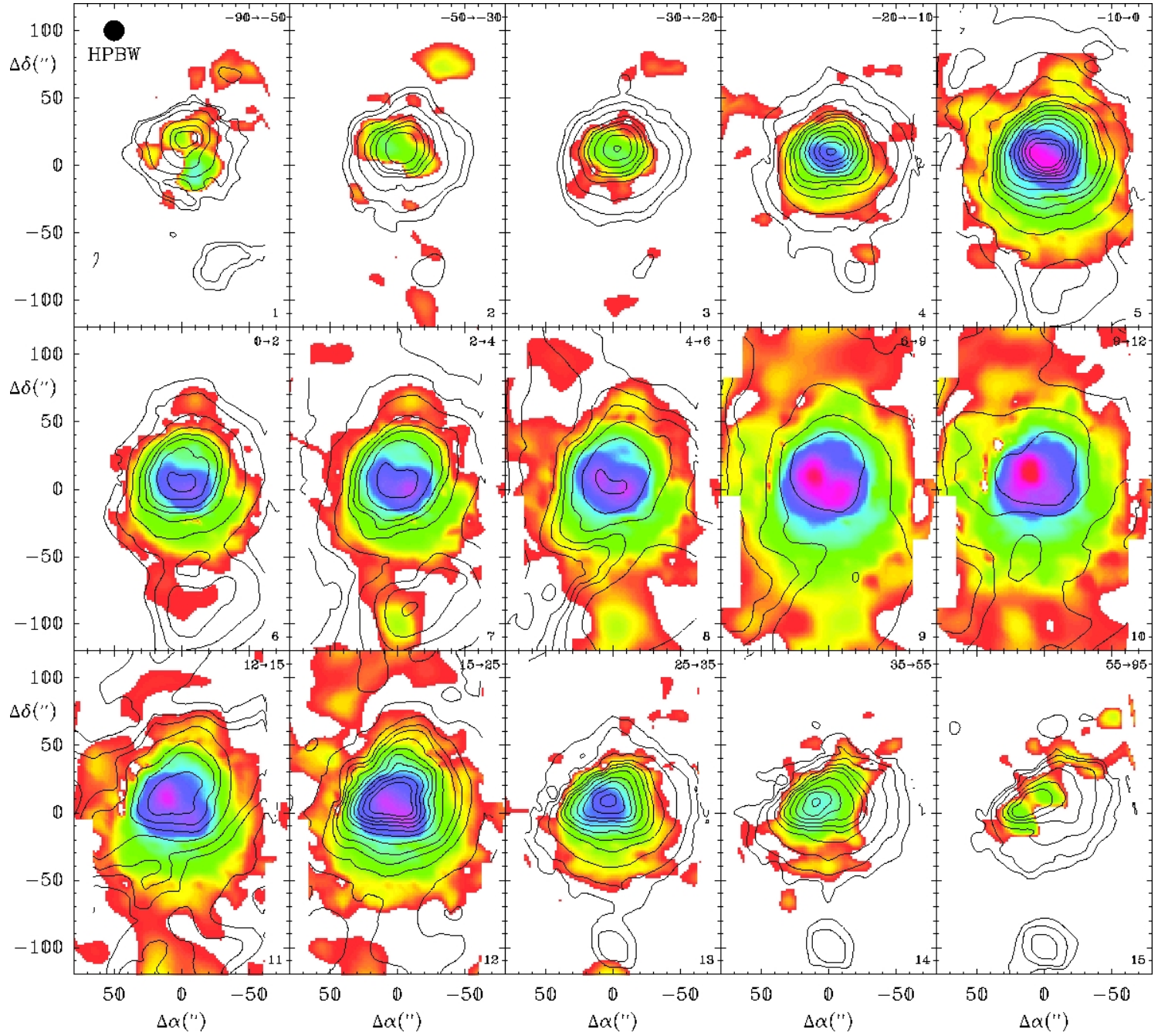
Water in Space as seen by ISO

José Cernicharo
DAMIR
Instituto de Estructura de la Materia
CSIC
cerni@damir.iem.csic.es

The Quest for H_2O

- **Detected in 1969 by Cheung et al through the maser emission at 22 GHz of the 6_{16}-5_{23} transition (Eupp=609 K, Aij=1.9 10-9)**
- **Observed in small regions with peculiar physical conditions (shocks)**
- **Earth atmosphere blocks almost all millimeter and submillimeter lines of water**
- **Most interesting lines in the far infrared and in the mid-infrared (bending mode). High Aij's, high energy levels, high frequencies**

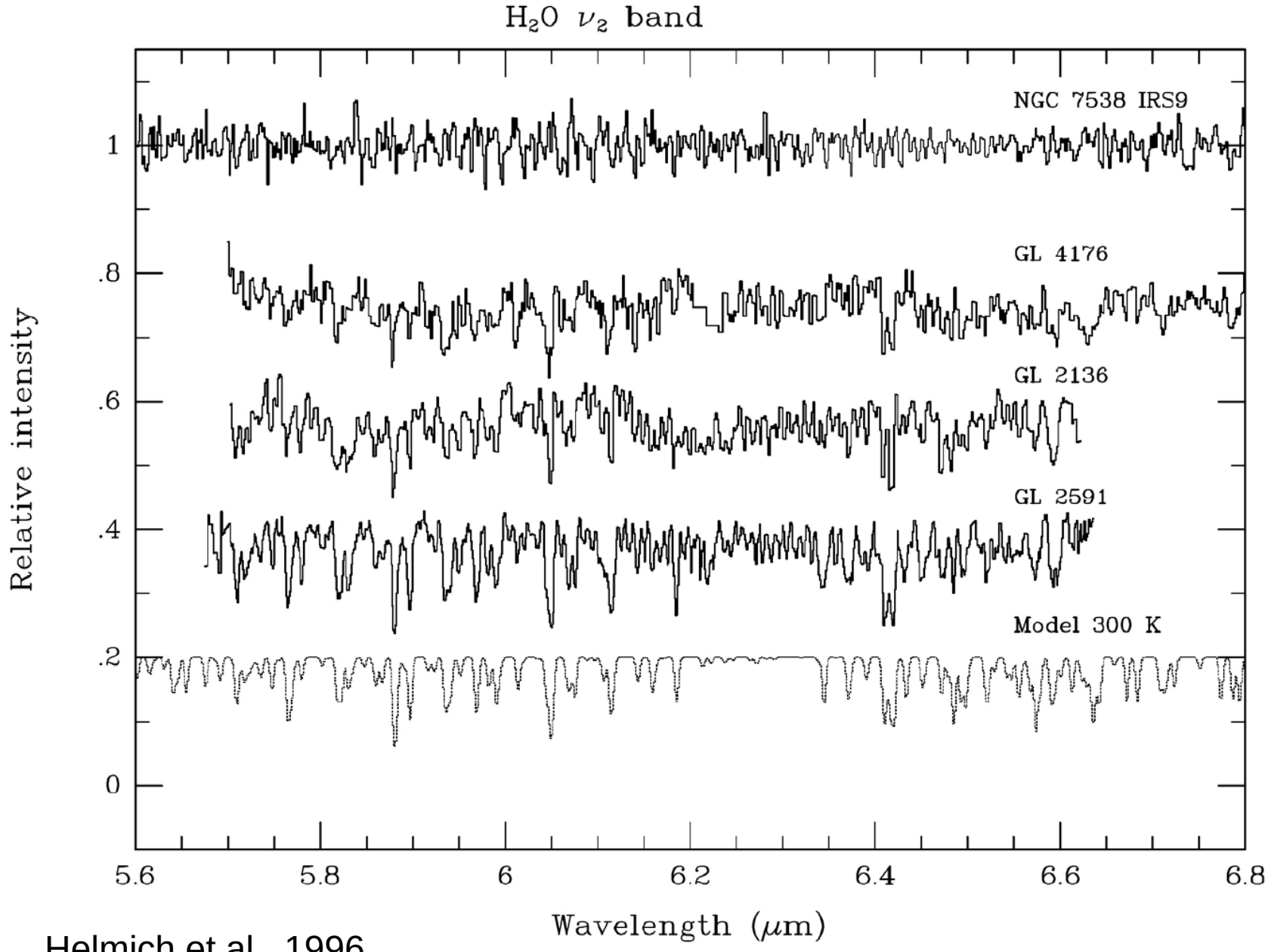
Water in Orion observed with the 30-m telescope (beam 14”). Cernicharo et al., 1994



ISO capacities for the observation of water

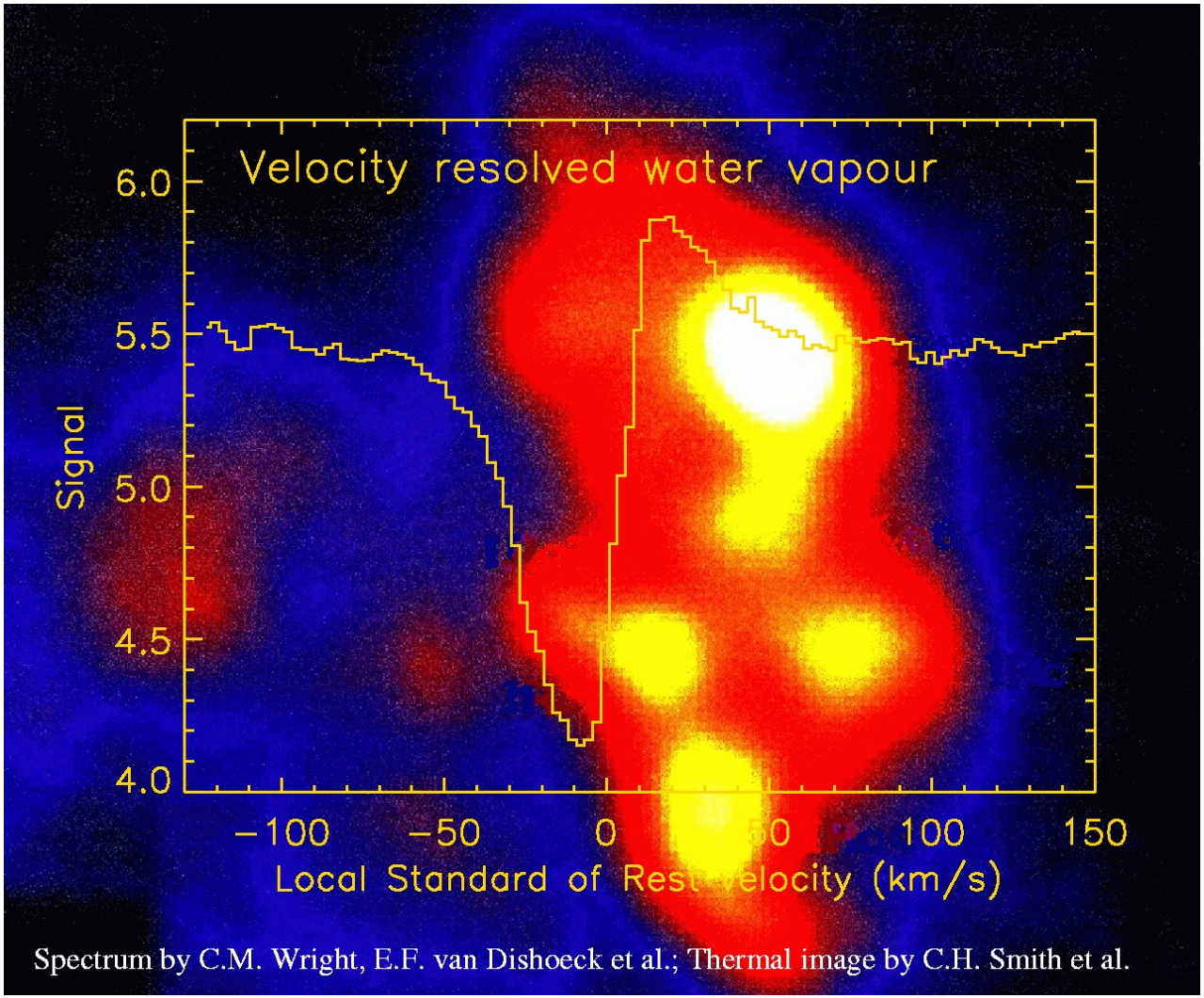
- SWS : high excitation pure rotational lines and the ro-vibrational lines of the stretching and bending modes
- LWS : pure rotational lines
- ISOCAM and LWS : Water Ice
- Main goal in the GT and the open time for many observers

