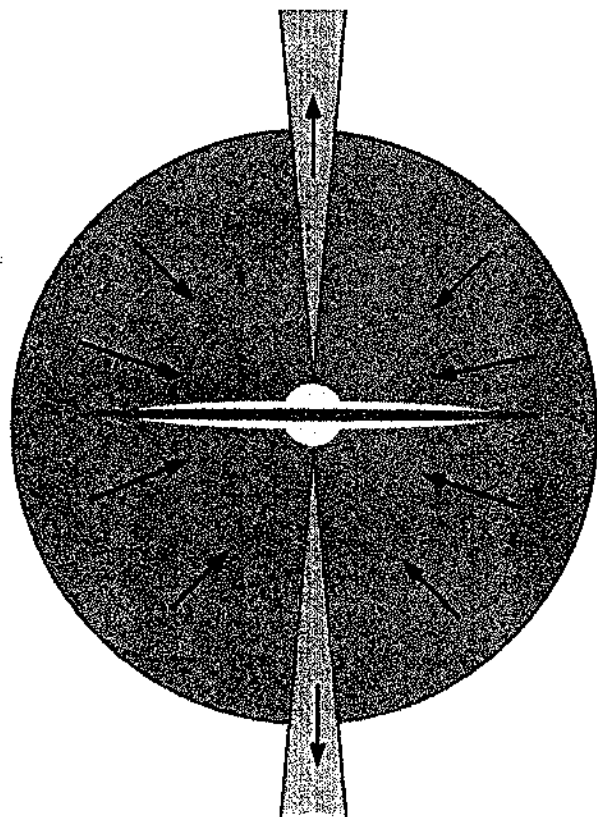


OBSERVING ACCRETION SHOCKS AND INNER COLLAPSE REGIONS WITH SOFIA

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ACCRETION SHOCKS
AND
COLLAPSING ENVELOPES
EMIT MOST OF THEIR ENERGY
AND CAN ONLY BE STUDIED
IN THE FIR TO mm WAVELENGTHS.
THEY ARE THEREFORE "OBVIOUS" TARGETS
FOR SOFIA.

THE COLLAPSING ENVELOPE:

WHAT CHEMICAL AND THERMAL STRUCTURE DO WE EXPECT?

RESULTS FROM THE MODEL BY Ceccarelli, Hollenbach & Tielens (1996) (within the “inside-out” collapse framework)

- CHEMICAL STRUCTURE OF THE MAIN GAS COOLANTS

THE ABUNDANCE OF THE DOMINANT COOLANTS IS PARTICULARLY SIMPLE:

- ALL GAS-PHASE CARBON REMAINS INCORPORATED IN CO.
- GAS-PHASE OXYGEN NOT INCORPORATED IN CO IS MOSTLY IN OI AND O₂ UNTIL THE GAS TEMPERATURE REACHES ~ 250K, WHERE ENDOTHERMIC REACTIONS DRIVE OI AND O₂ INTO H₂O.
- WHEN DUST IS WARMER THAN ~ 100K H₂O ICE EVAPORATES FROM THE GRAINS AND INJECTS ALL OF THE ICE MANTLE INTO THE GAS PHASE.

- THERMAL STRUCTURE:

$r \leq 200\text{AU}$: THE GAS IS HEATED BY THE H₂O ABSORPTION OF NIR PHOTONS FROM WARM DUST LOCATED CLOSER TO THE PROTOSTAR, AND COOLED MAINLY BY H₂O ROTATIONAL EMISSION.

$200 \leq r \leq 800\text{AU}$: THE GAS IS HEATED BY COMPRESSIONAL HEATING AND COOLED BY [OI]63 μm AND CO ROTATIONAL LINES.

$r \geq 800\text{AU}$: THE GAS IS HEATED BY COLLISIONS WITH WARMER DUST AND COOLED BY CO ROTATIONAL LINES.

