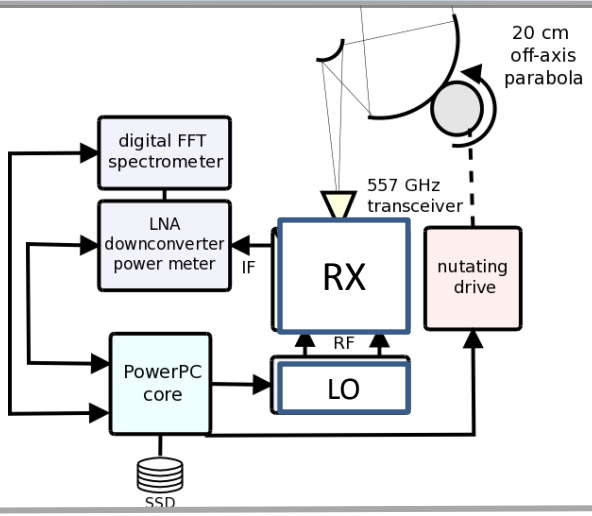
HORUS: HeterOdyne Regolith Universal Surveyor or... H_2O Regolith Universal Surveyor

Objectives

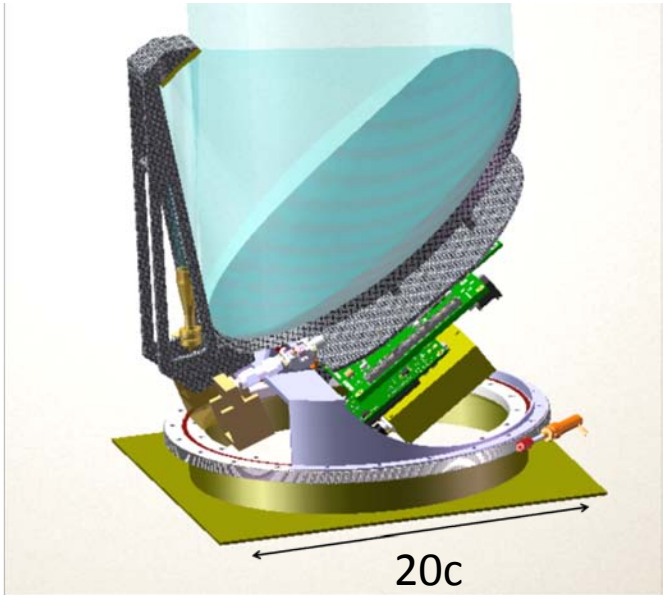
Technology Description: HORUS consists of a *compact, low-power submillimeter-wave telescope and heterodyne spectrometer. All flight components are of high TRL; several draw heritage from existing space projects.*

Planned Objectives: *A high resolution spectrometer tuned to the 557 GHz 1_{10}-1_{01} ground state transition of H_2O, HORUS will be sensitive to minute outgassing from 1999 RQ36. During the lengthy transit to & from 1999 RQ36, HORUS will perform a Galactic Plane Survey for water in star forming interstellar clouds, the first of its kind.*

Block Diagram



Preliminary Solid Model



Projected Power & Mass Budget

Symmetricom 100 MHz reference: 2W
Miteq PLDRO ~3W
VDI 557 GHz heterodyne receiver: ~5W
Xilinx or Actel FPGA spectrometer: ~3W
PowerPC 405 Control CPU: 2W
Motion Control: <1W
Total in passive spectroscopy mode: 14-16W

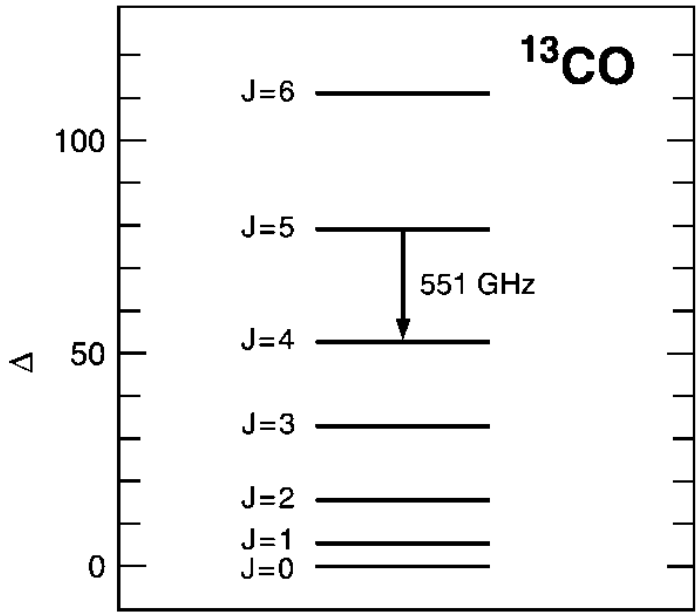
Electronics: 0.3 kg

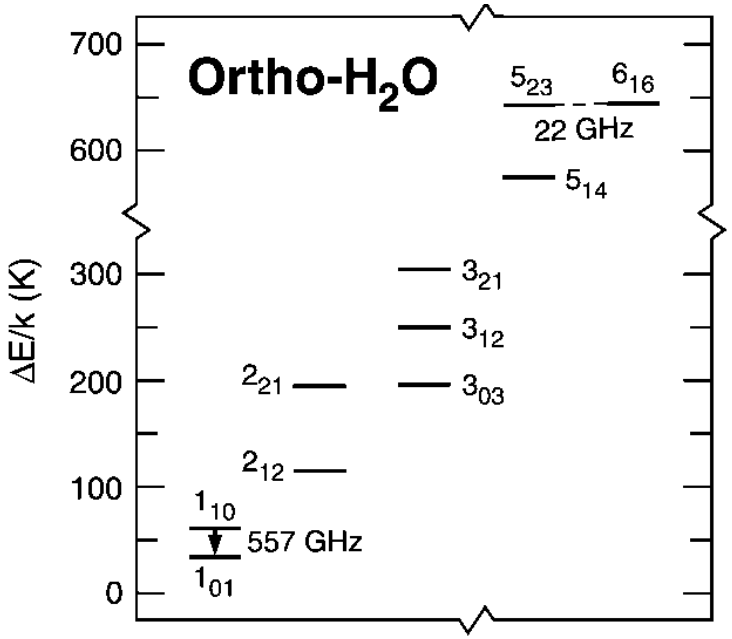
Carbon fiber 20 cm off-axis antenna: 1.1 kg
Heterodyne transceiver components: 0.4 kg
Motion Control: 0.2 kg
Total mass: 2.0 kg

Why water?