WATER IN WARM REGIONS AROUND HIGH MASS STARS

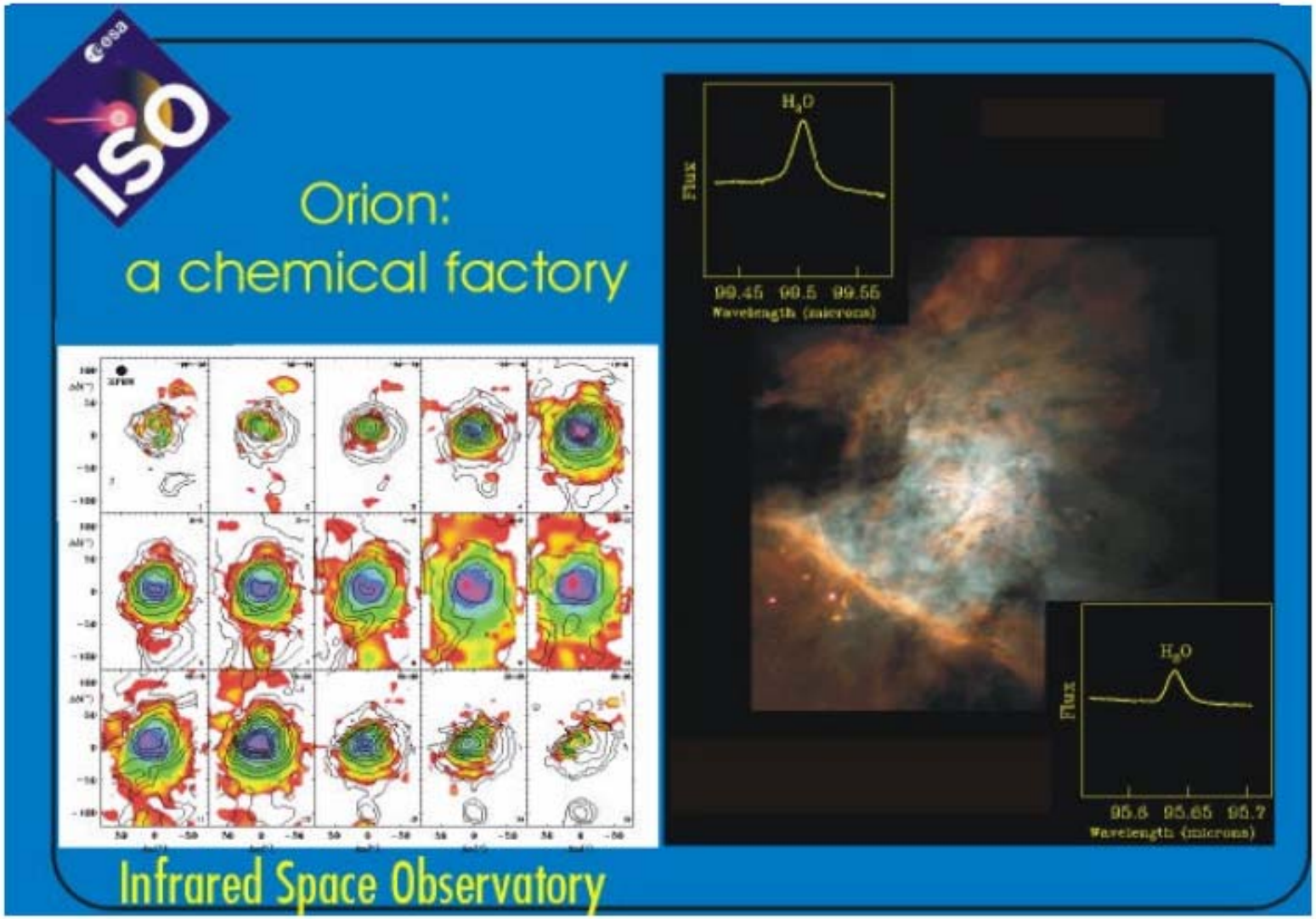


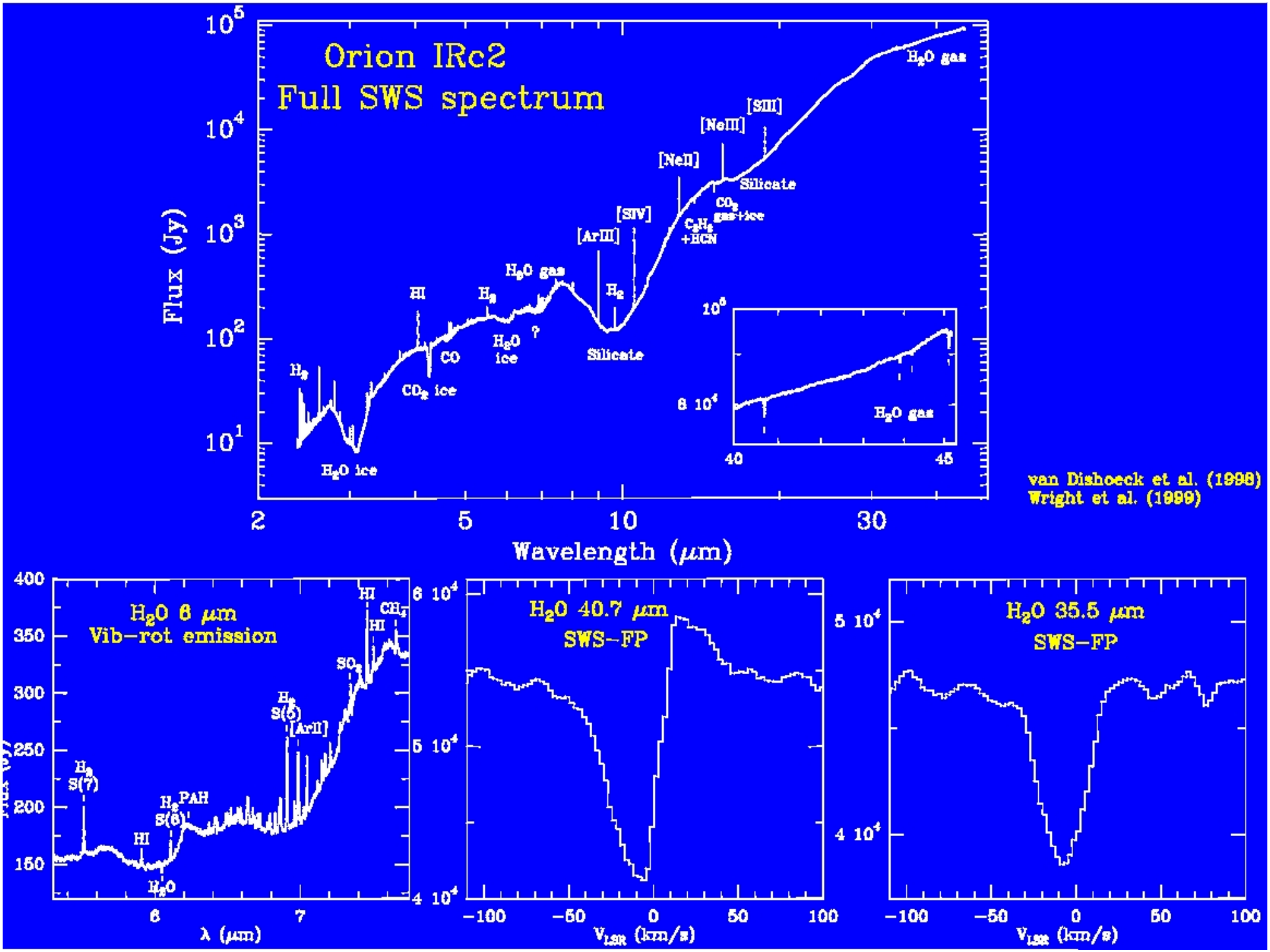
Helmich et al., 1996

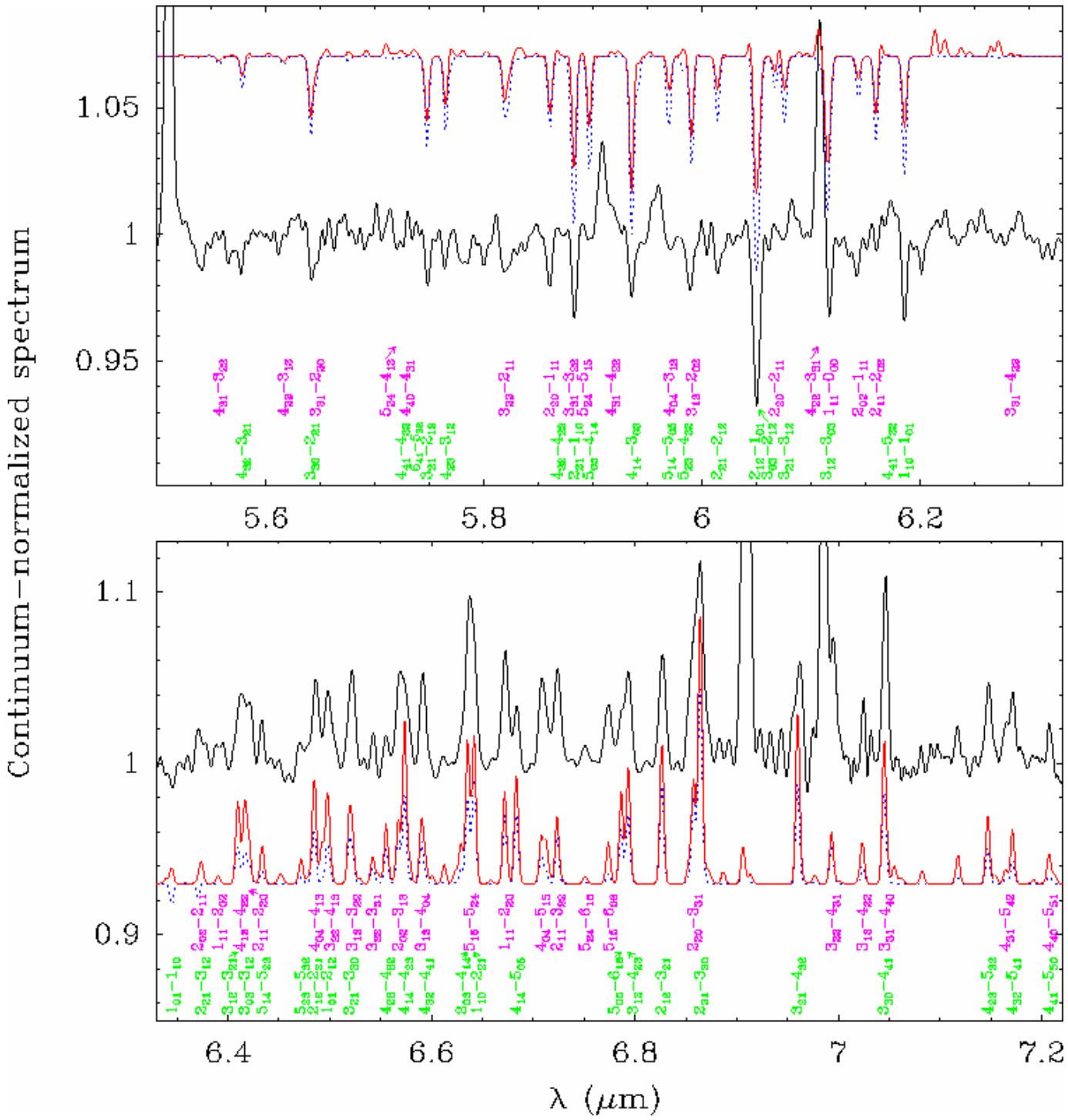
Water in High Mass Star Forming Regions



Water, water everywhere !