THEORETICAL CHEMICAL STRUCTURE OF THE INFALLING ENVELOPE

No. 1, 1996

PROTOSTELLAR ENVELOPE FIR LINE EMISSION

407

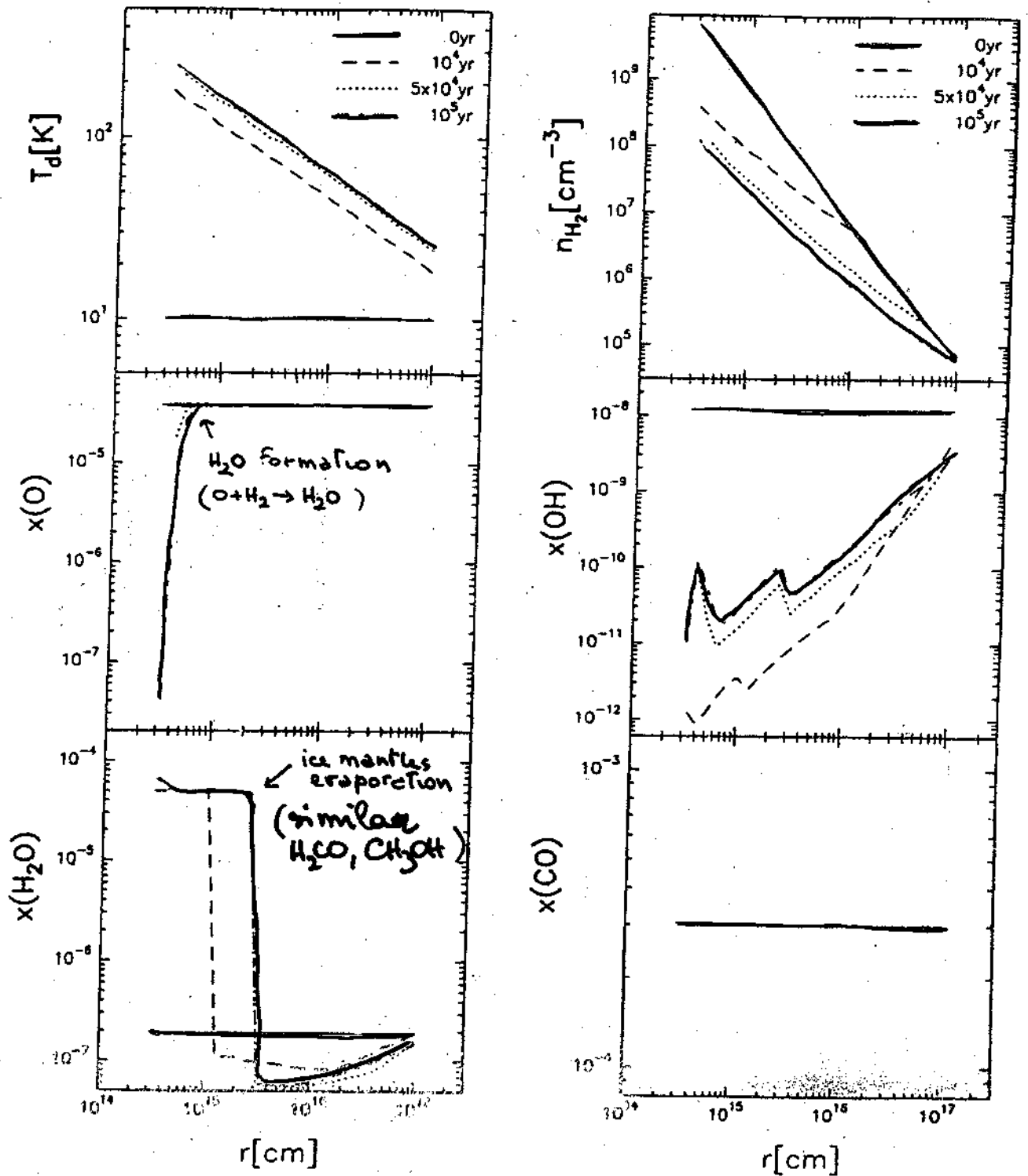
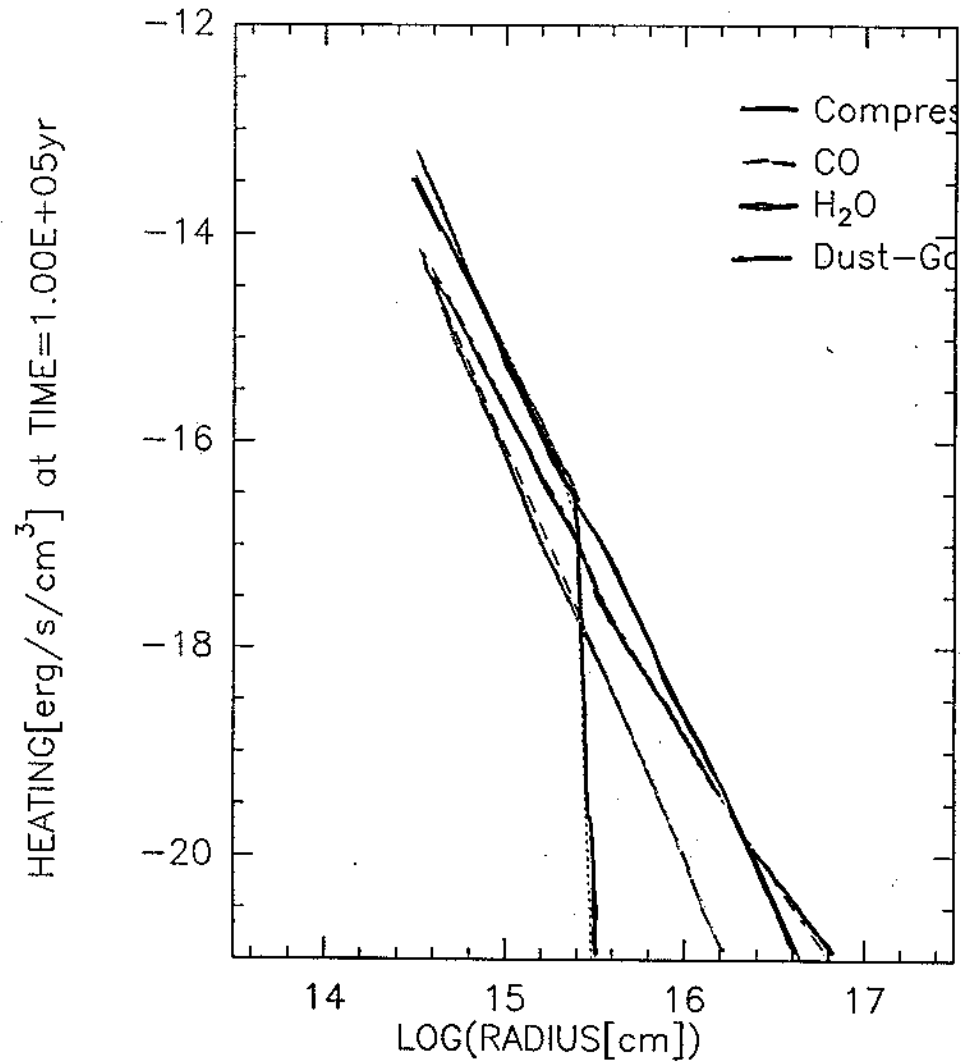
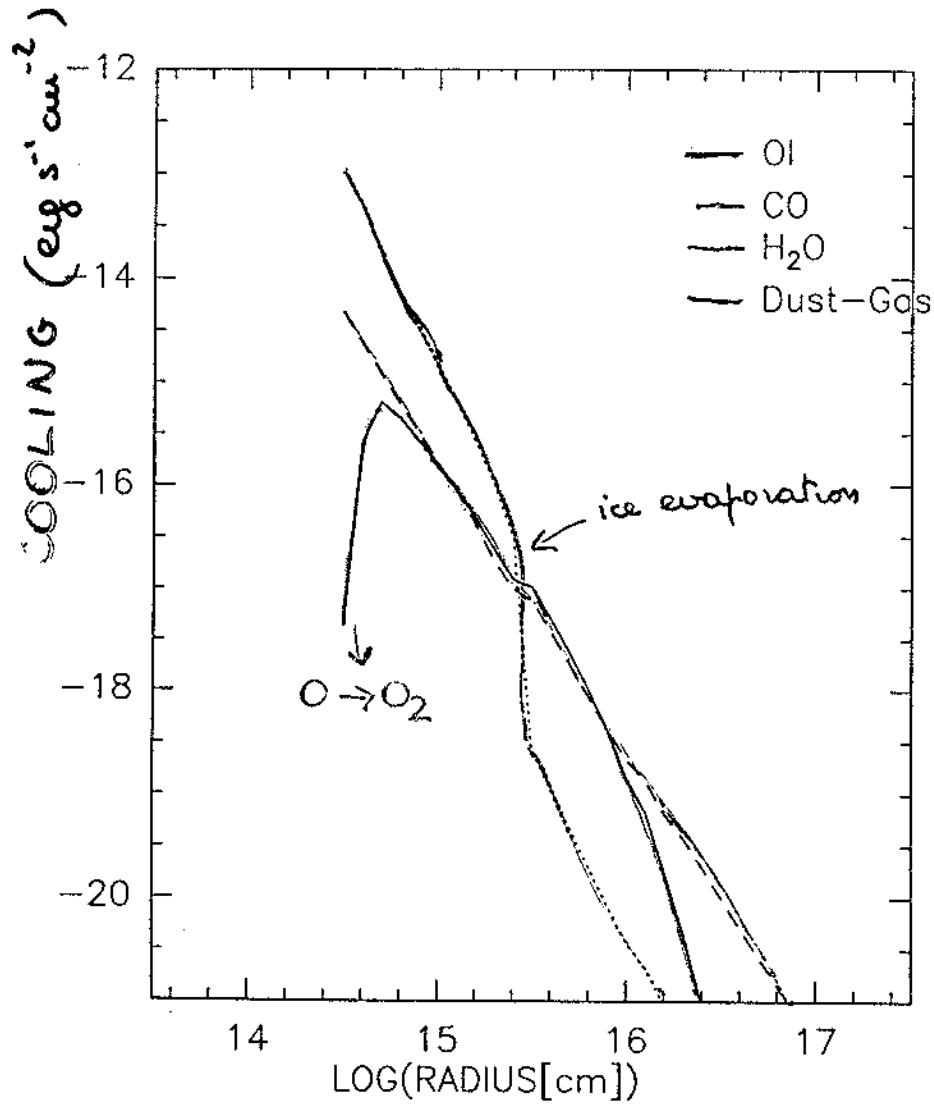