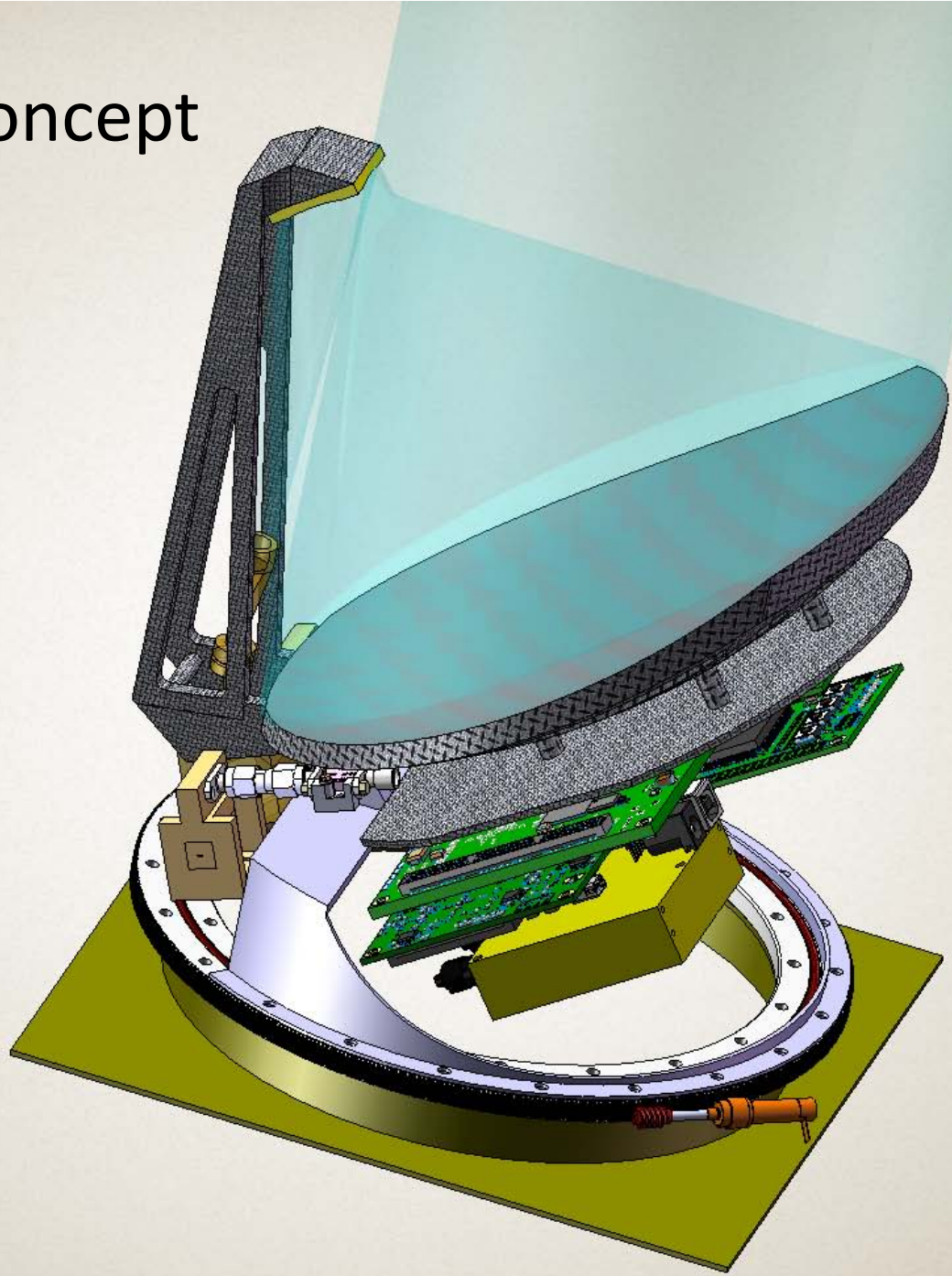
- Main reservoir of oxygen affects chemistry of all other species
- H_2O abundance shows large variations in SF regions: $<10^{-8}$ (cold) – 3. 10^{-4} (warm) unique probe of different physical regimes
- Natural filter of warm gas
- Traces basic processes of freeze-out onto grains and evaporation, which characterize different stages of evolution
- Astrobiology: water associated with life on Earth characterize water ‘trail’ from clouds to planets, including origin of water on Earth
- Comets & Exosolar Kuiper Belt Objects

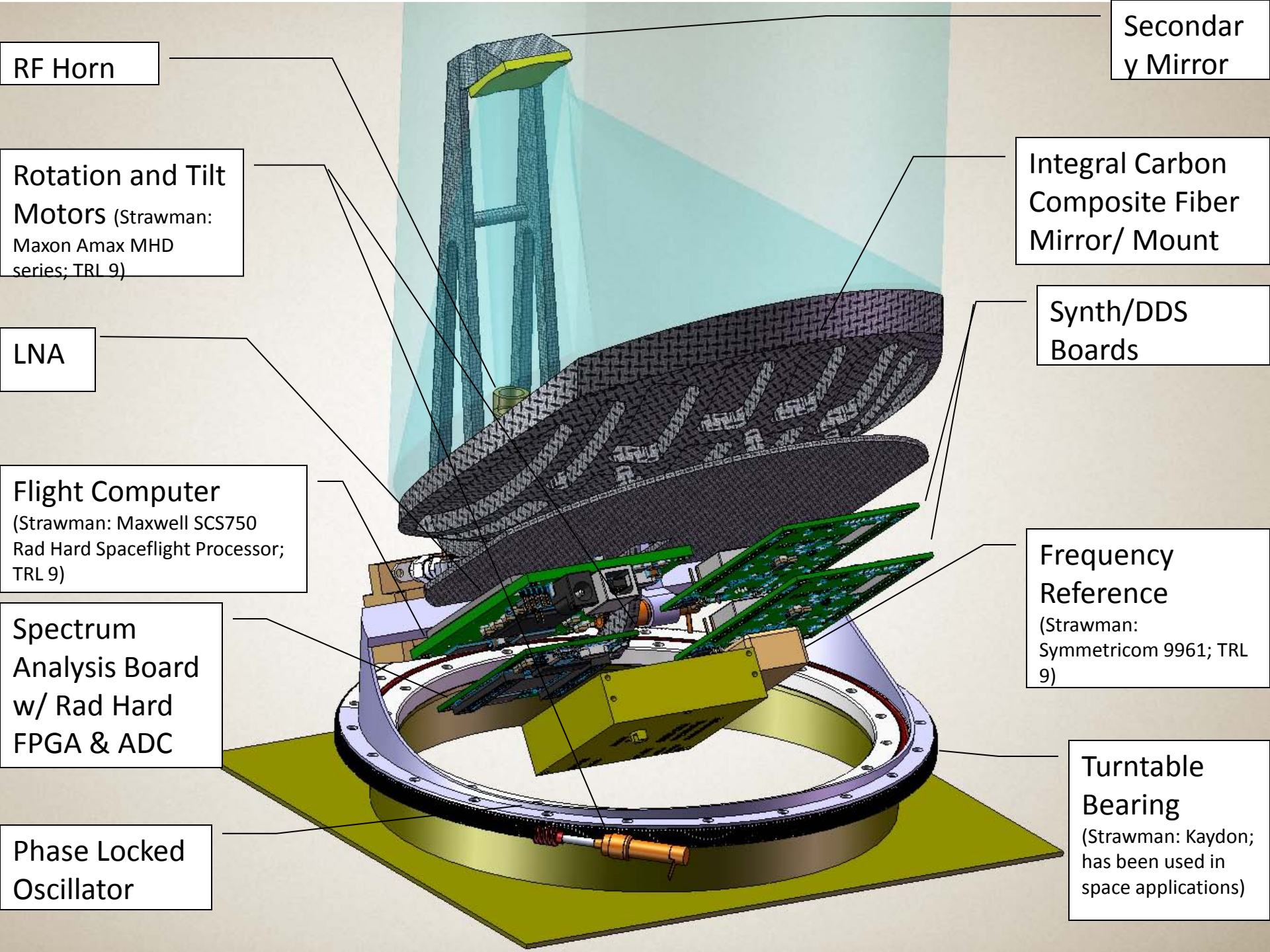
What Lines will HORUS Observe?