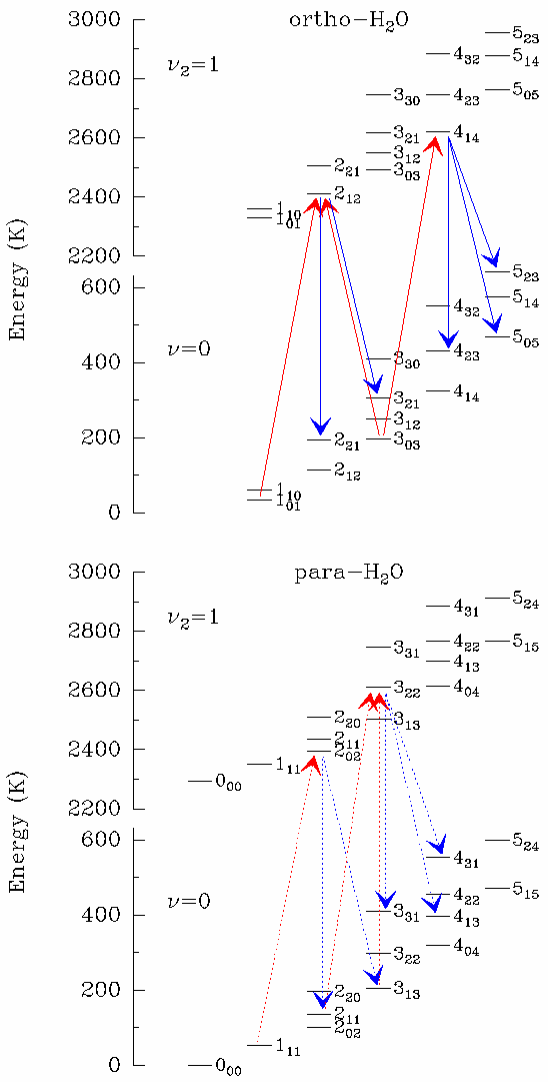

Orion IRc2
Full SWS spectrum
Flux (Jy)
Wavelength (μm)
H2O ice
H2
HI
CO2 ice
CO
H2O ice
H2O gas
?
H2
[ArIII]
[SIV]
Silicate
C2H2 +HCN
CO2 gas+ice
[NeII]
[NeIII]
[SIII]
Silicate
H2O gas
H2O gas
van Dishoeck et al. (1998)
Wright et al. (1999)
H2O 6 μm
Vib−rot emission
H2 S(7)
HI
H2O
H2 S(6)
PAH
H2 S(5)
[ArII]
SO2
HI
HI
CH4
λ (μm)
H2O 40.7 μm
SWS−FP
VLSR (km/s)
H2O 35.5 μm
SWS−FP
VLSR (km/s)

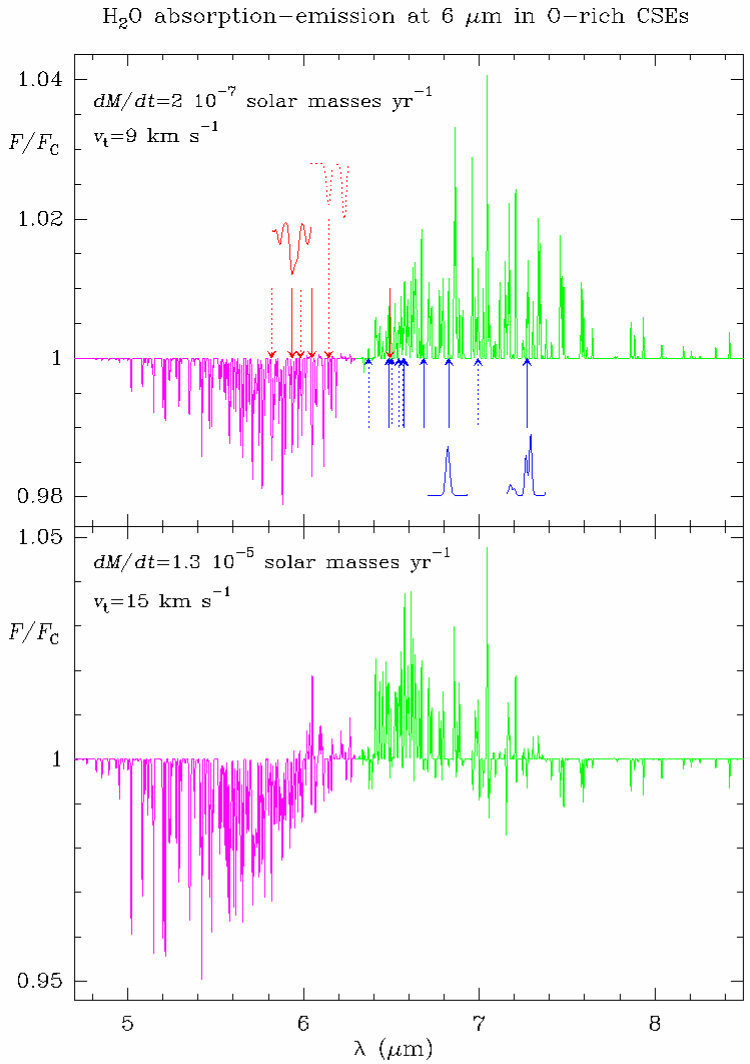


The pumping of H_2O is strongly affected by the dust grains absorption/ emission.

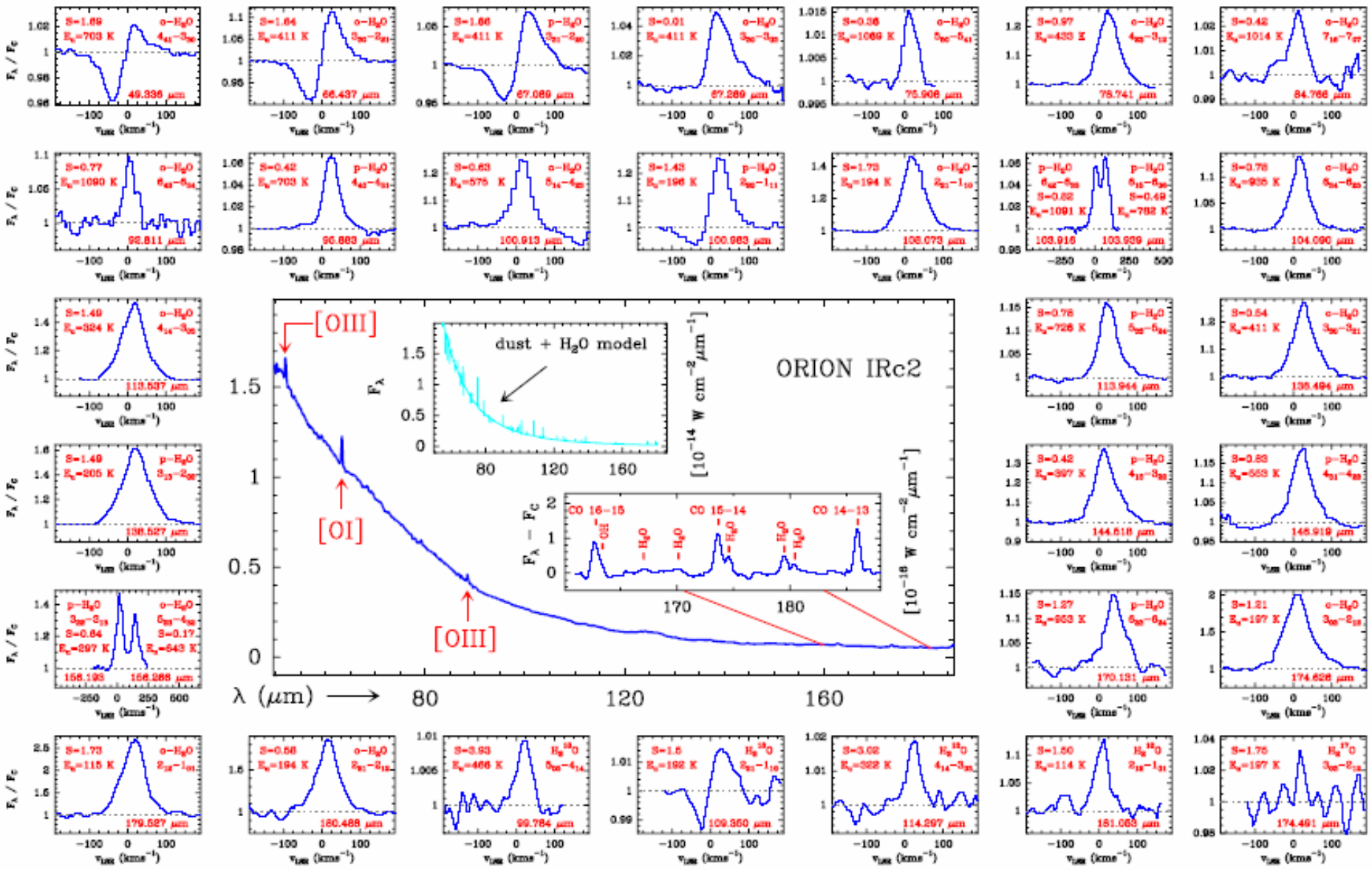
Radiative transfer models have to include these effects as they become crucial as soon as the dust opacity is ≈ 1.

González-Alfonso et. al. 1998, ApJ Letters, 502,L169





González-Alfonso et al., 1999



Cernicharo et al., 2006

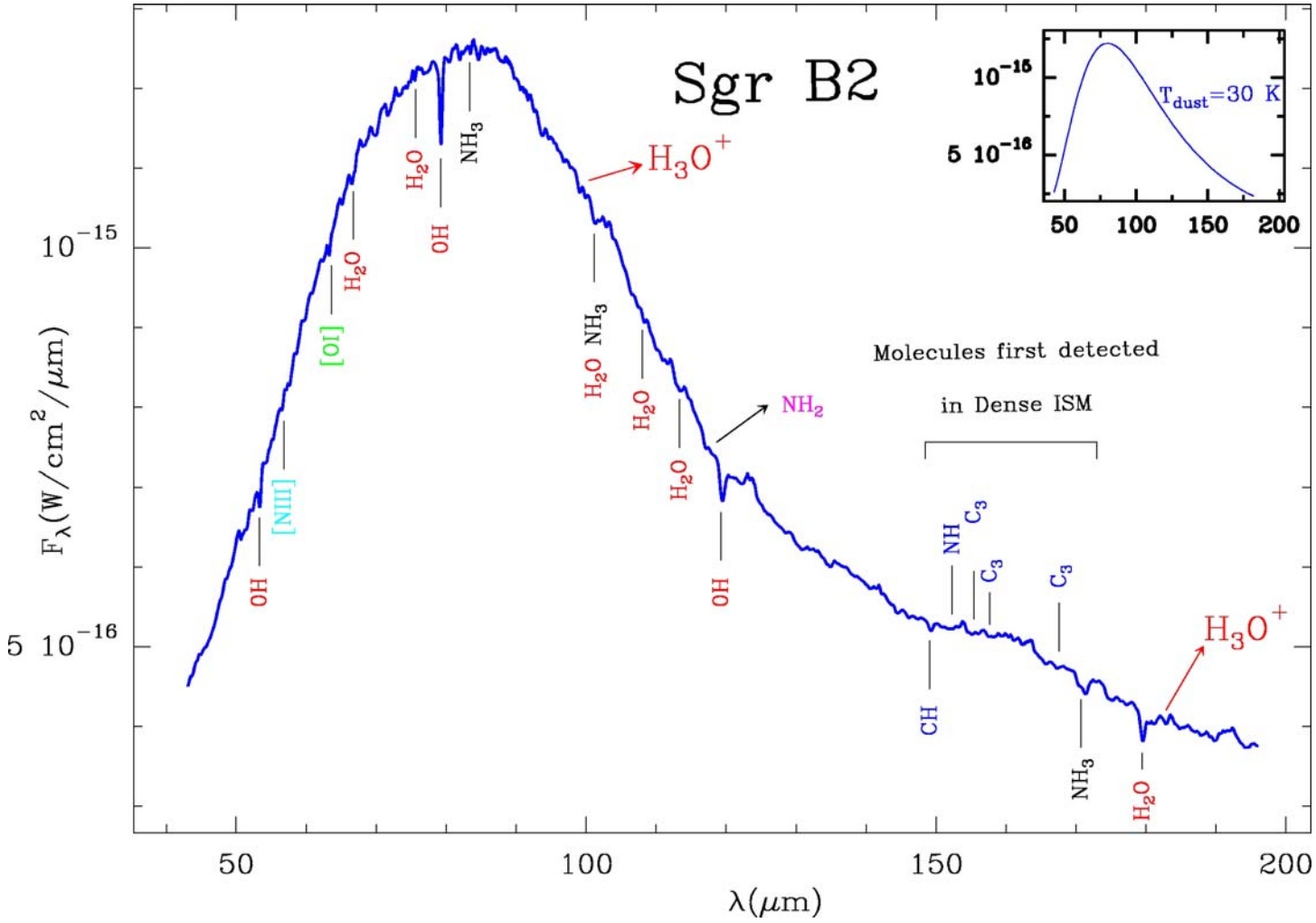
Astron. Astrophys. 323, L25–L28 (1997)