FIG. 2a

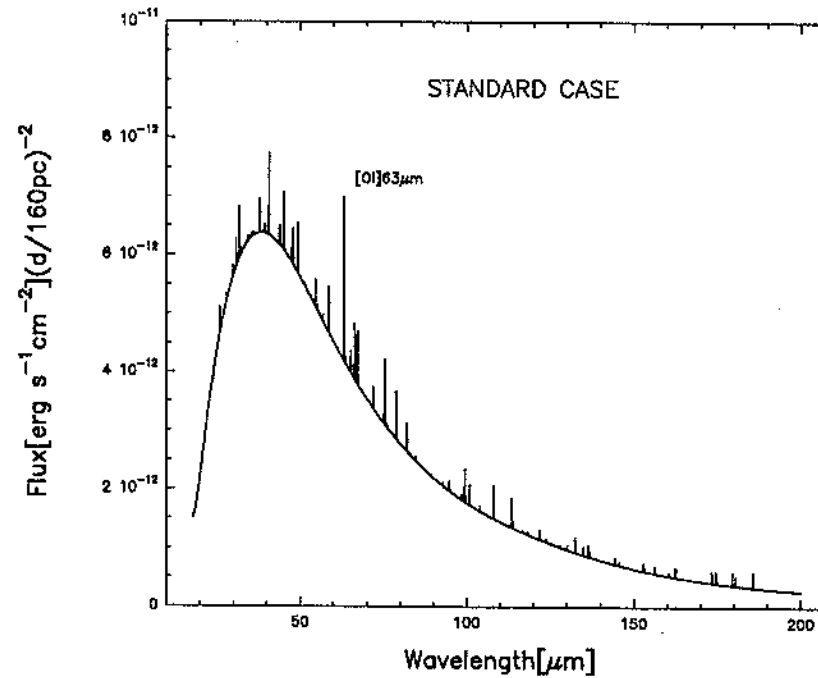
FIG. 2.—The dust temperature, H₂ density profile, and fractional abundances of species with respect to H nuclei for a protostar accreting at $10^{-5} M_{\odot} \text{ yr}^{-1}$ (after Shu 1977 and Adams & Shu 1985) at the start of the collapse (solid line) and at 10^4 yr (dashed line), 5×10^4 yr (dotted line), and 10^5 yr (dash-dotted line) from the start of the collapse.

STANDARD MODEL: THERMAL STRUCTURE

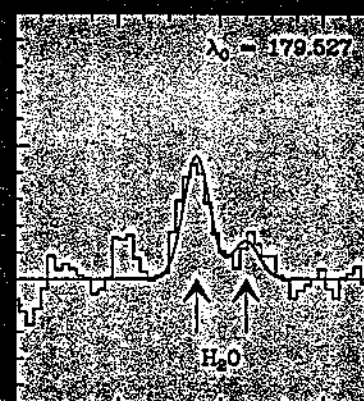
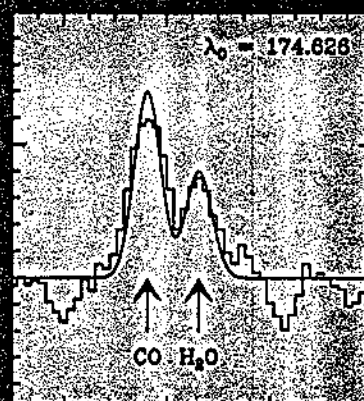
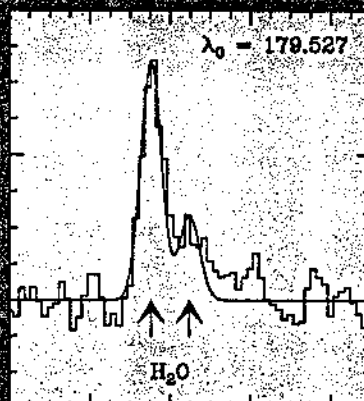
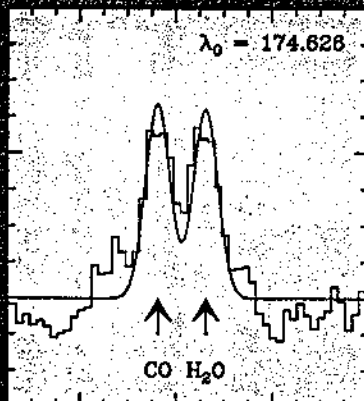
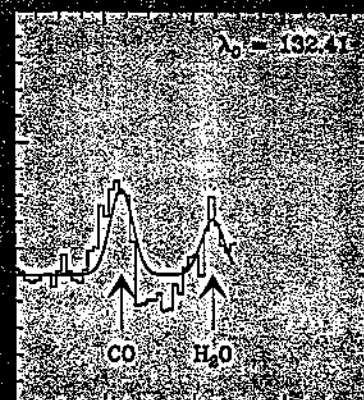
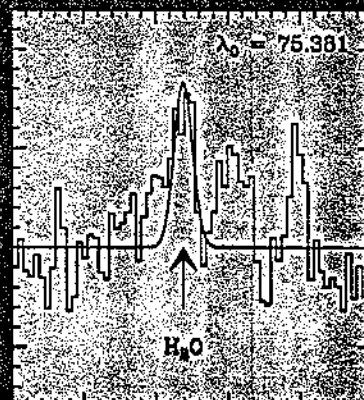
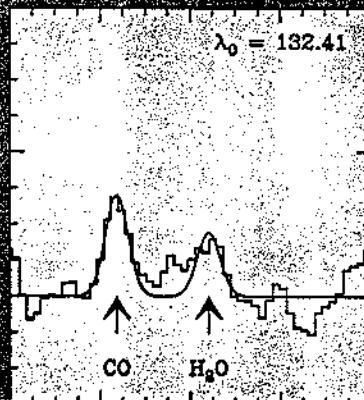
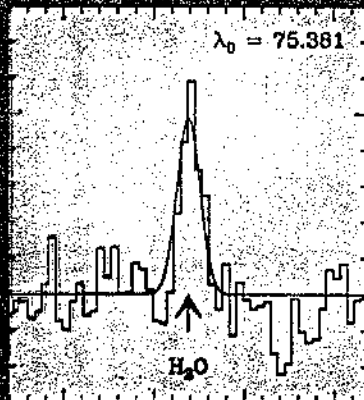
$L^*=65.1L_{\odot}$, $M^*=1.00M_{\odot}$, Run1



THE COLLAPSING ENVELOPE: THE EXPECTED LINE+DUST SPECTRUM OF A COLLAPSING ENVELOPE



...ANY OBSERVATION SUPPORTING THE CASE ?...