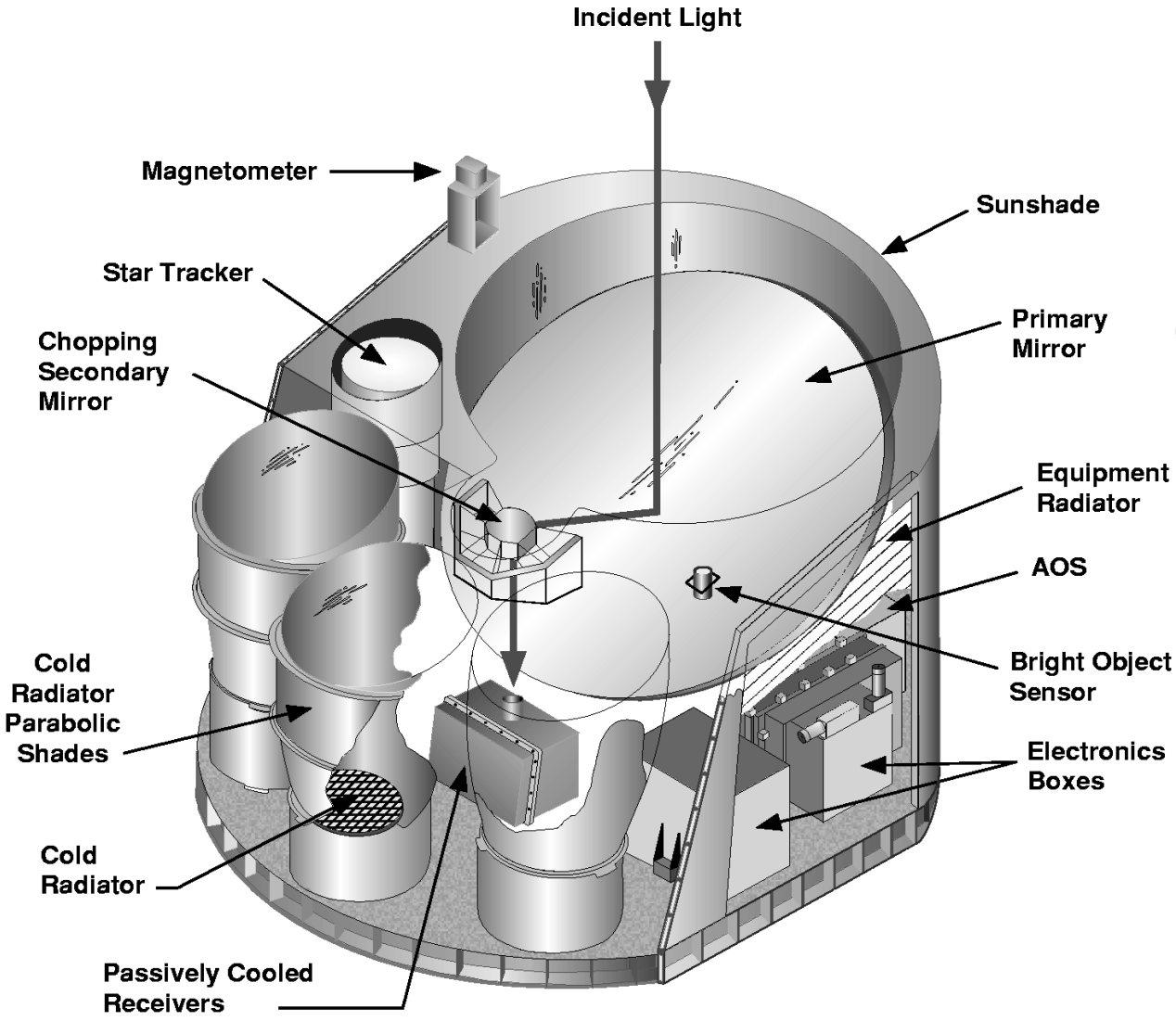


HORUS Concept



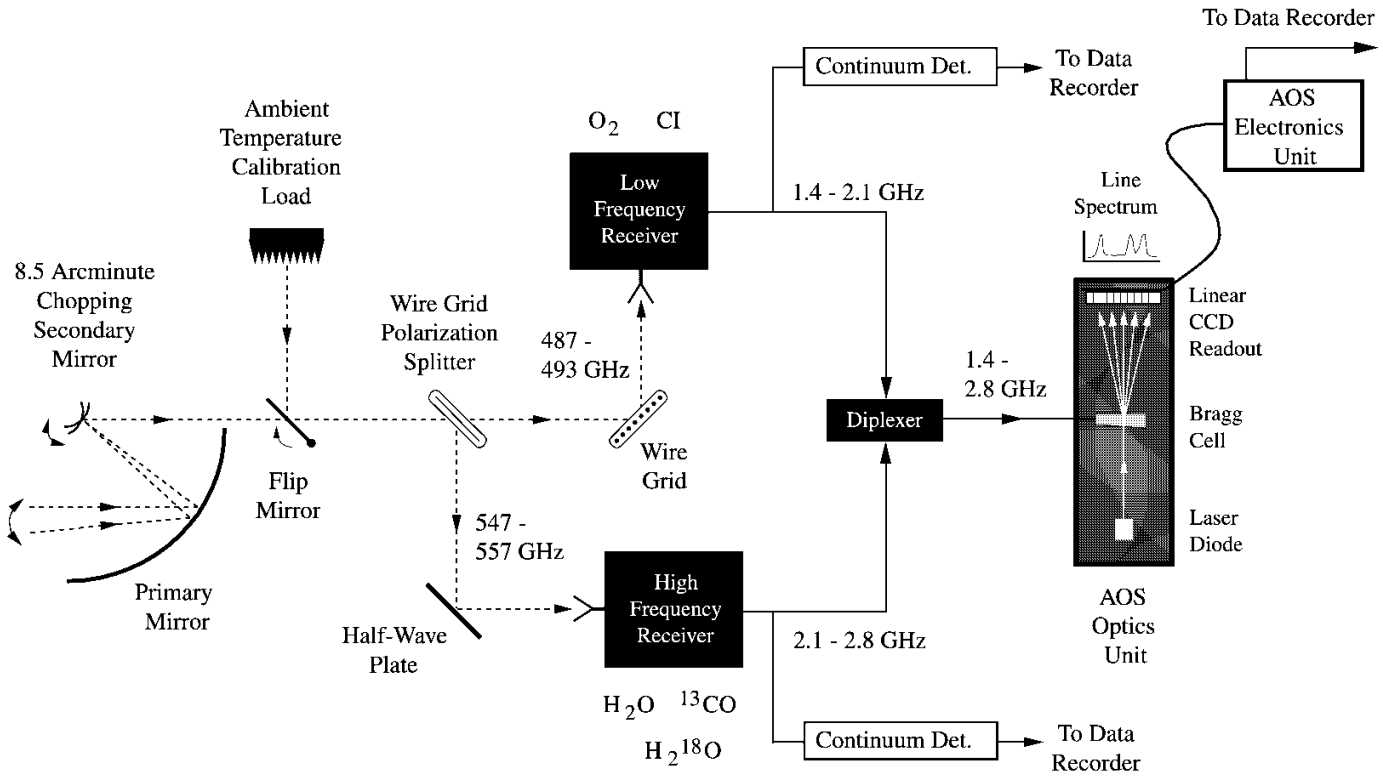

RF Horn
Secondary Mirror
Rotation and Tilt Motors (Strawman: Maxon Amax MHD series; TRL 9)
Integral Carbon Composite Fiber Mirror/ Mount
LNA
Synth/DDS Boards
Flight Computer (Strawman: Maxwell SCS750 Rad Hard Spaceflight Processor; TRL 9)
Frequency Reference (Strawman: Symmetricom 9961; TRL 9)
Spectrum Analysis Board w/ Rad Hard FPGA & ADC
Turntable Bearing (Strawman: Kaydon; has been used in space applications)
Phase Locked Oscillator