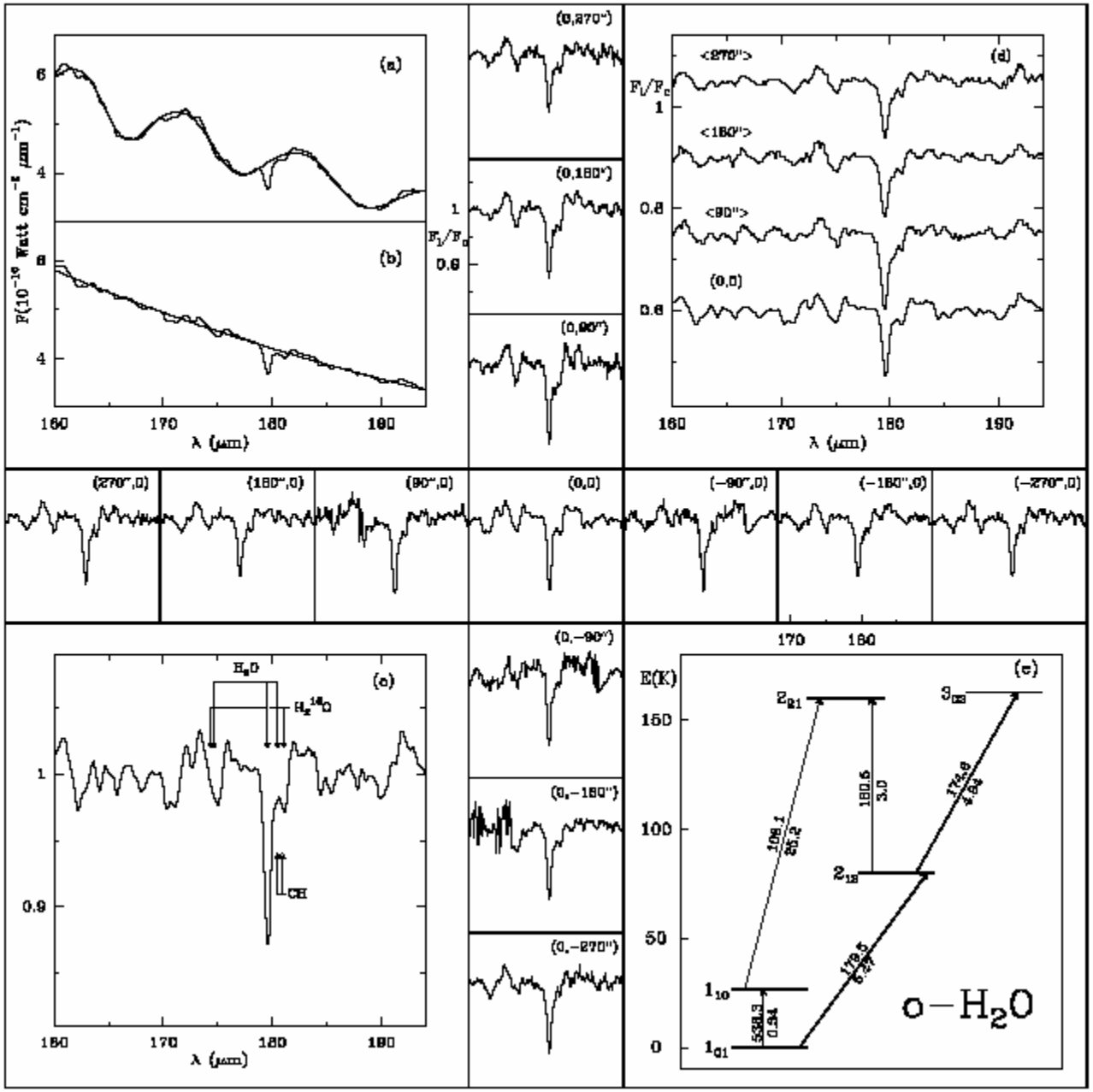
ASTRONOMY
AND
ASTROPHYSICS

Letter to the Editor

Widespread water vapour absorption in SgrB2[1]

J. Cernicharo[1], T. Lim[2], P. Cox[3], E. González-Alfonso[4,5], E. Caux[6], B.M. Swinyard[7], J. Martín-Pintado[5], J.P. Baluteau[8], and P. Clegg[9]




(a)
(b)
(c)
(d)
(0,270")
(0,180")
(0,90")
(0,0)
(0,-90")
(0,-180")
(0,-270")
(270",0)
(180",0)
(90",0)
(-90",0)
(-180",0)
(-270",0)
<270">
<180">
<90">
F(10^-16 Watt cm^-2 μm^-1)
F_l/F_c
λ (μm)
H2O
H2 18O
CH
E(K)
2_21
3_03
2_12
1_10
1_01
o−H2O
538.3
0.34
179.5
6.47
180.5
3.0
174.6
4.84
196.1
25.2

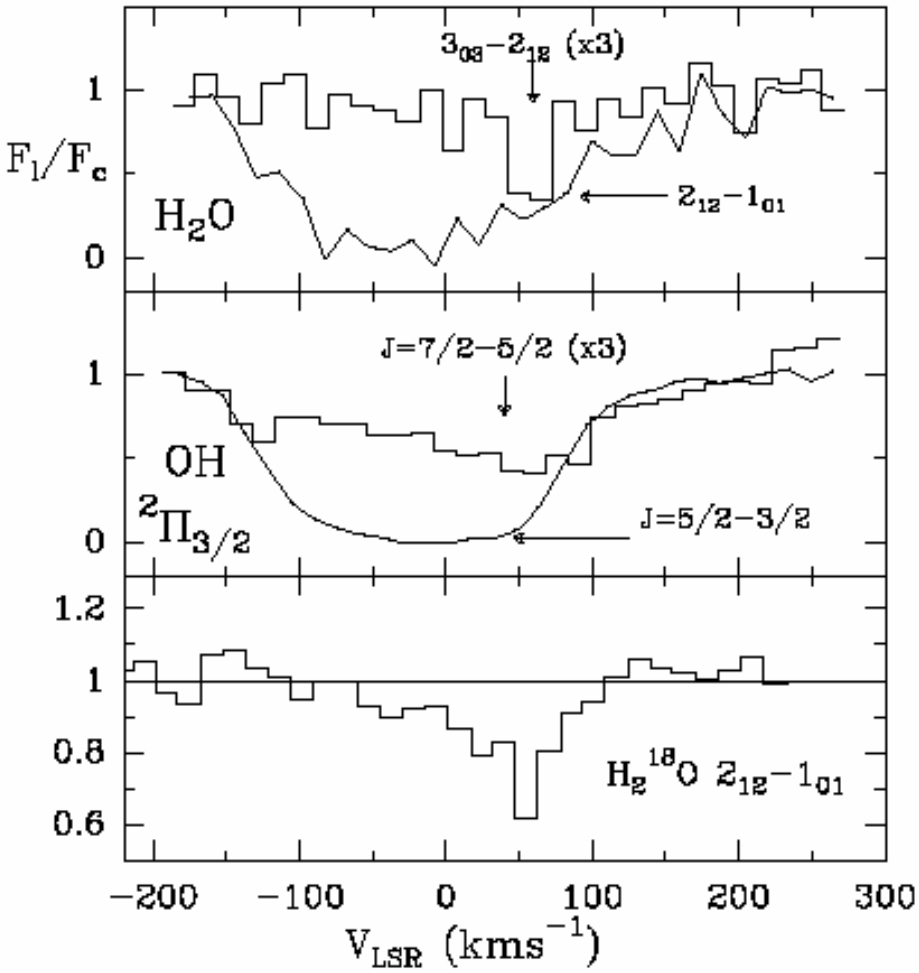


Fig. 2. LWS Fabry-Perot observations of the central position of SgrB2. (a) The 2_{12}-1_{01} and 3_{03}-2_{12} lines of water at 179.52 and 174.6 μm, respectively; (b) the 5/2-3/2 and 7/2-3/2 lines of the $^2\Pi_{3/2}$ state of OH at 119 and 84 μm; (c) the 2_{12}-1_{01} $H_2{}^{18}O$ line at 181.05 μm

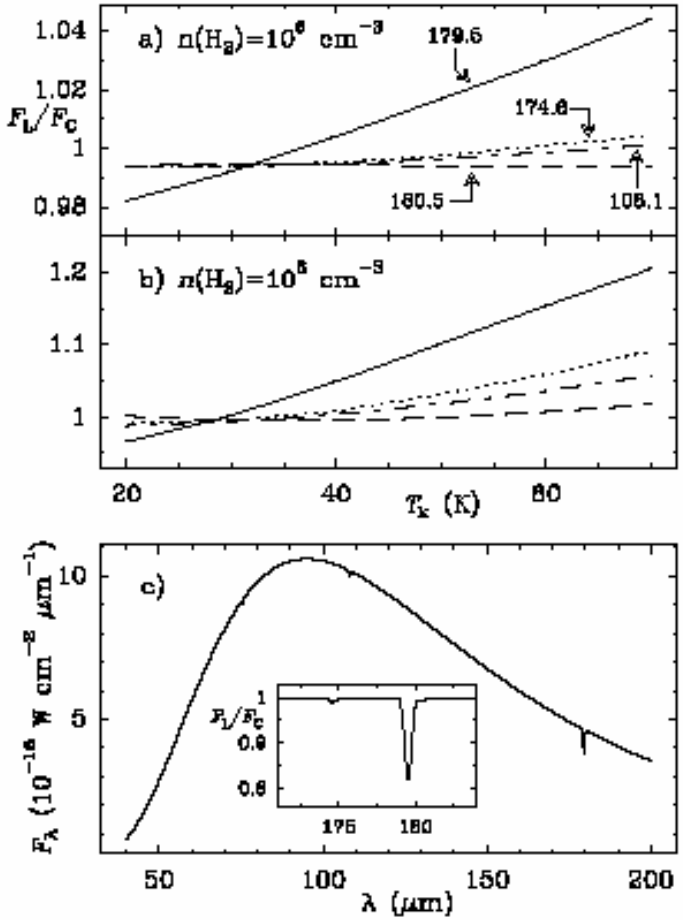
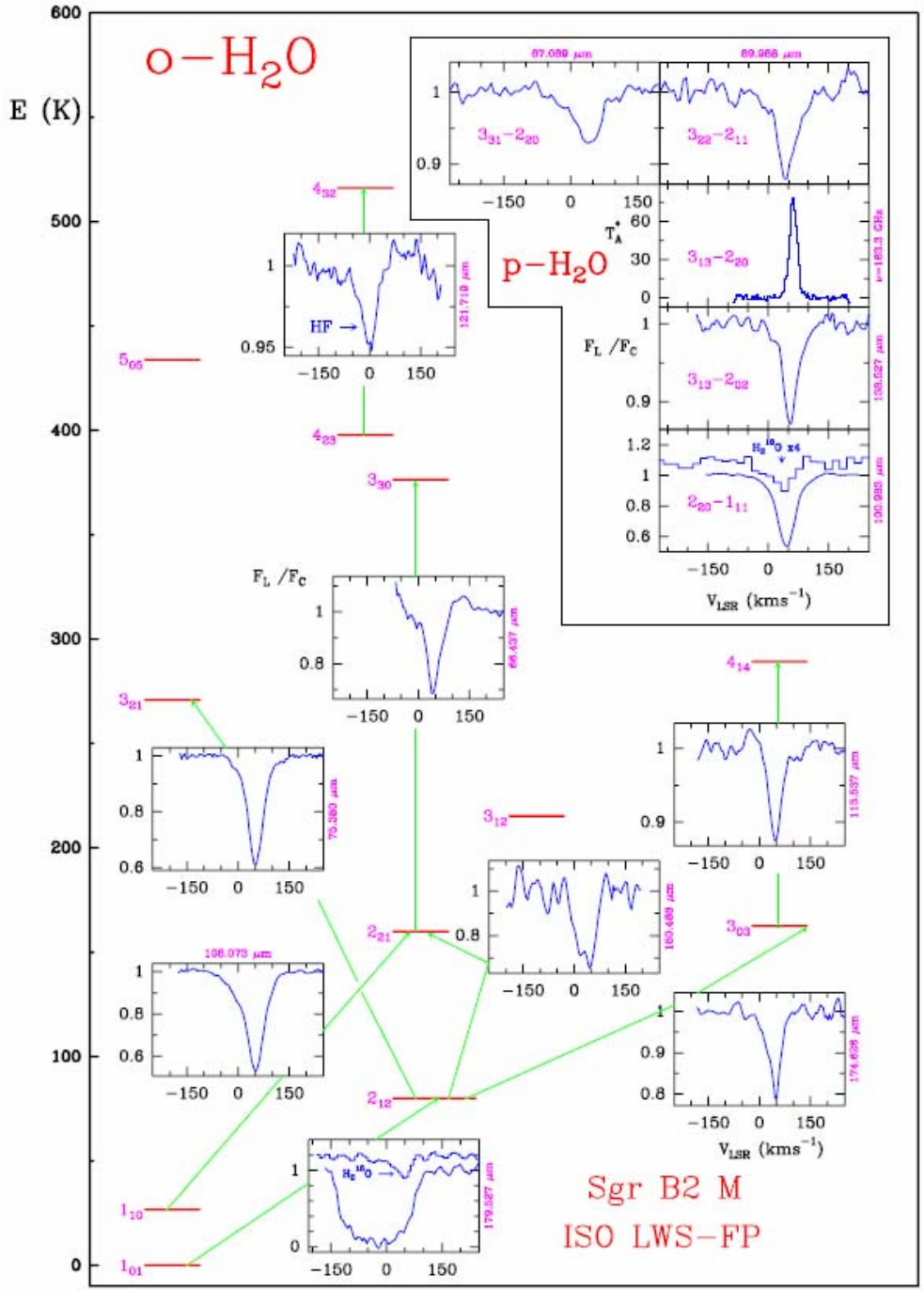
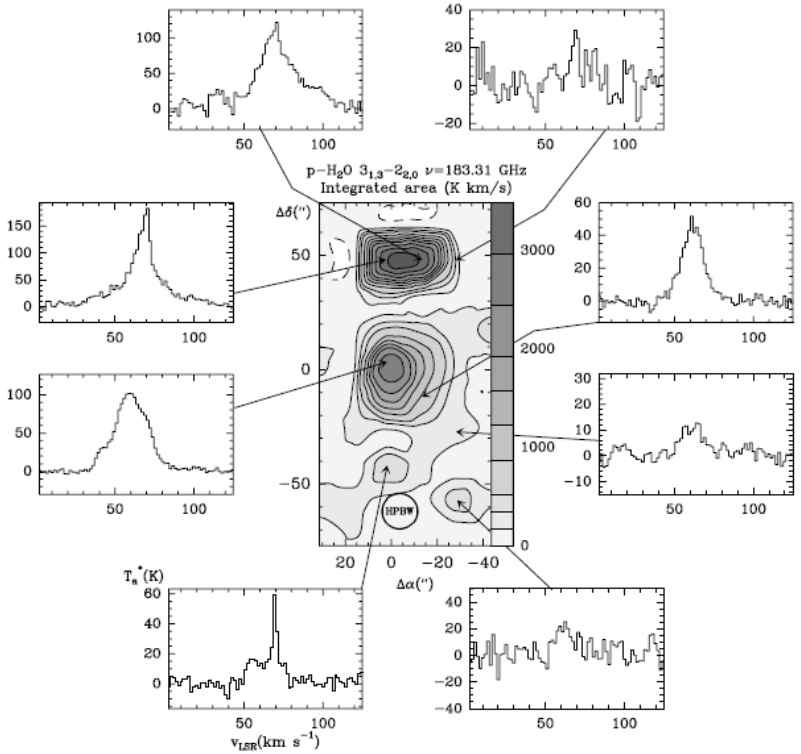