Water Nitric Oxide

Guarelli et al 1959 A8
 342, L2

INTERPRETING THE OBSERVED WATER+OI LINES
 AS DUE TO THE COLLAPSING ENVELOPE:
 IRAS16293-2422, a $27L_{\odot}$ source at 160pc in ρ Oph

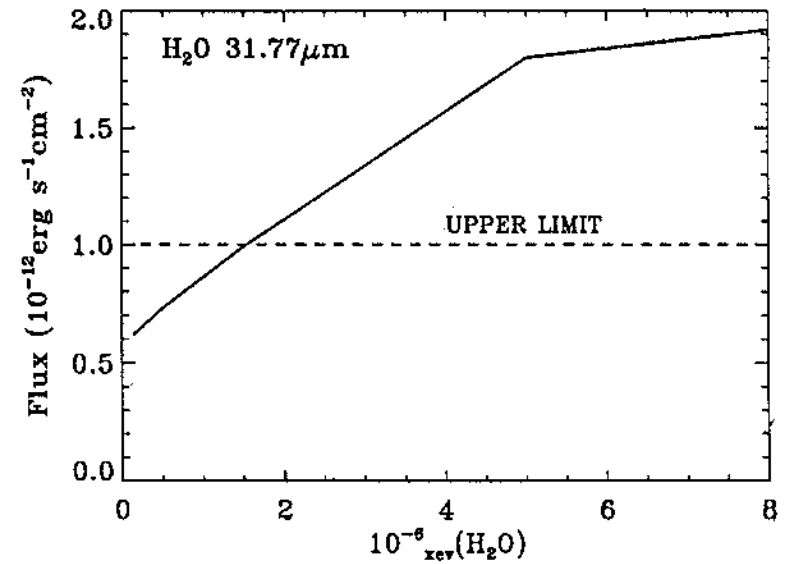
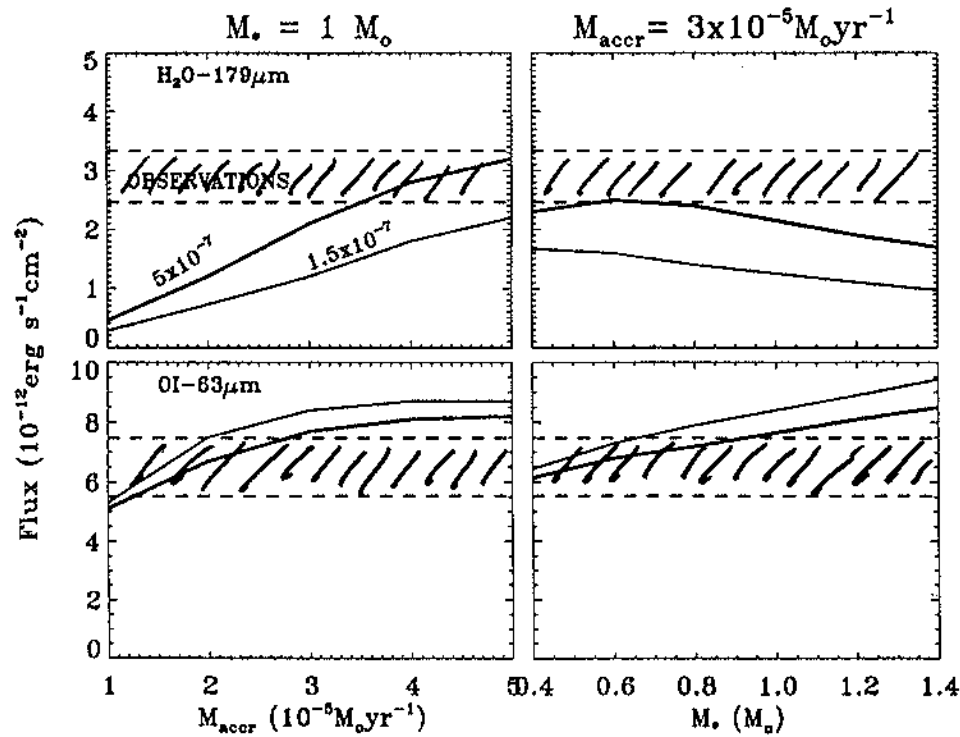
THE MODEL PARAMETERS:

QUANTITY	VALUE	NOTE
OI / H	2.5×10^{-4}	FROM [OI]-63 and $145 \mu m$ OBSERVATIONS in Caux et al. 1999 A&A Letter poster by Ceccarelli et al.
CO / H	1×10^{-5}	
H ₂ O / H	$1.5 - 5 \times 10^{-7}$	
H ₂ O ICE / H	FREE PARAMETER	
CENTRAL MASS	FREE PARAMETER	
MASS ACCRETION RATE	FREE PARAMETER	

CONSTRAINING THE MODEL FREE PARAMETERS:

MASS ACCRETION RATE,
CENTRAL MASS
H₂O ABUNDANCE

H₂O ICE ABUNDANCE



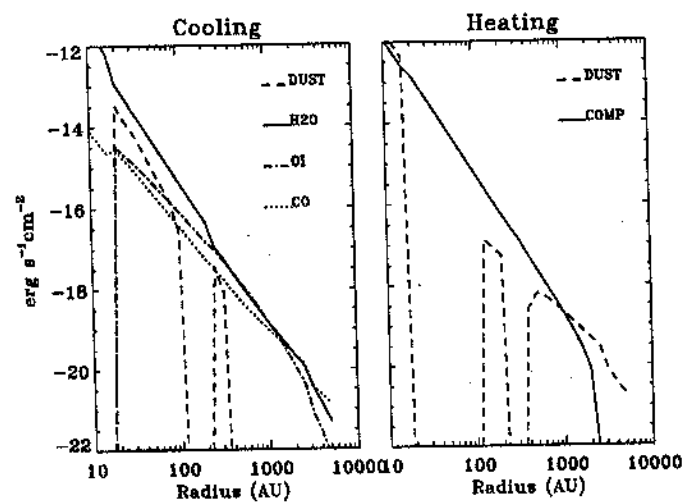
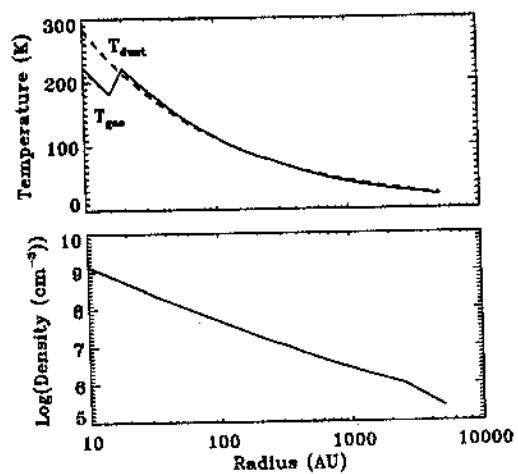
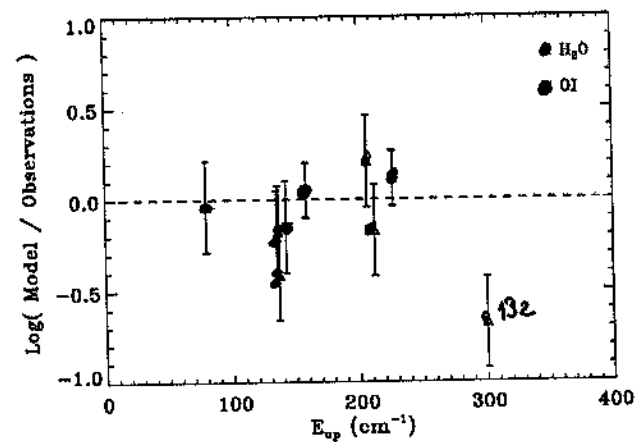
THE BEST FIT MODEL:

$$M_{\star} = 0.8 M_{\odot}$$

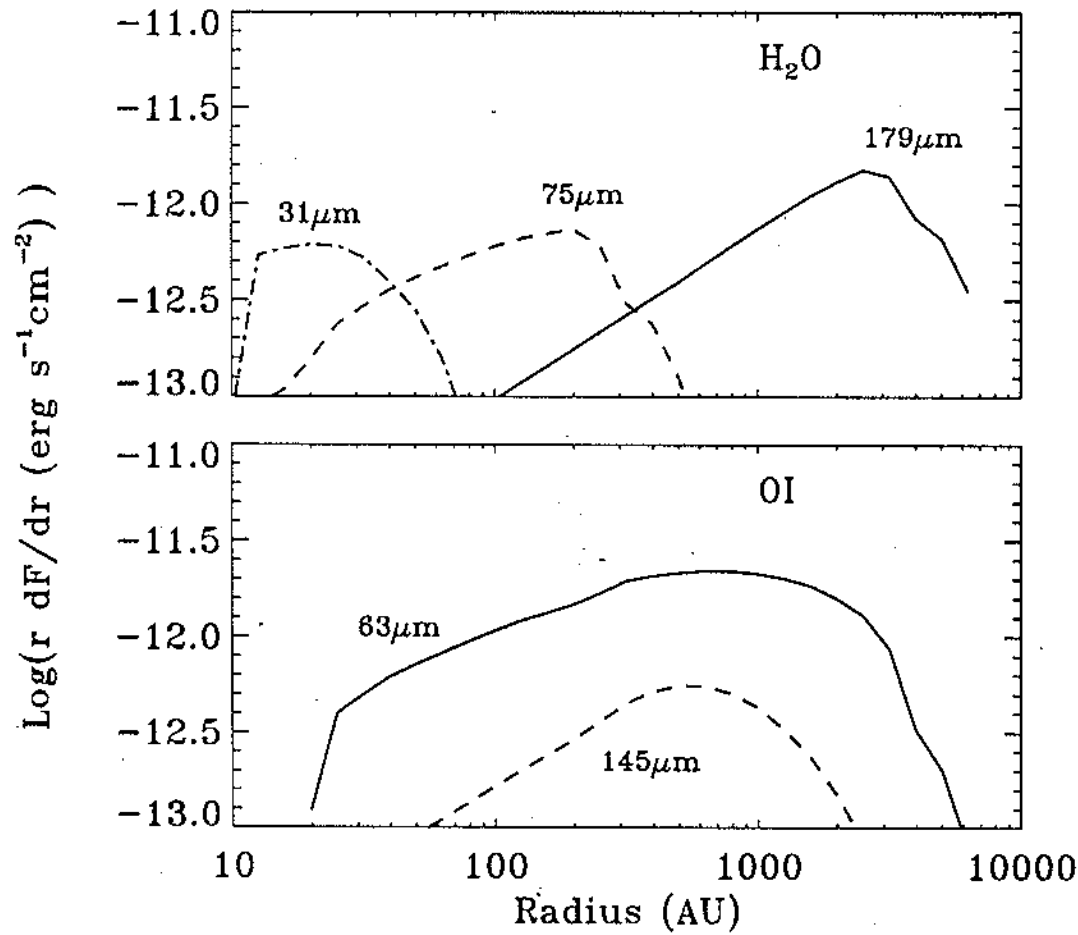
$$\dot{M} = 3.5 \times 10^{-5} M_{\odot} \text{ yr}^{-1}$$

$$\text{H}_2\text{O} / \text{H} = 5 \times 10^{-7}$$

$$\text{H}_2\text{O ICE} / \text{H} = 1.5 \times 10^{-6}$$



THE BEST FIT MODEL:



WHY SOFIA ?

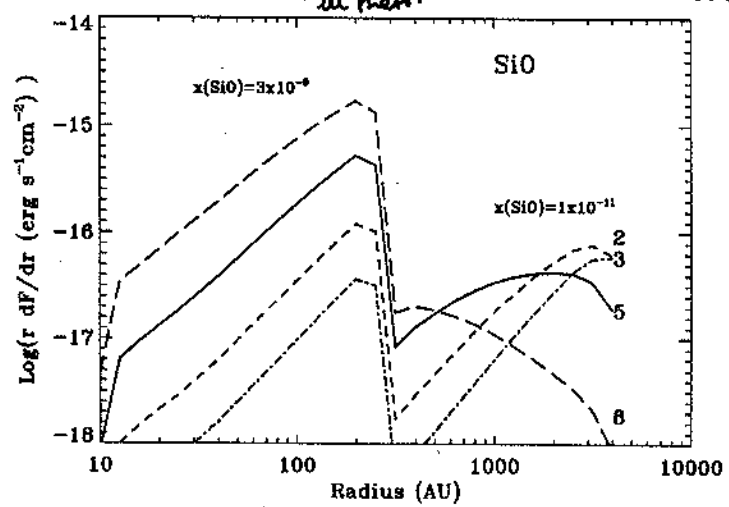
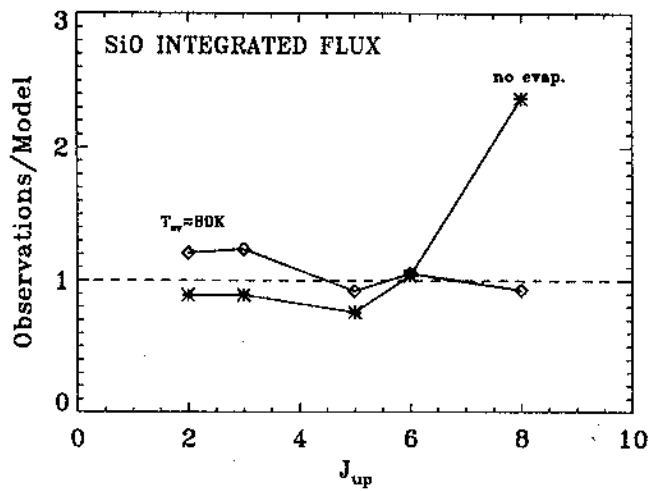
A- WE NEED HIGHER SPATIAL AND SPECTRAL OBSERVATIONS:

- GREAT WILL RESOLVE SPECTRALLY THE [OI]-145 μ m LINE *and 63 μ m ?*
- AIRES & FIFILS WITH A BEAM $\sim 8'' \rightarrow r \sim 1400$ AU *H₂¹⁸O ?*
- WILL RESOLVE SPATIALLY THE [OI]-63 μ m LINE EMISSION
- CASIMIR \rightarrow H₂¹⁸O LINES ?

B- MANY OTHER MOLECULAR LINES CAN BE USED TO TRACE THE INNER COLLAPSE REGIONS.