SWAS….$120M (1998)

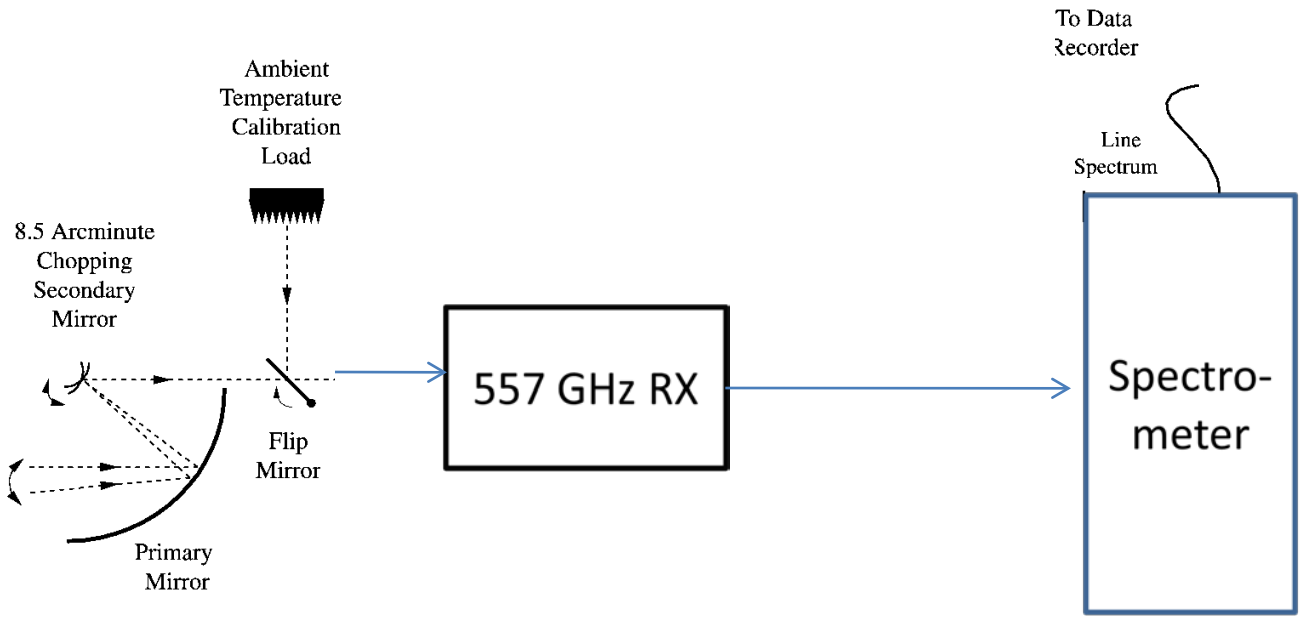


(~50cm)

SWAS Instrument…



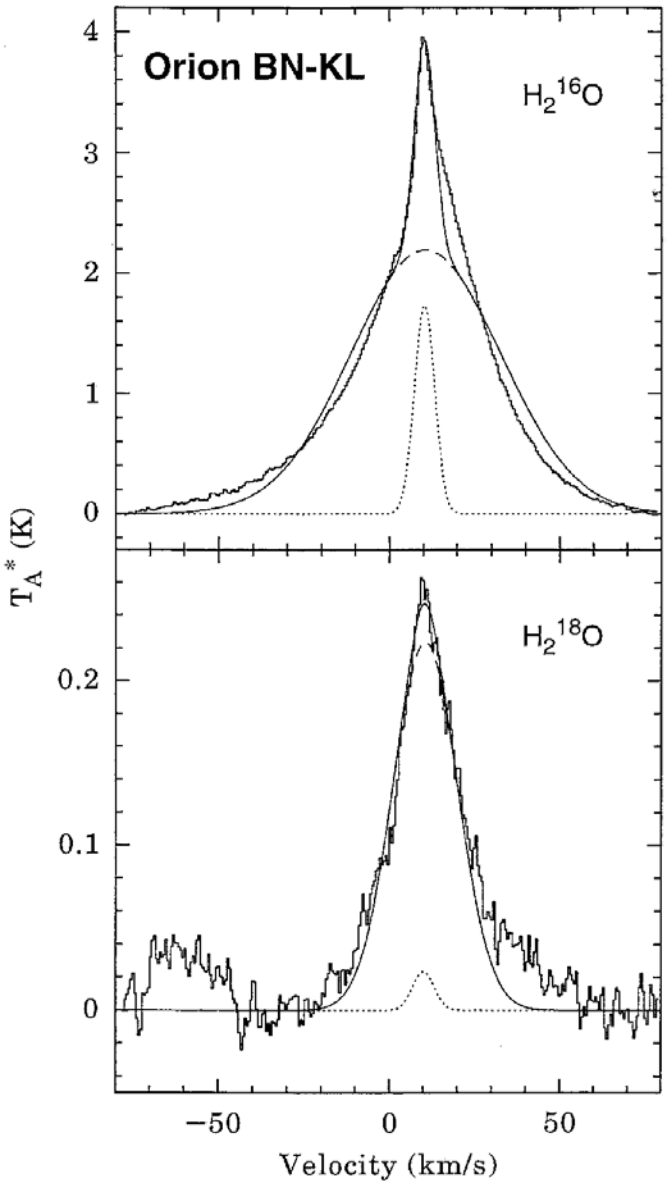
…HORUS is simpler.



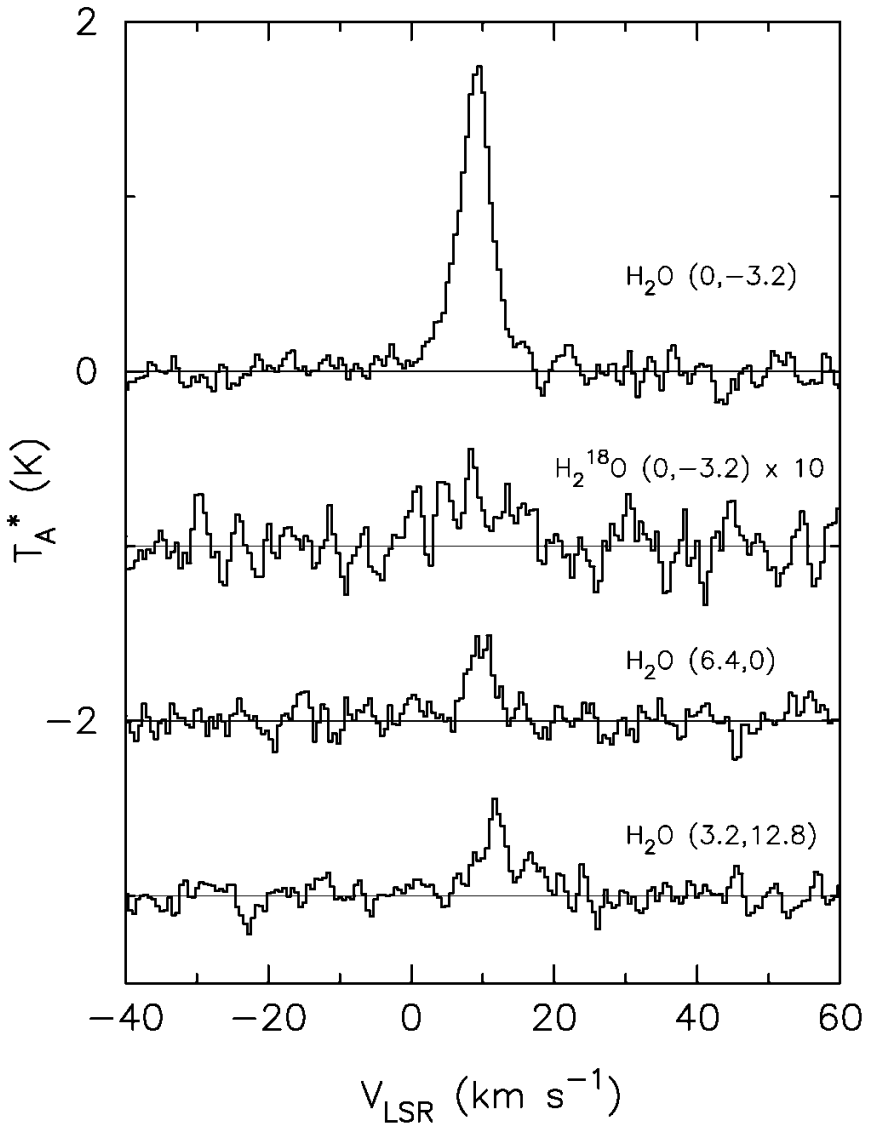
The Milky Way Today…..