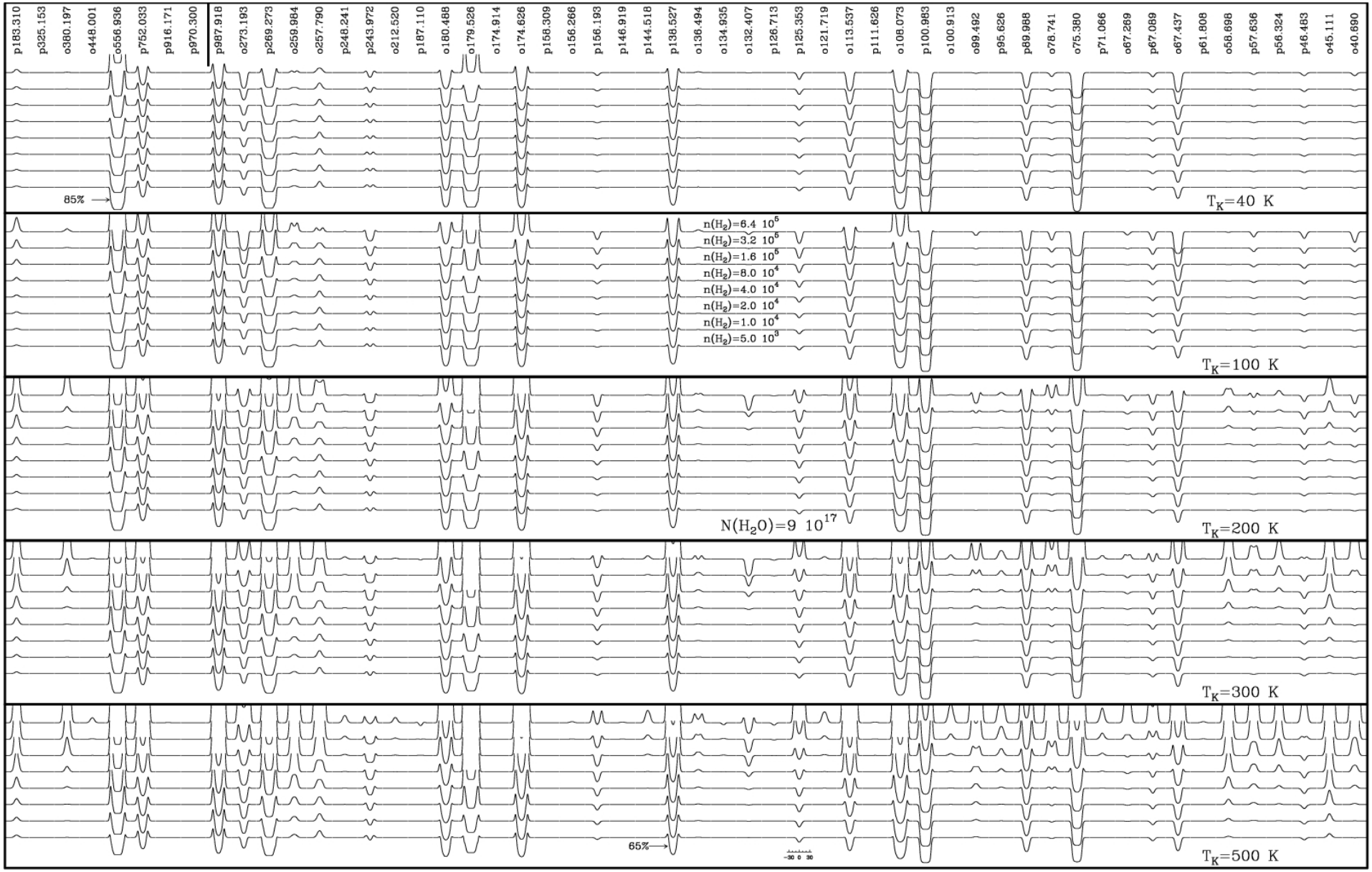
Fig. 3. a) and b) Results of model calculations showing the line over continuum flux ratio of four o-H_2O transitions (labelled with their wavelengths) as a function of kinetic temperature. c) Model spectrum for a cloud with an external absorbing shell (see text for details)