- EXPECTED ABUNDANT/OBSERVABLE MOLECULES IN THE SOFIA RANGE INCLUDE H₂, HD, OH, H₂S, H₃O⁺, NH₃
- THE SiO EXAMPLE: (Observations obtained with IRAM, SEST, JCMT)

Accardi et al. Van Dishoeck et al 1995 in Mem.

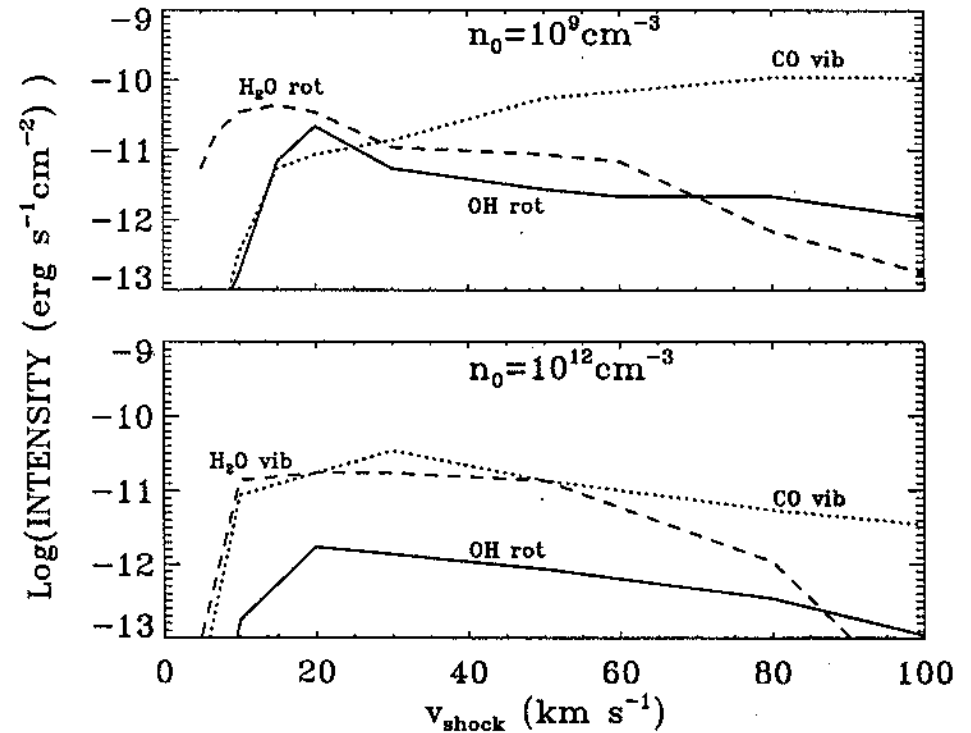
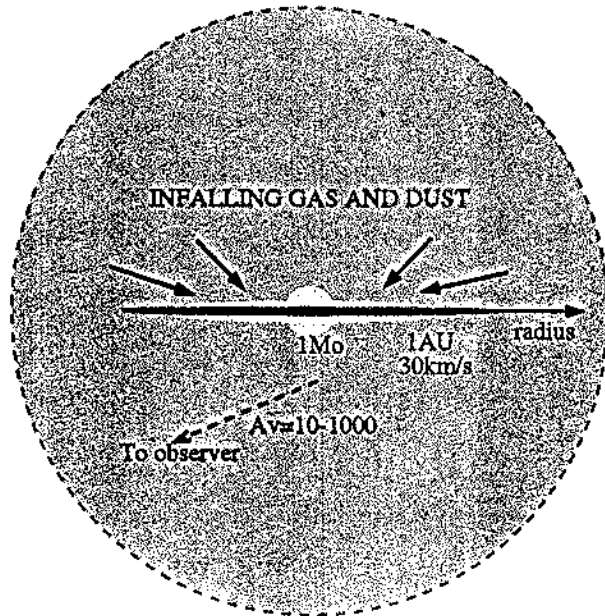


THE ACCRETION SHOCK:

WHAT DO WE EXPECT ?

RESULTS FROM THE MODEL BY Neufeld & Hollenbach (1994)

$$L_{shock} \sim 5.5 \times 10^{-11} \left(\frac{\dot{M}}{10^5 M_{\odot} \text{yr}^{-1}} \right) \left(\frac{v_{shock}}{10 \text{ km s}^{-1}} \right)^2 \left(\frac{\text{dist}}{160 \text{ pc}} \right)^{-2} \text{ erg s}^{-1} \text{ cm}^{-2}$$



WHY SOFIA ?

OH WILL BE A GOOD DIAGNOSTIC TO OBSERVE THE ACCRETION SHOCKS
AS WE DO NOT EXPECT STRONG OH EMISSION
FROM THE INNER COLLAPSE REGIONS

...HOWEVER SINCE OH LINES ARE WEAK WITH RESPECT TO THE
UNDERLYING CONTINUUM

WE NEED HIGH SPATIAL AND SPECTRAL OBSERVATIONS

- GREAT WILL RESOLVE SPECTRALLY THE OH 163, 119, 99, 84 μm LINES
- AIRES & FIFILS MAY RESOLVE SPECTRALLY THE HIGHER LYING OH LINES, E.G. THE 65, 56, 53 AND 46 μm LINES