Orion Nebula…`standard’ candle

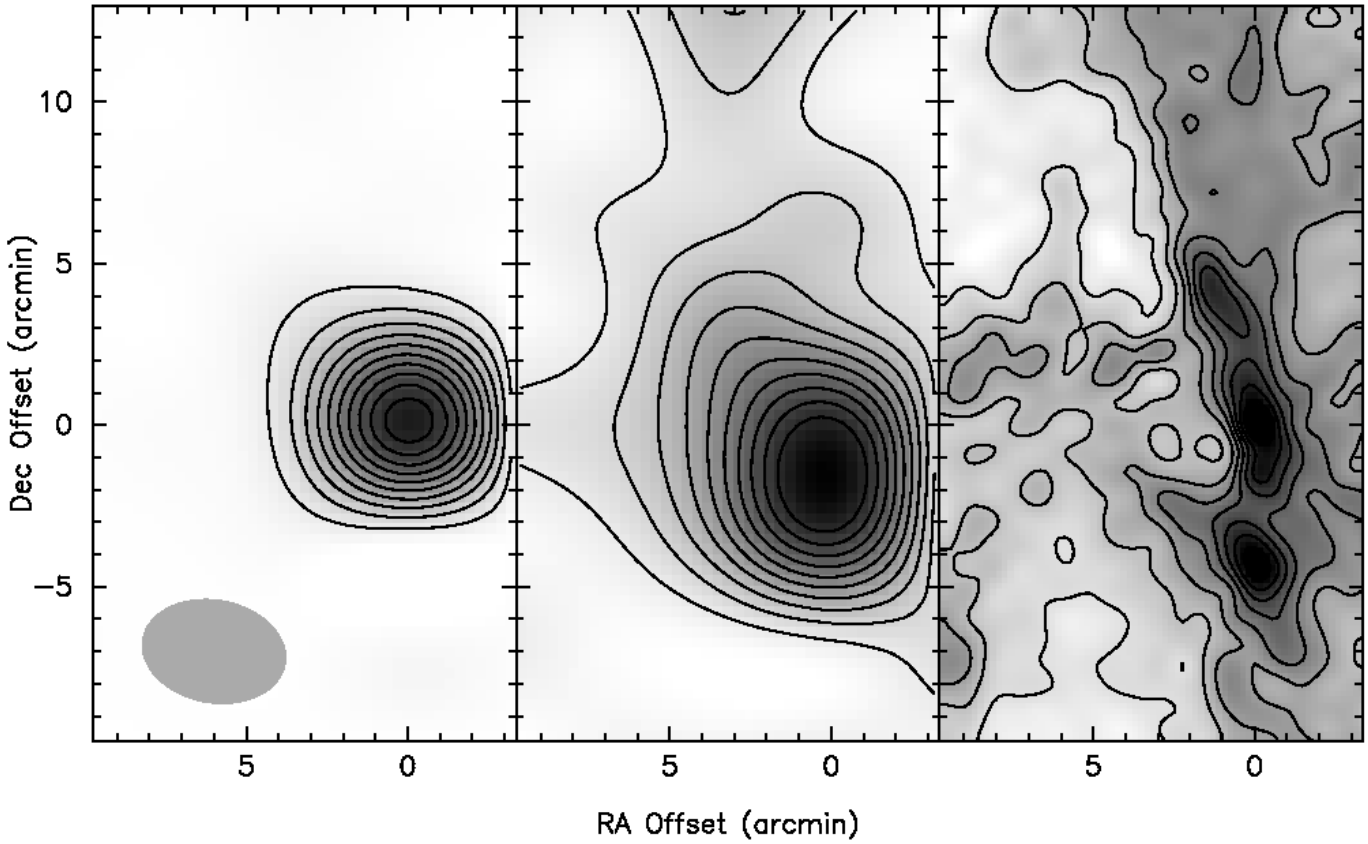
557GHz H_2O in Orion BN-KL



H_2O Spectra taken off the peak….

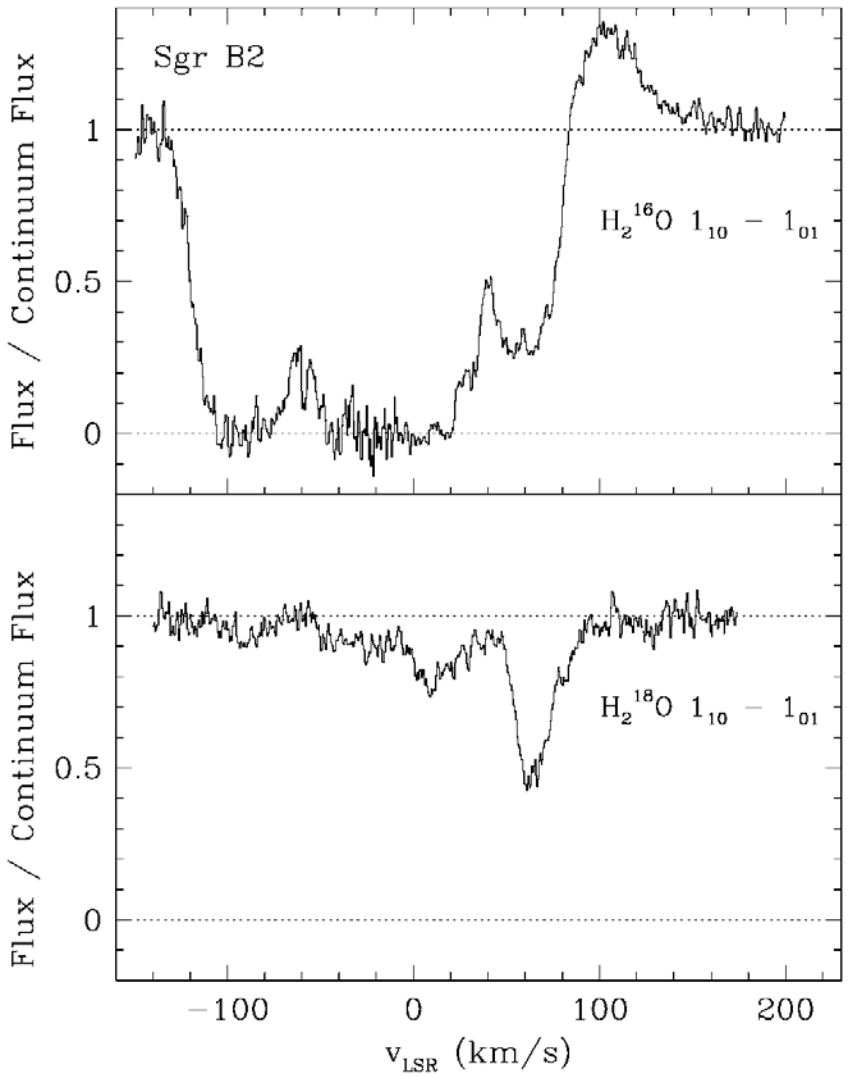


Extended H_2O Emission



Left panel shows a map of the integrated intensity of the 557 GHz H2O line in Orion. The middle panel shows a map of the integrated intensity of just the narrow water line component in Orion. The right panel is a map of the integrated intensity of the 13CO emission obtained at FCRAO.

