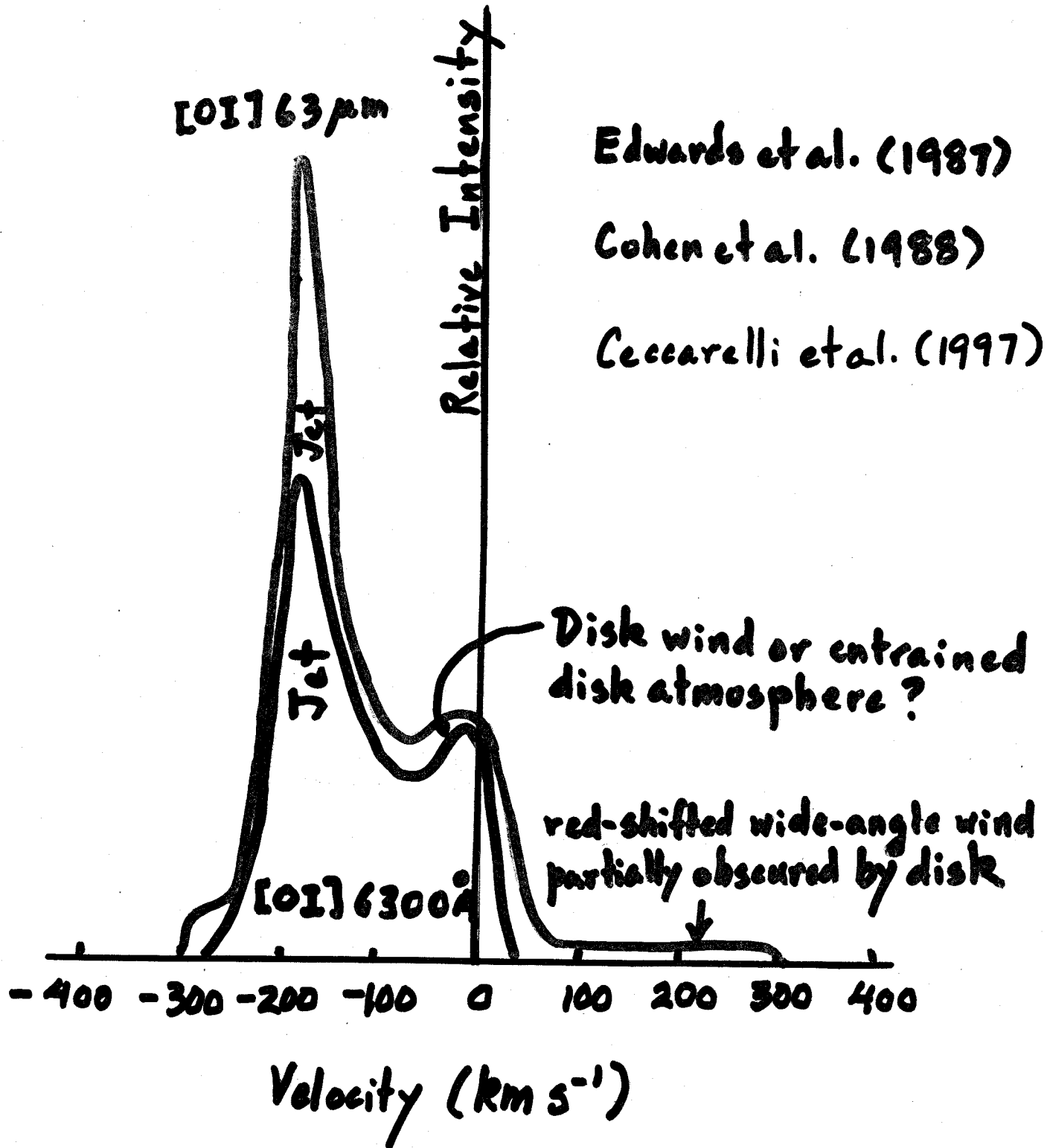


$$\lambda = \frac{c}{\nu} = \frac{c}{\nu_E} = \frac{ch/\nu_E}{T_{MB}} \quad (ch/k_B = 1.43877 \text{ cm K})$$

$$\nu_E = \frac{ch}{\lambda}$$

$$ch = 1.986(-10) \text{ erg cm}$$

What can SOFIA tell us about X-winds?