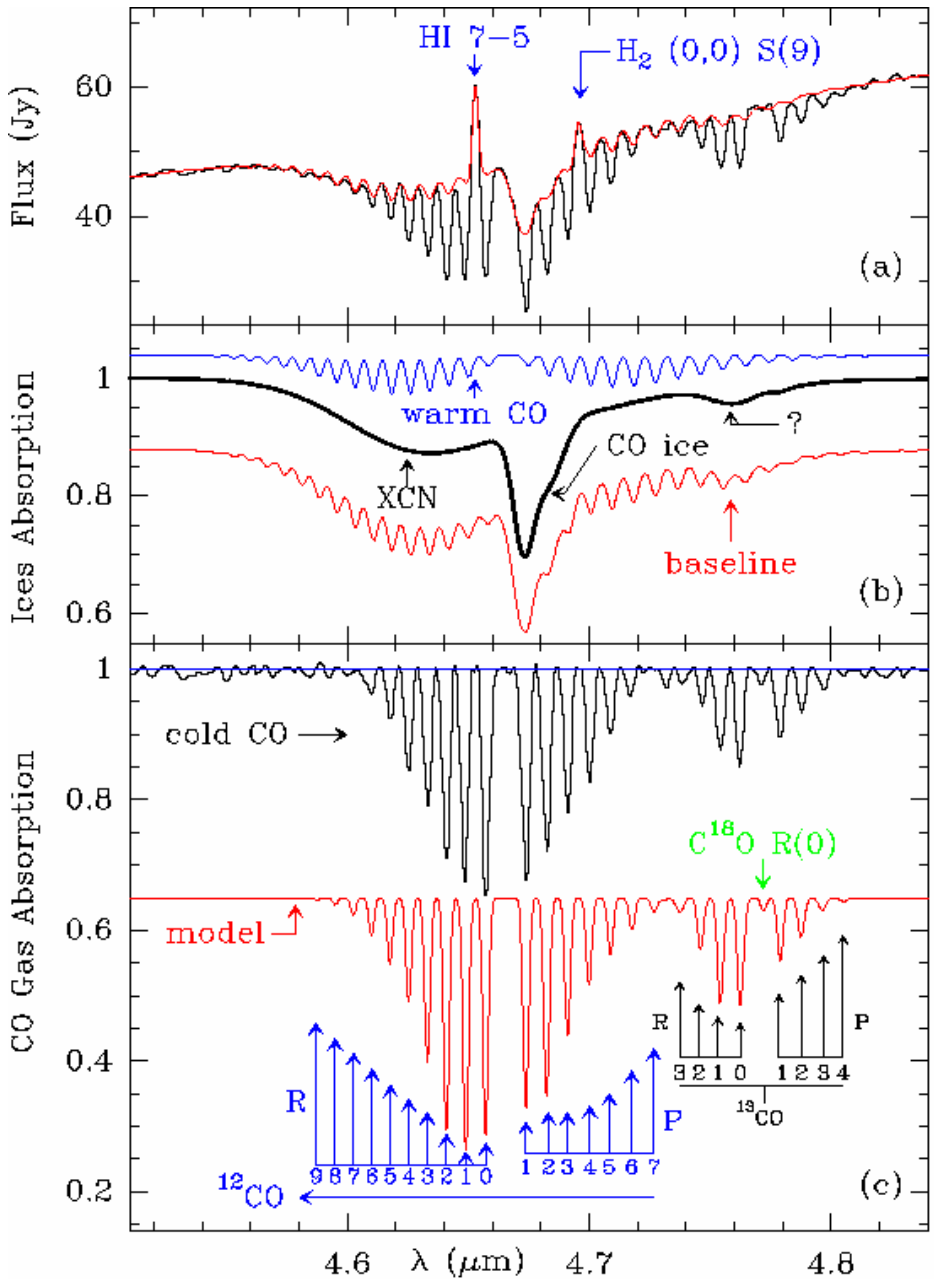
Cernicharo et al., 2006

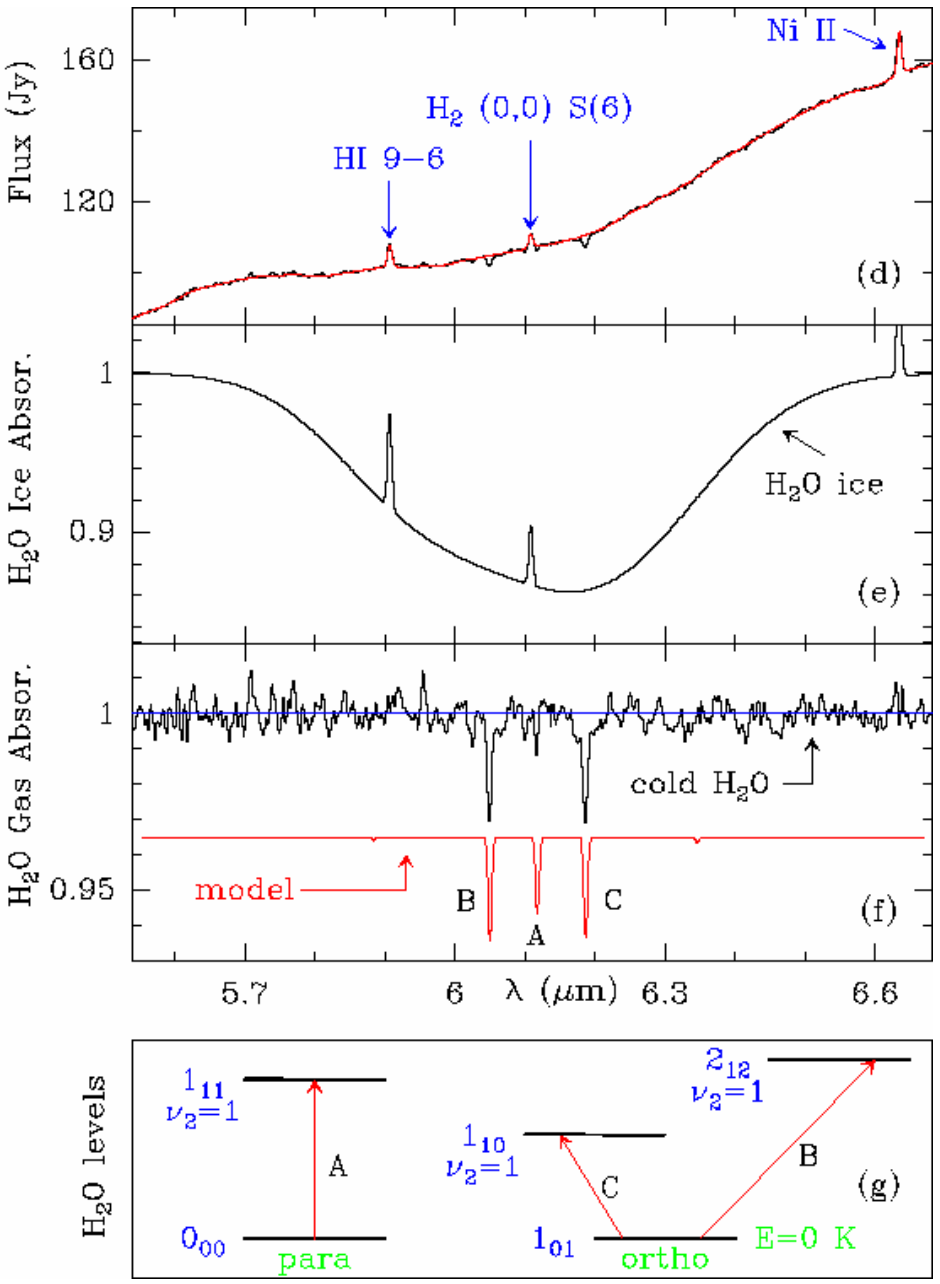
$N(H_2O)=1.8\ 10^{17}\ cm^{-2}$



COLD WATER

- FIRST DETECTION OF WATER VAPOR IN COLD DARK CLOUDS WITH ISO !!
- SWAS & ODIN have not detected H_2O towards these objects (only upper limits)

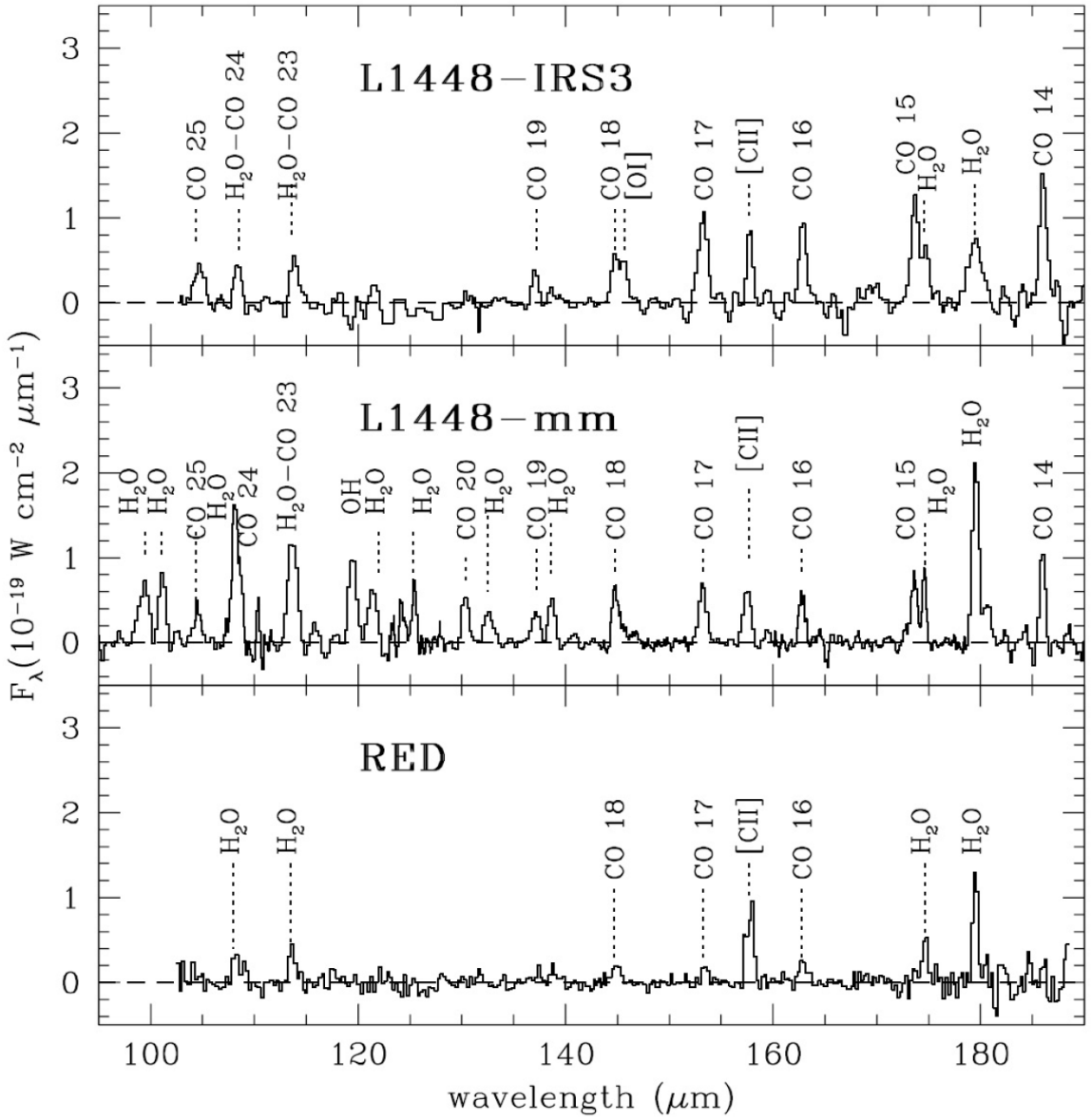




ISO/SWS data on Sgr A*

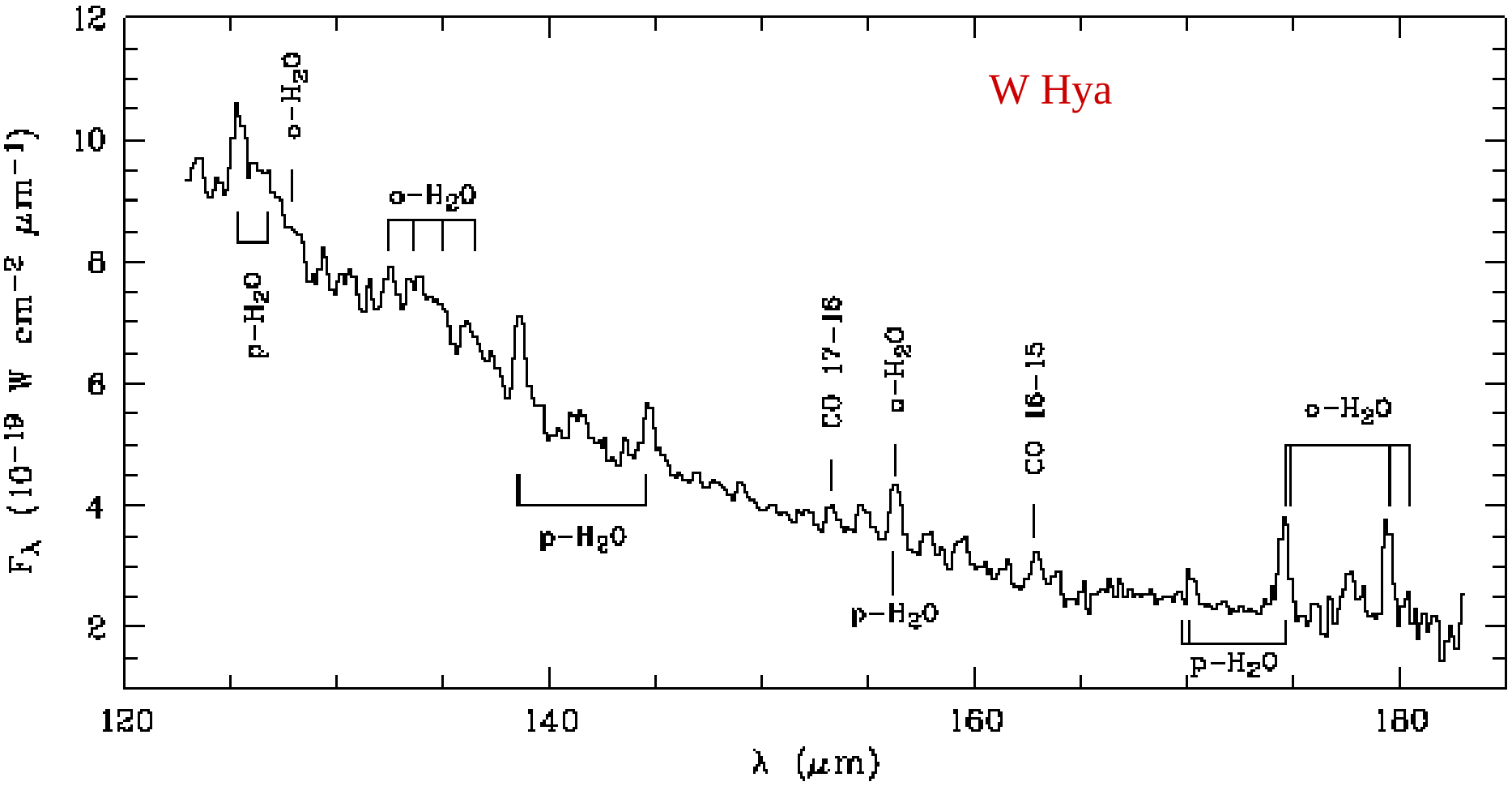
(Moneti, Cernicharo & Pardo ApJ Letters,2001)