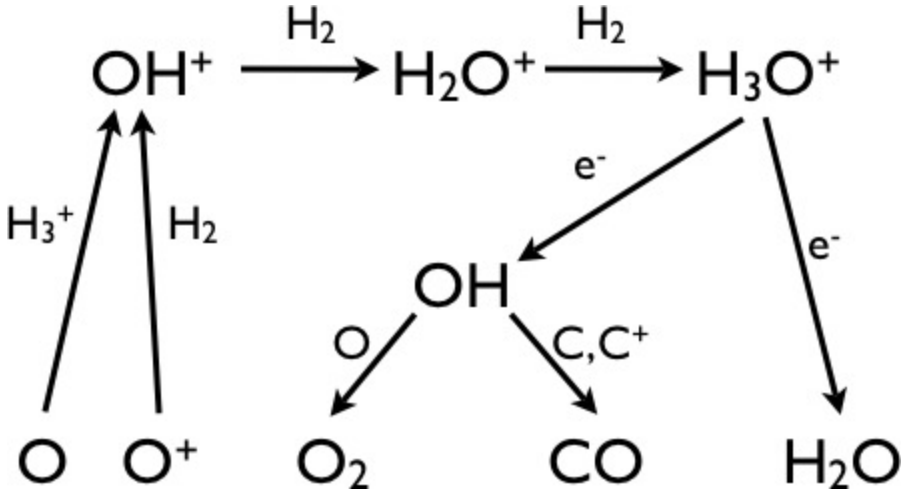
557GHz H_2O Line in Galactic Center



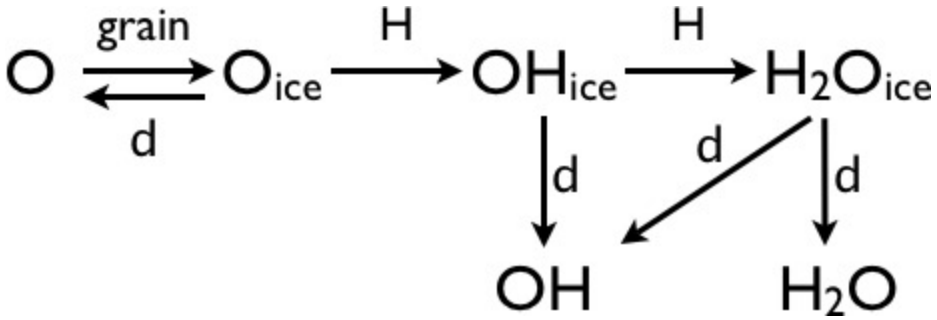
Water vapor spectra obtained toward Sgr B2 by *SWAS.*

So, where does the water come from?

Gas?



Grains?



Keeping Theorists Honest….

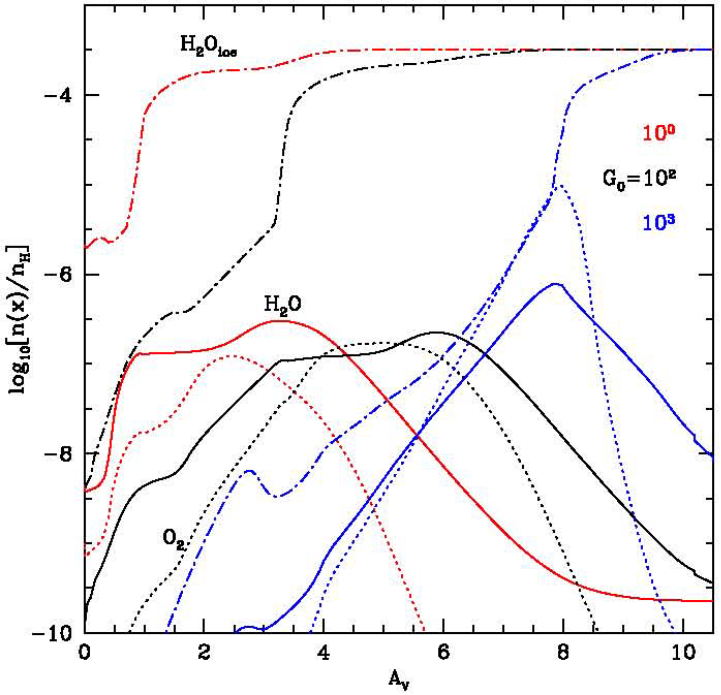


Figure 5. H_2O, O_2, and H_2O_{ice} abundances for a cloud with $n = 10^4$ cm^{-3} but with a variety of FUV field strengths incident on the cloud surface. Results are shown for FUV fields $G_0 = 1$, 10^2 and 10^3 times the average interstellar field. H_2O_{ice} is dot-dashed, H_2O is solid, and O_2 is dotted lines. Higher G_0 drives curves to the right. Although the depth at which freeze-out occurs is affected by G_0, the total H_2O column is not. The increase in the peak abundance of O_2 seen for $G_0 = 1000$ is caused by thermal desorption of atomic O from the warm grains, which suppresses H_2O_{ice} formation and keeps more elemental O in the gas phase.

(A color version of this figure is available in the online journal.)

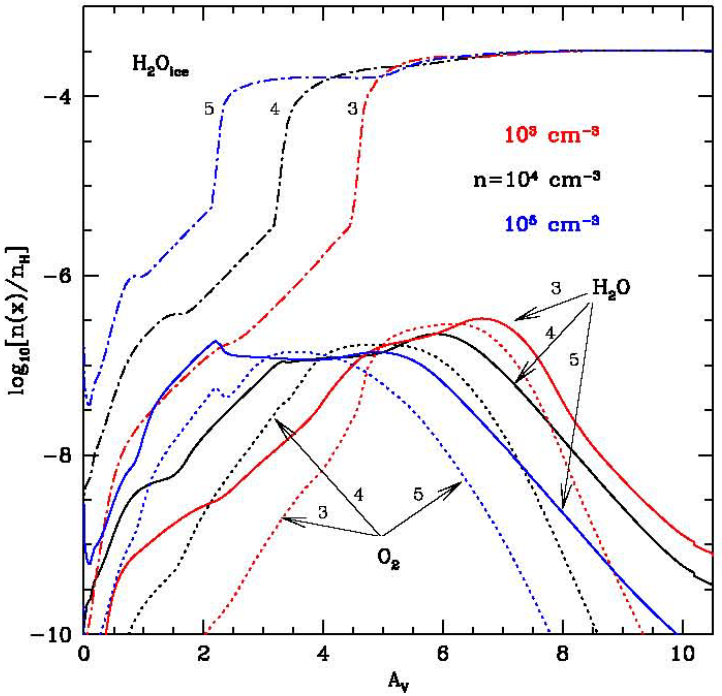
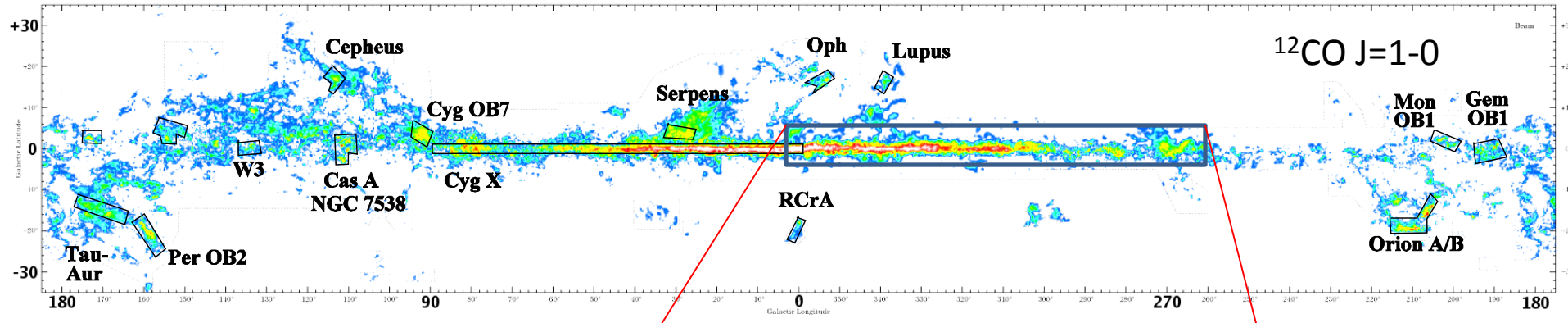