Expected ratio $\frac{[\text{O I}] 63 \mu\text{m}}{[\text{O I}] 145 \mu\text{m}} \approx 15$ in jet
 > 15 in wide-angle wind

Measurement of ratio yields thermometer of X-wind

Nisini et al.
(1996)

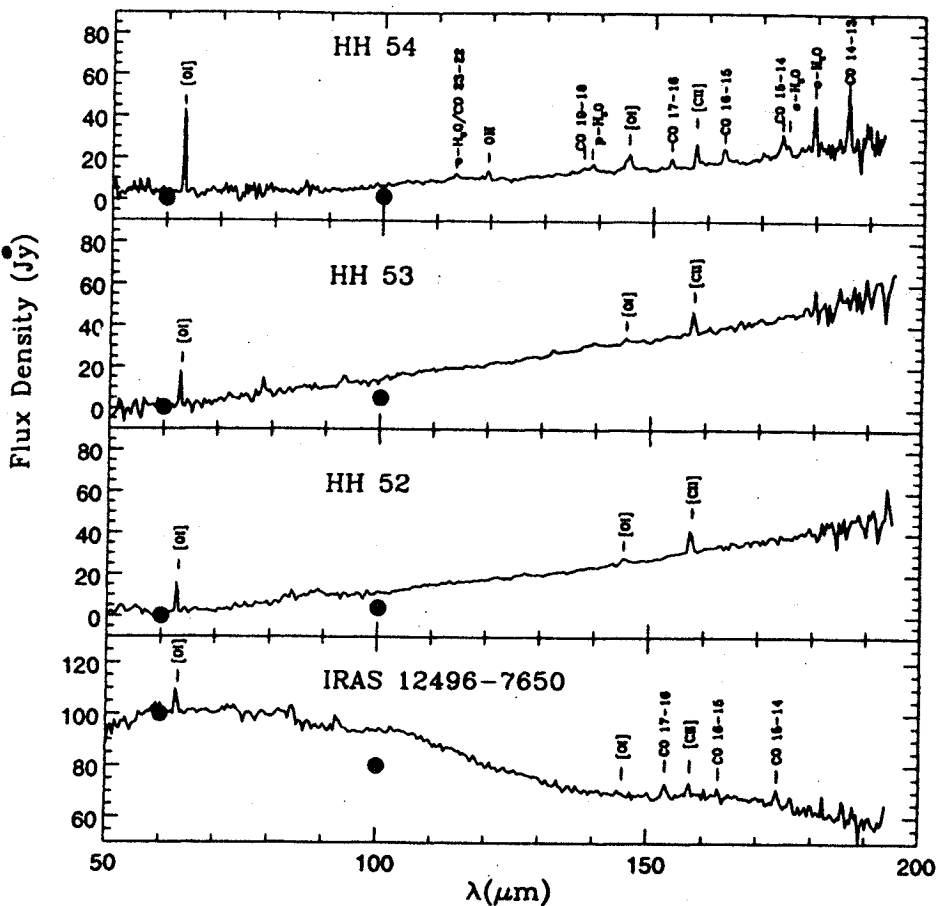


Fig. 1. LWS spectra of HH 54, HH 52, HH 53 and IRAS 12496-7650. The spectra have been rebinned at $\Delta\lambda = 0.4 \mu\text{m}$. Filled dots are the fluxes (ADDSCAN, Cohen & Schwartz, 1987) of the IRAS sources present in the beam: IRAS 12522-7640 in the beam of HH 54 and IRAS 12515-7641 in the beams of HH 52 and 53.

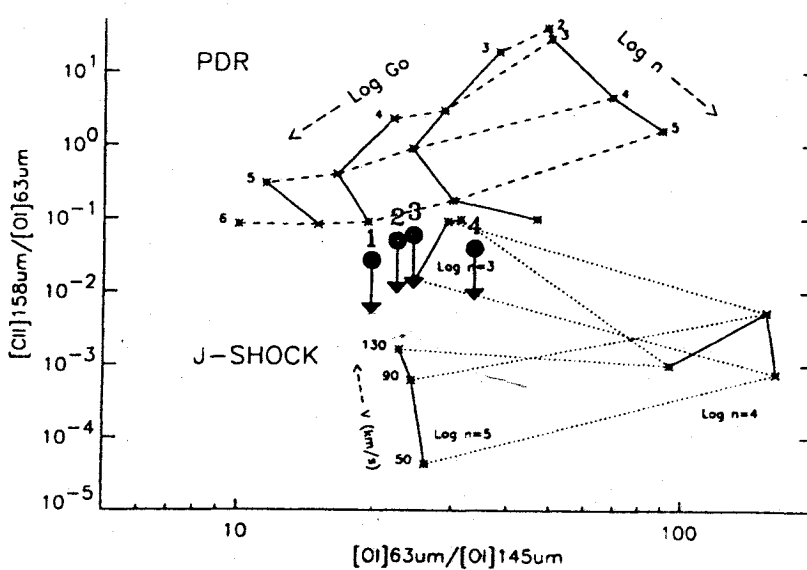


Fig. 2. The $[\text{OI}]63\mu\text{m}/[\text{OI}]145\mu\text{m}$ and $[\text{CII}]158\mu\text{m}/[\text{OI}]63\mu\text{m}$ ratios are plotted as a function of different emitting conditions. For the PDR, we plot the model results by Wolfire et al. (1990), while for J-shock the model of Hollenbach & McKee (1989) is reported. The sources are labelled as (1) for HH54, (2) for HH53, (3) for HH52 and (4) for IRAS 12496