Low Mass Star Forming Regions

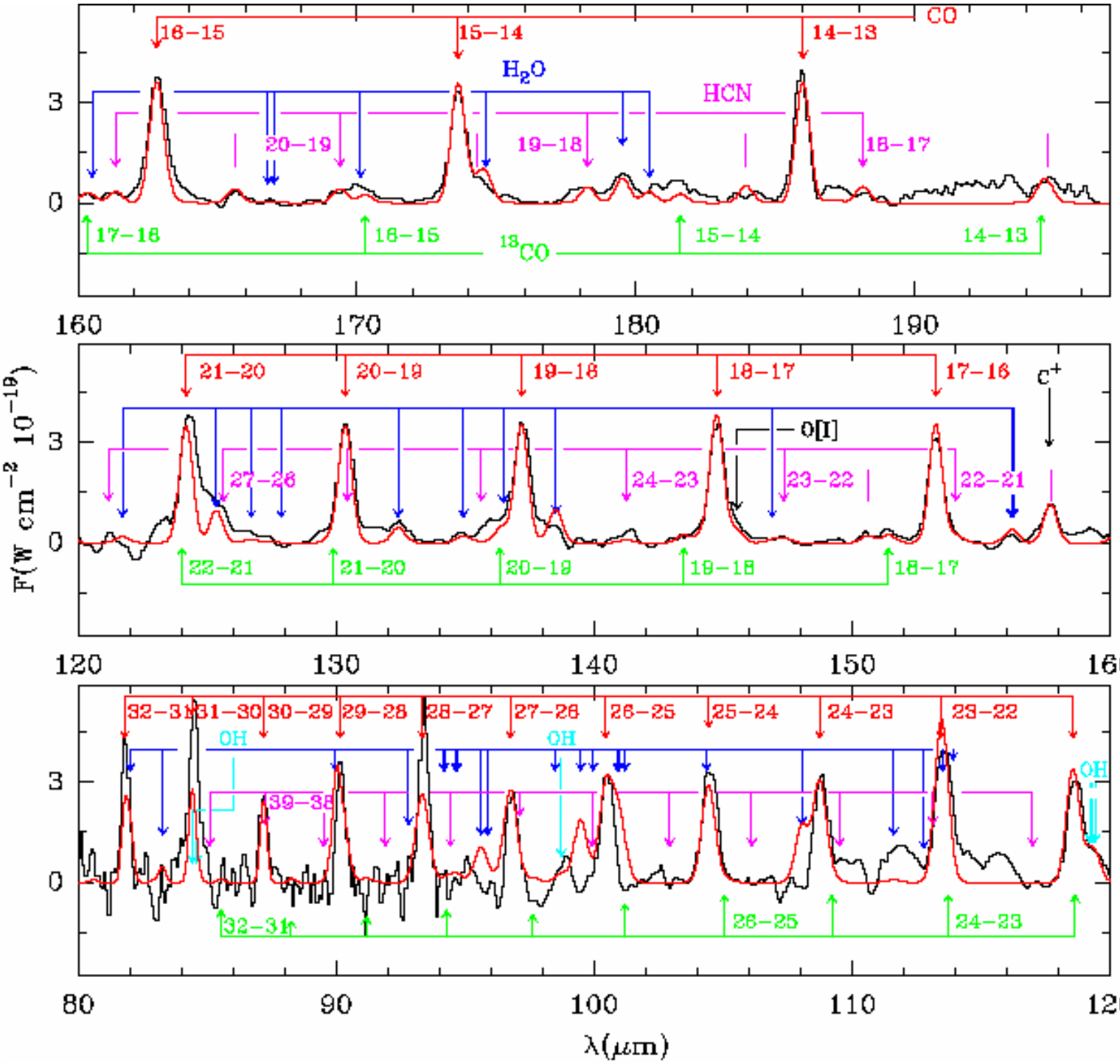


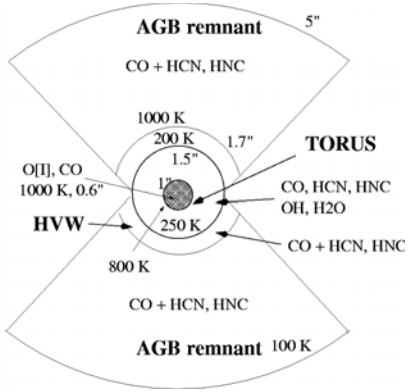
Nisini et al.,2000

In AGB stars



Barlow et al., 1996; Neufeld et al., 1996





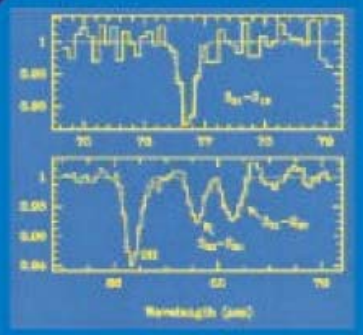
In C-rich AGB stars

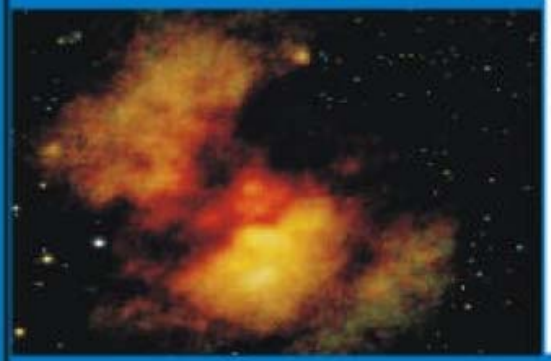
Herpin & Cernicharo, 2000, ApJ Letters, 530, L129

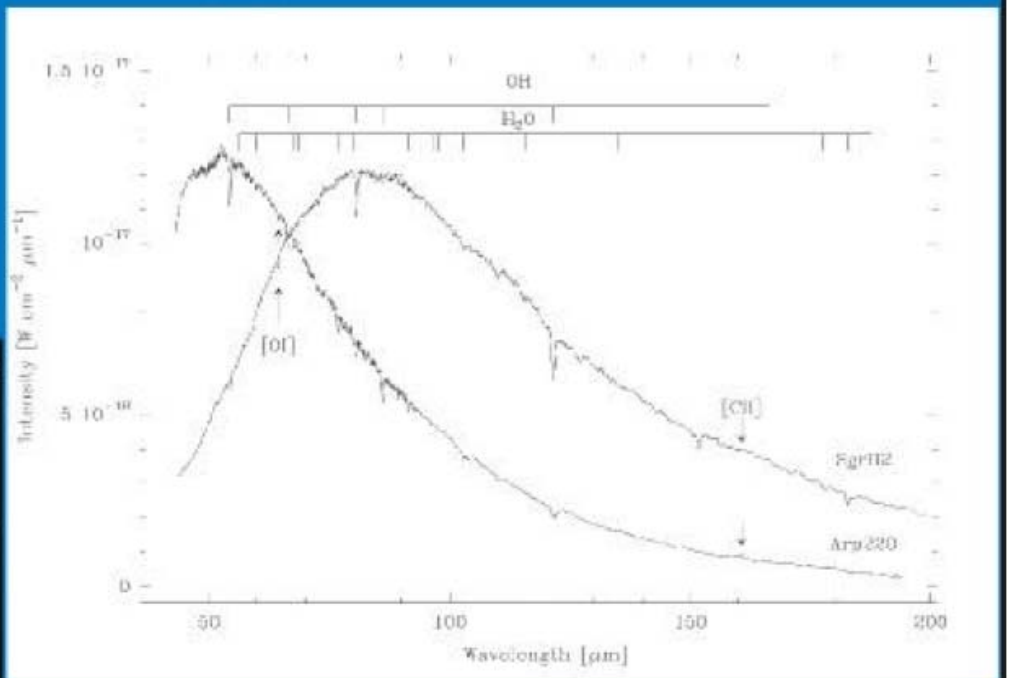
See Chemical Modelling by Cernicharo 2004, ApJ Lett.

Water, water everywhere !

In other galaxies







ARP 220

Infrared Space Observatory

González-Alfonso Et al., 2004

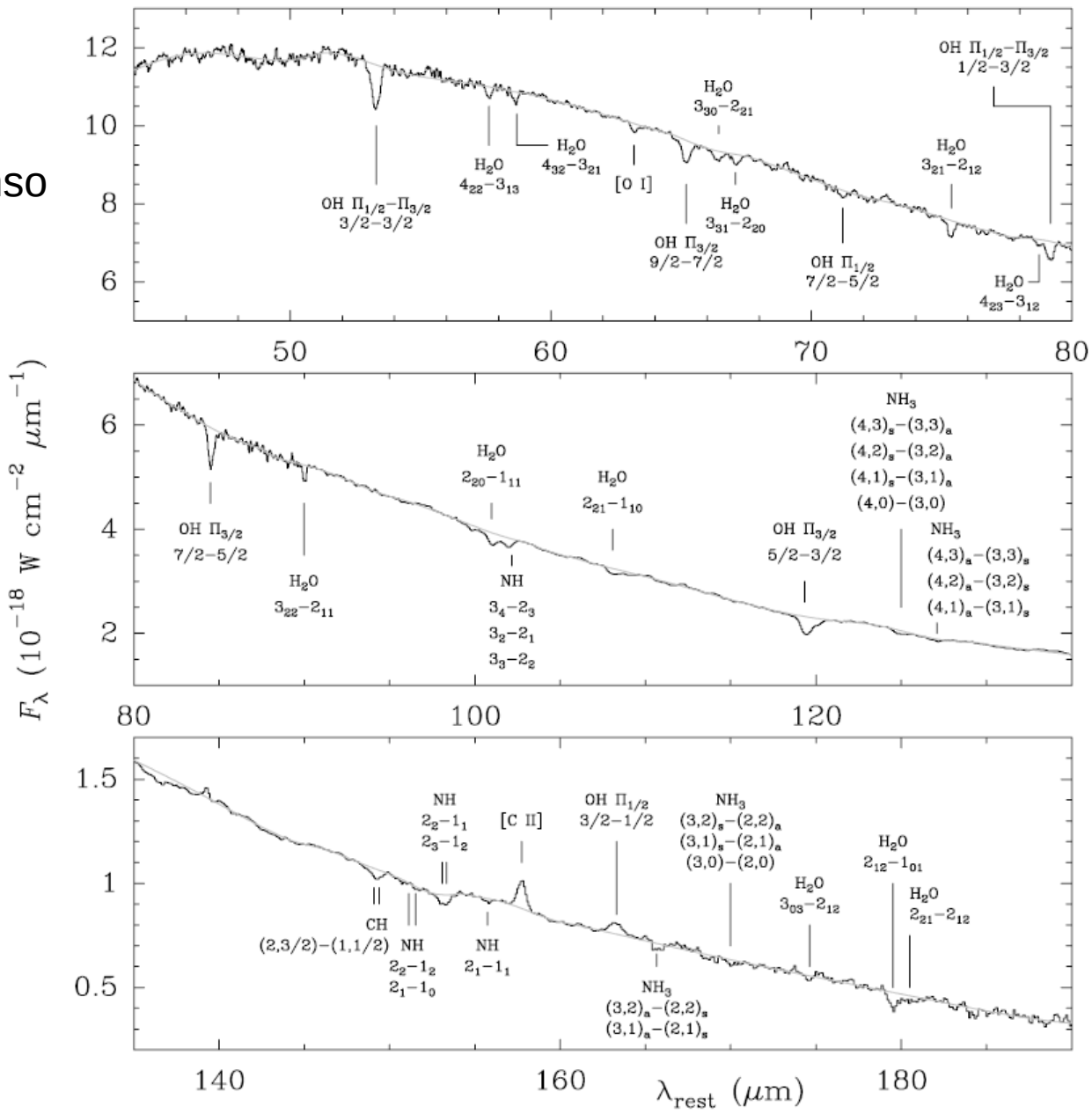
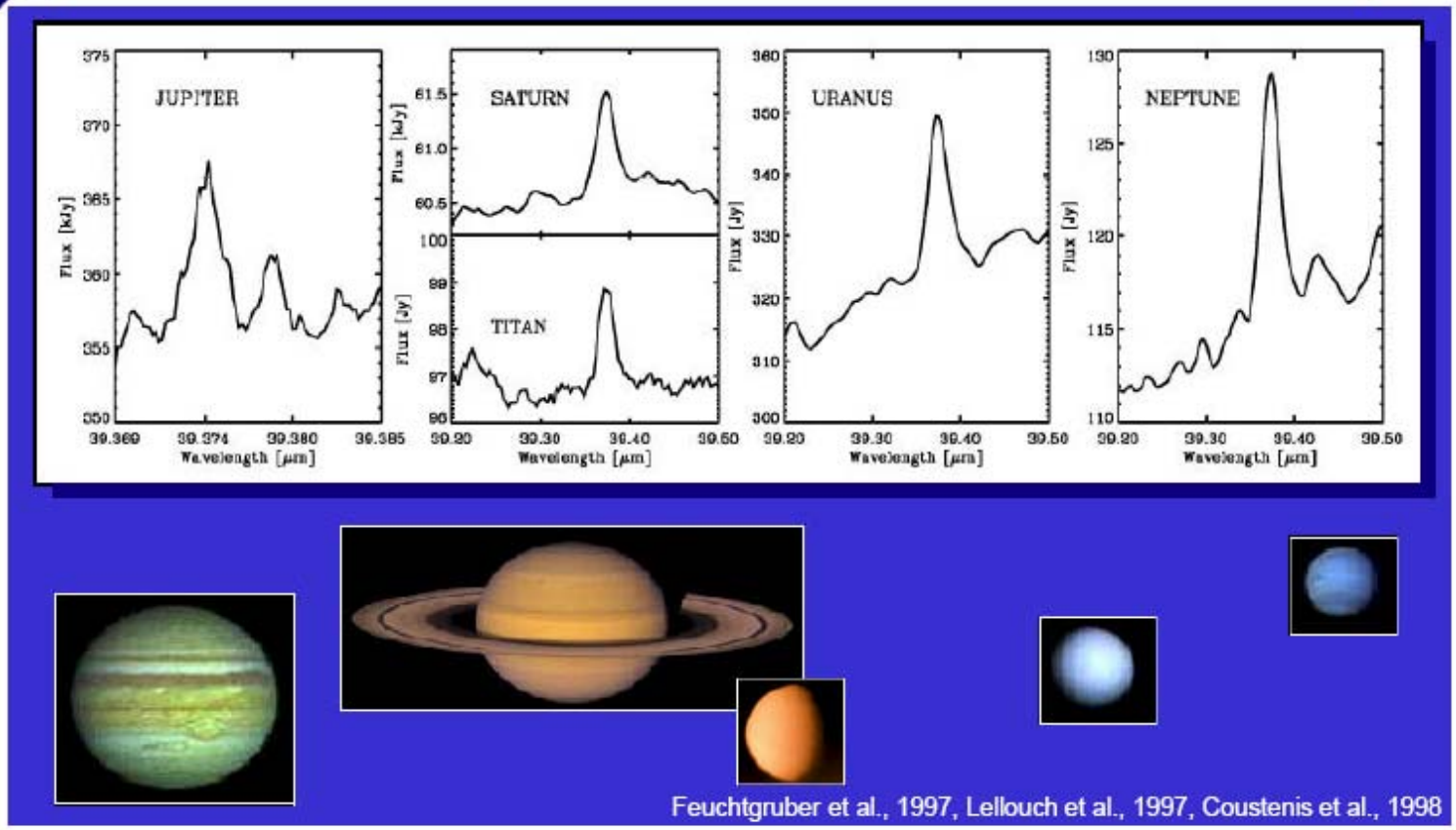


FIG. 1.—*ISO* LWS spectrum of Arp 220, where the most prominent line features are identified (see text). The gray line shows the adopted baseline (continuum level). Wavelengths in this and following figures are rest wavelengths.