Figure 6. Effect of changing the gas density. Results are shown for $n = 10^3$, 10^4, and 10^5 cm^{-3} and for the standard FUV field $G_0 = 10^2$. The threshold A_V for water ice formation and the A_V where H_2O and O_2 peak increase for increasing G_0/n. The peak abundances do not change with n. The labels on the arrows refer to the log of the density n.

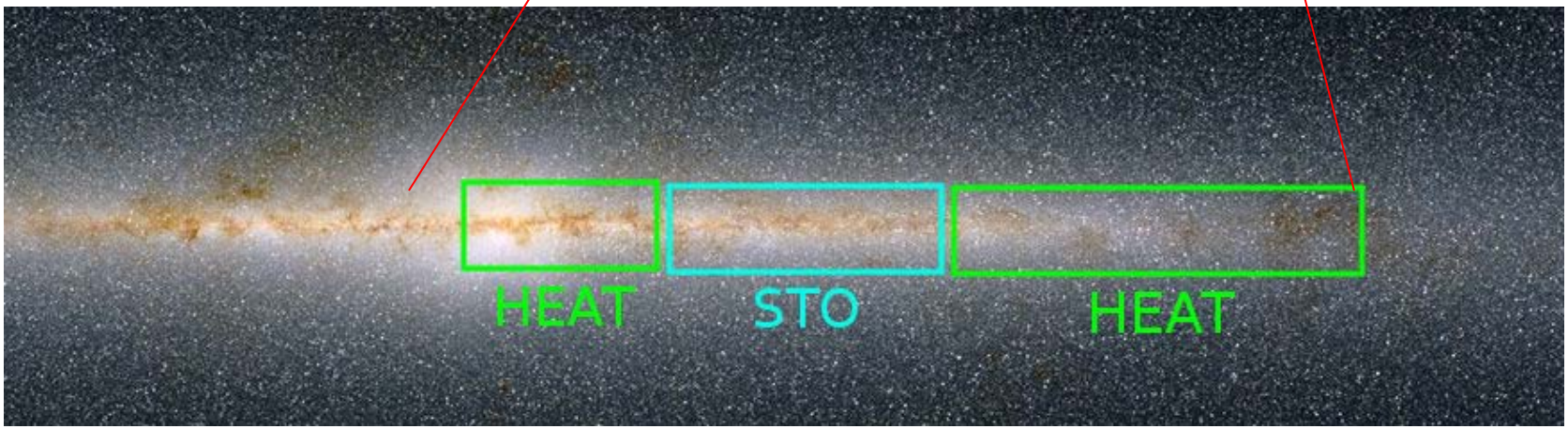
(A color version of this figure is available in the online journal.)

times the local FUV field. Therefore, the water peak moves into the cloud with decreasing density. However, the column or A_V where the water starts to decline from its peak (plateau) value is insensitive to n. Thus, the plateau starts to become narrower and

What does a ≥100 sq. degree survey look like?

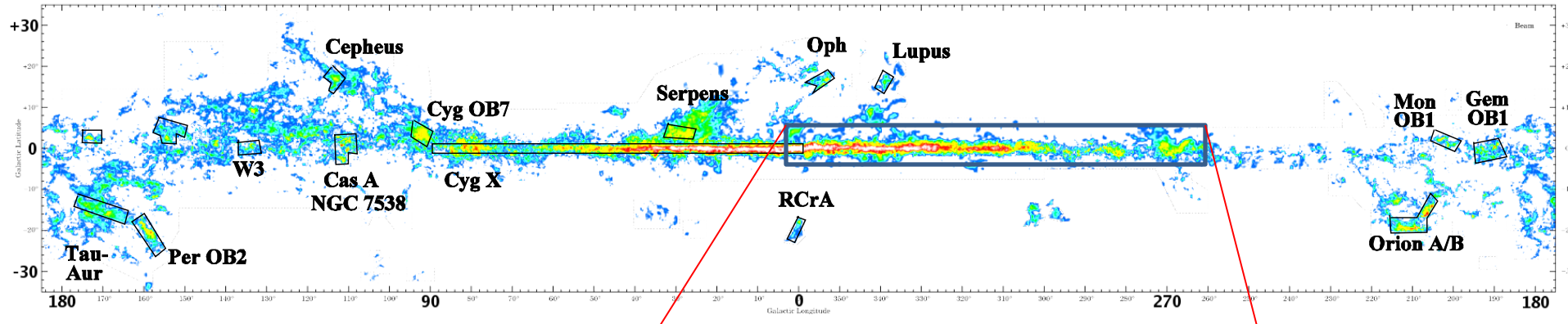


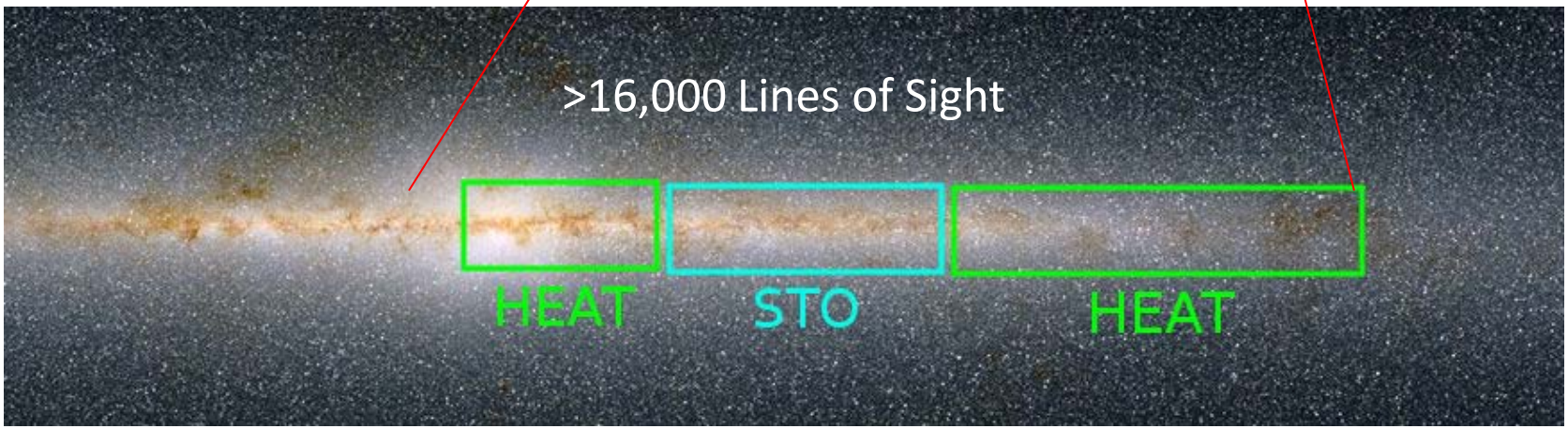
Dame et. al. 1987



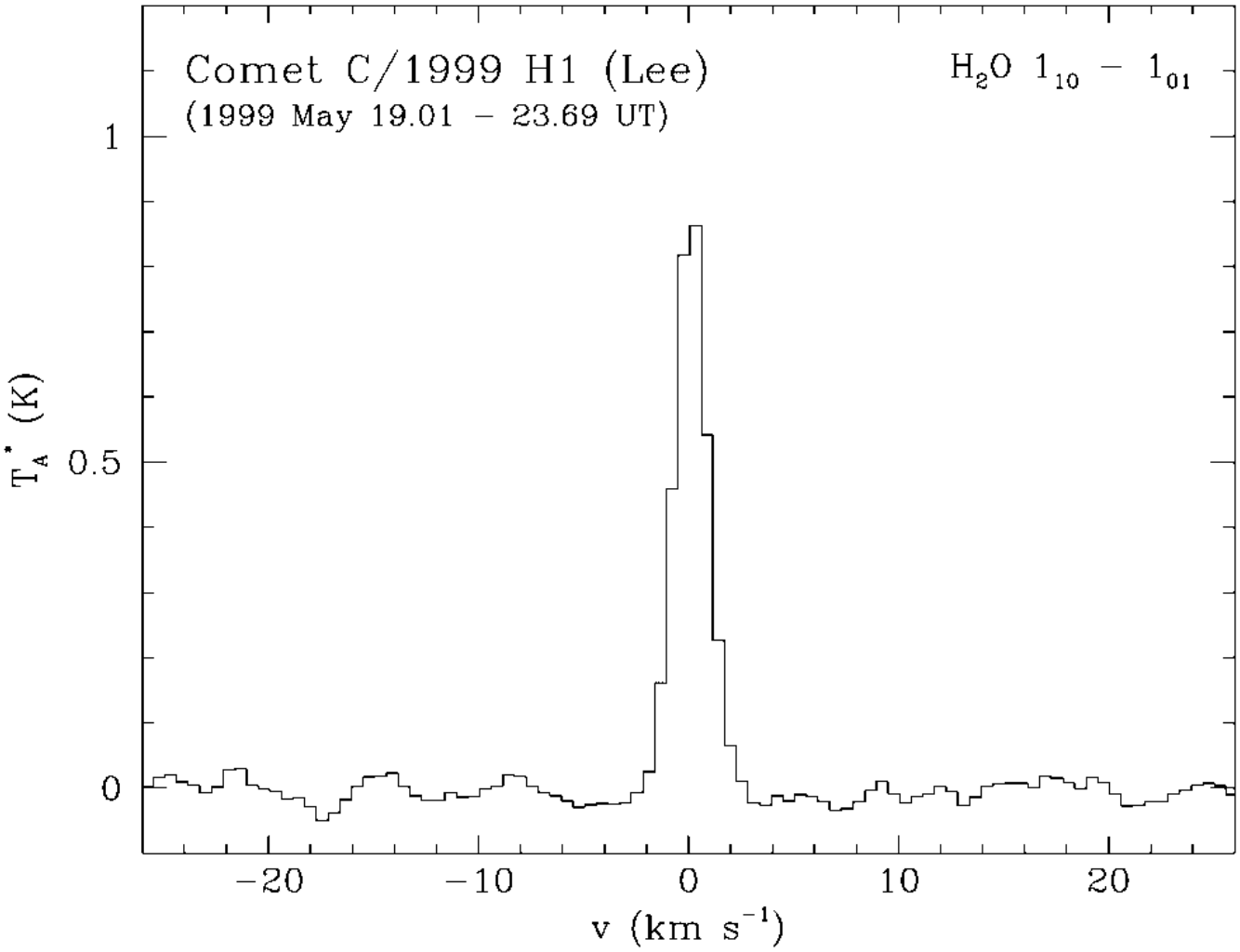
What does a ≥100 sq. degree survey look like?

Impressive

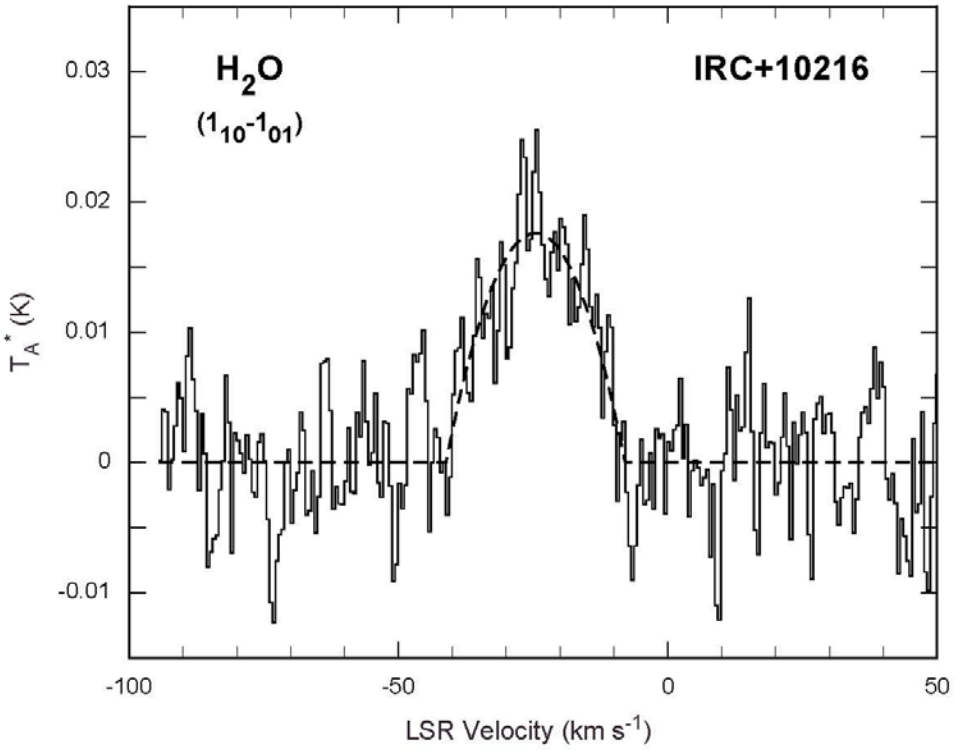




Oh yeah….*comets* too…



Exosolar Kuiper Belt Objects?



melnick_fig1. The *SWAS* $1_{10} - 1_{01}$ 556.936 GHz ortho-$H_2{}^{16}O$ continuum-subtracted spectrum obtained toward IRC+10216. The dashed line is a parabolic curve fitted to the spectrum (see text). All data were obtained with the telescope pointed at the position $\alpha = 9^h\ 47^m\ 57.4^s$, $\delta = 13°\ 16'\ 44''$ (J2000). The observations were carried out by nodding the observatory between the source position and a reference position 30 arcminutes north of the source,