H_2O in the Solar System

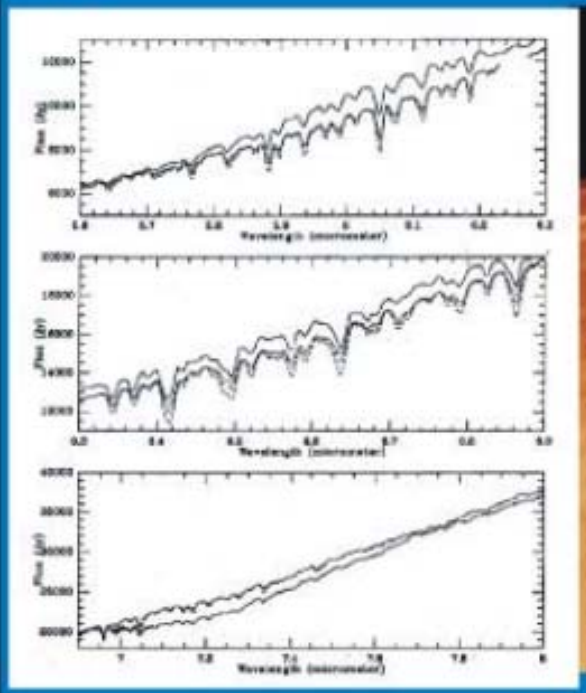
Water in Giant Planets' Atmospheres

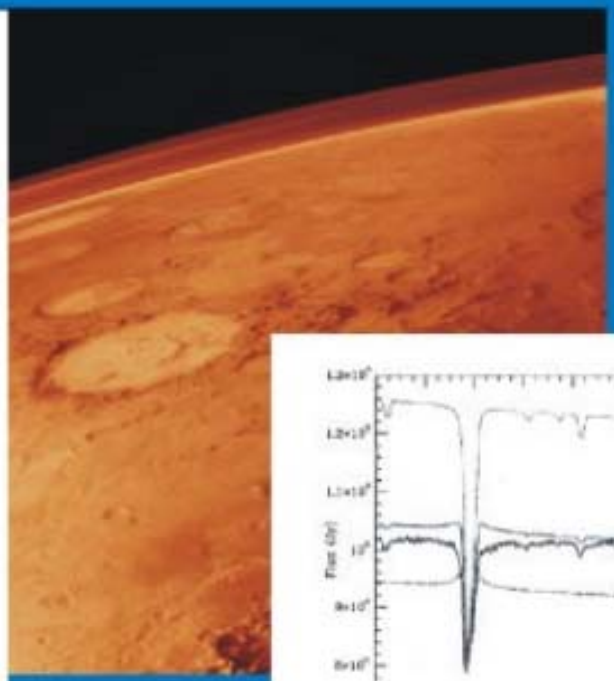


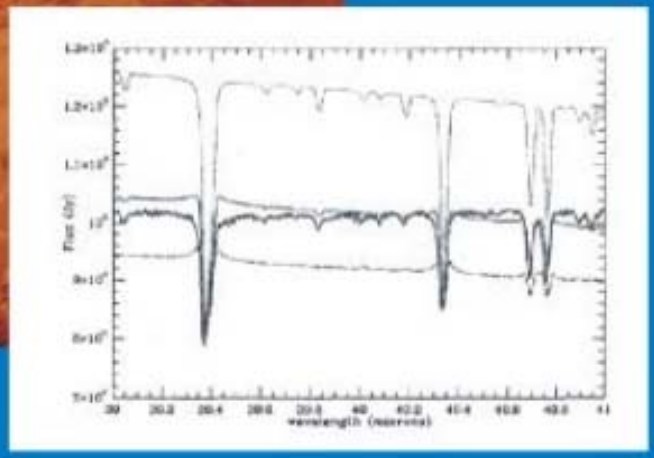
- First detection of stratospheric H_2O on giant planets and Titan.
- External source of oxygen required.

Water, water everywhere !

In Mars' atmosphere





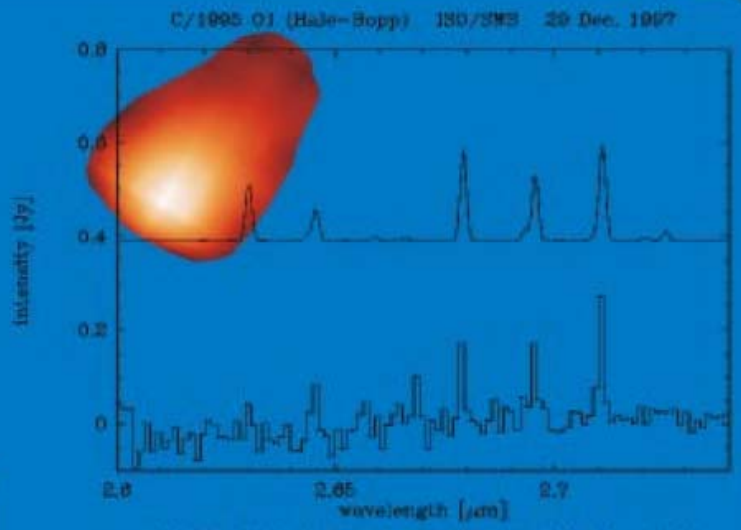


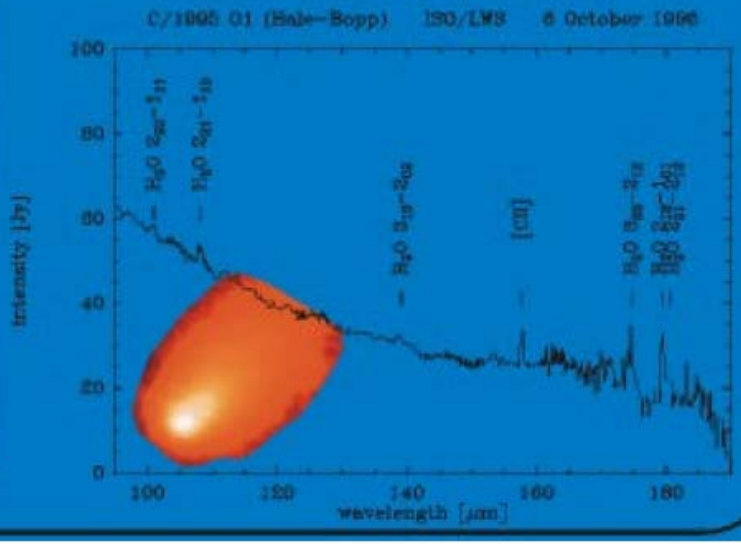
Infrared Space Observatory

Water, water everywhere !

In comets

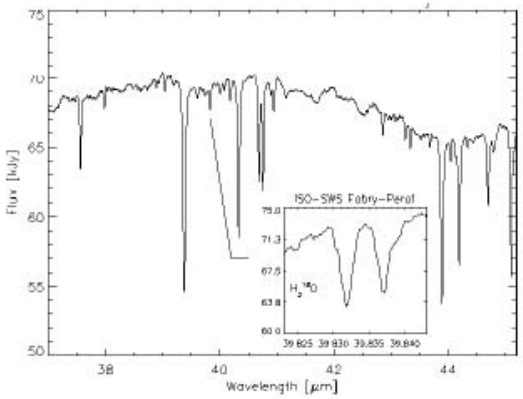
Infrared Space Observatory



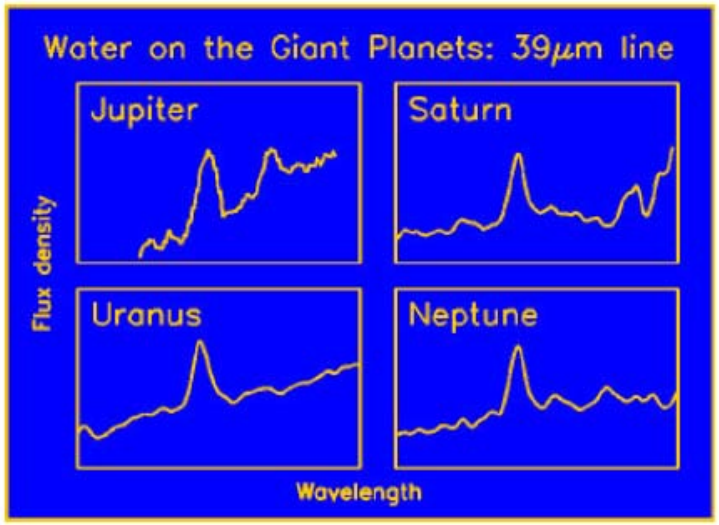


Water! Water! Everywhere!

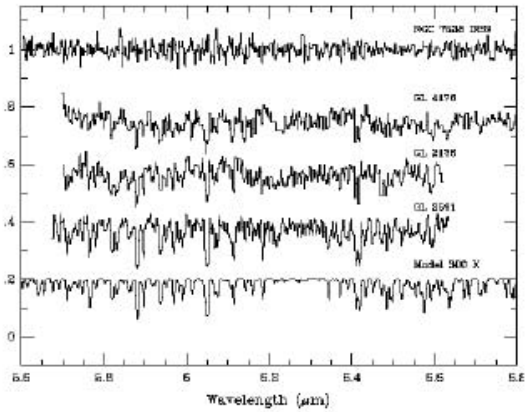
Mars



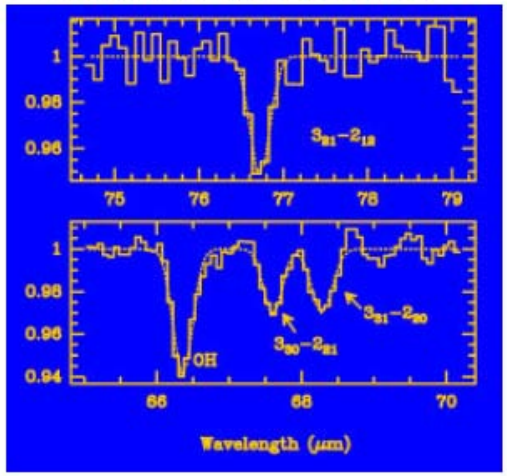
Giant Planets



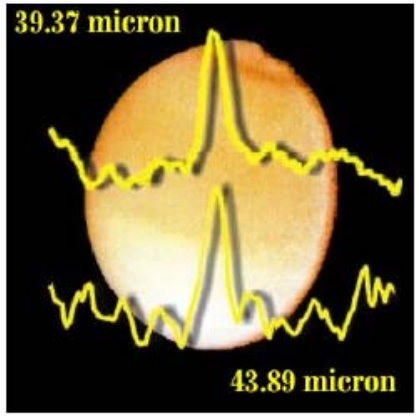
Circumstellar envelopes



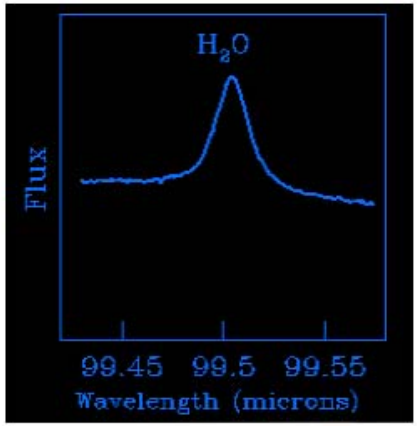
Ultra-luminous galaxy Arp 220



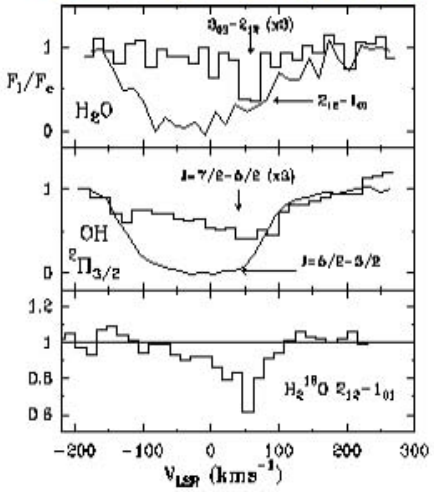
Titan



Shocks (Orion)



cold interstellar medium



Now waiting for Herschel !