# Astronomical radioreception techniques to detect the emission of molecular and short lived species in a cold plasma/gas chamber

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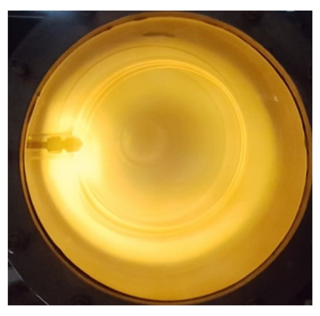
## Abstract

In this work we prove the viability of the use of HEMT radioastronomy receivers to detect rotational spectral lines emitted at room temperature by different molecular precursors and plasma products introduced or generated in a low pressure plasma chamber, placed in the beam path of the 40 m observatory radiotelescope of Yebes (Spain).

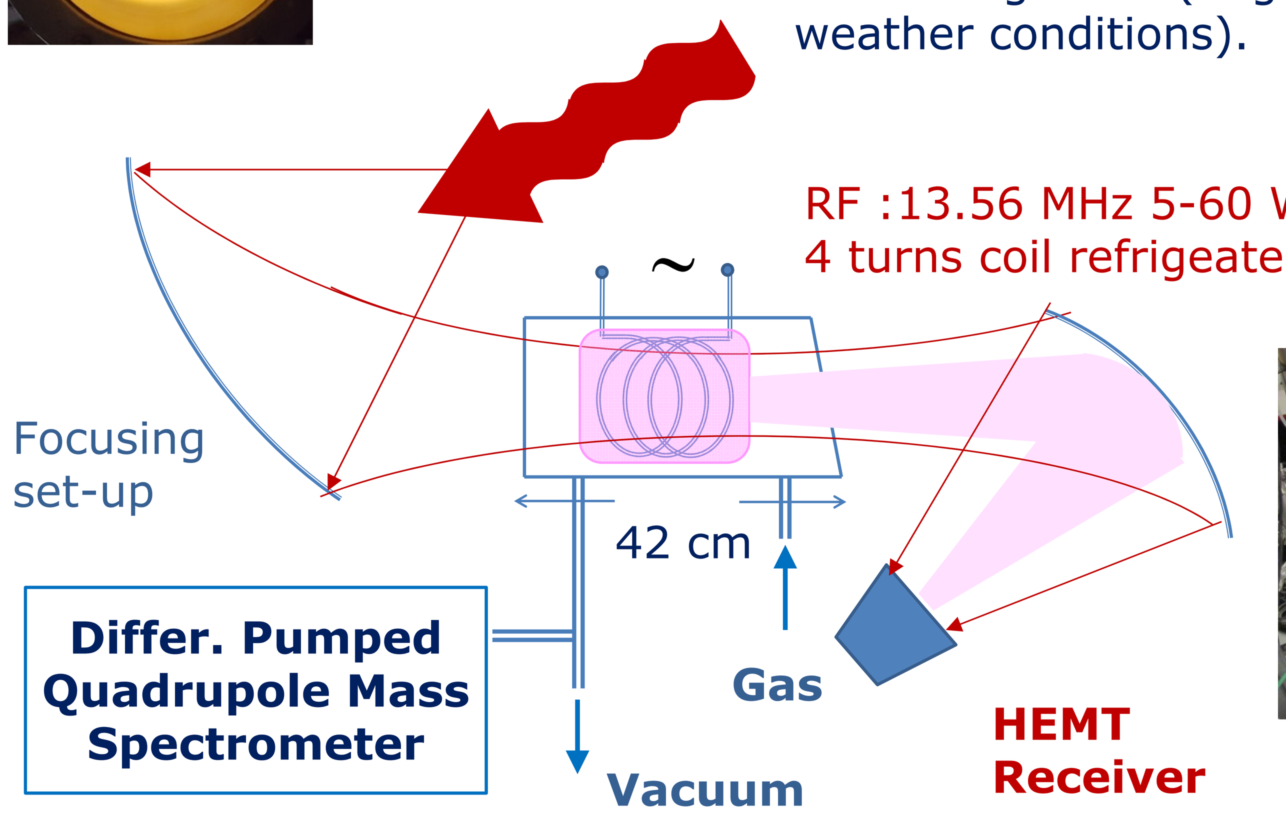
## Experimental Set Up

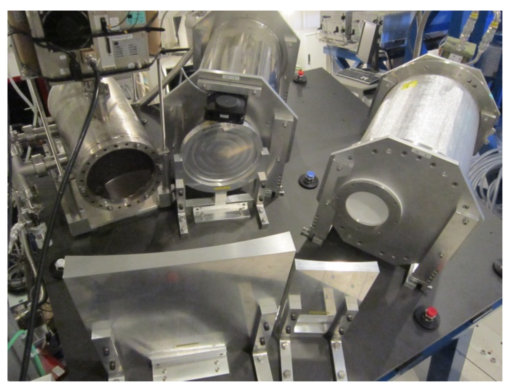


**PLASMA**

**40 m Radio Telescope**
Sky radiation from the radio-telescope used as cold background (in good weather conditions).

RF :13.56 MHz 5-60 W
4 turns coil refrigeated by water



**HEMT Receiver**
Spectral range: 33-50 GHz. Instantaneous bandwidth 2x2.5 GHz with FFTs.
Spectral resolution: 0.19 MHz for broadband spectroscopy, 38.1 KHz for high resolution spectroscopy

**PLASMA:**
Inductively Coupled RF Discharge, 13.56 MHz, 5-60 W
Coil: 4 turns,10 cm length, 17 cm diameter, Cu tube refrigeated by water

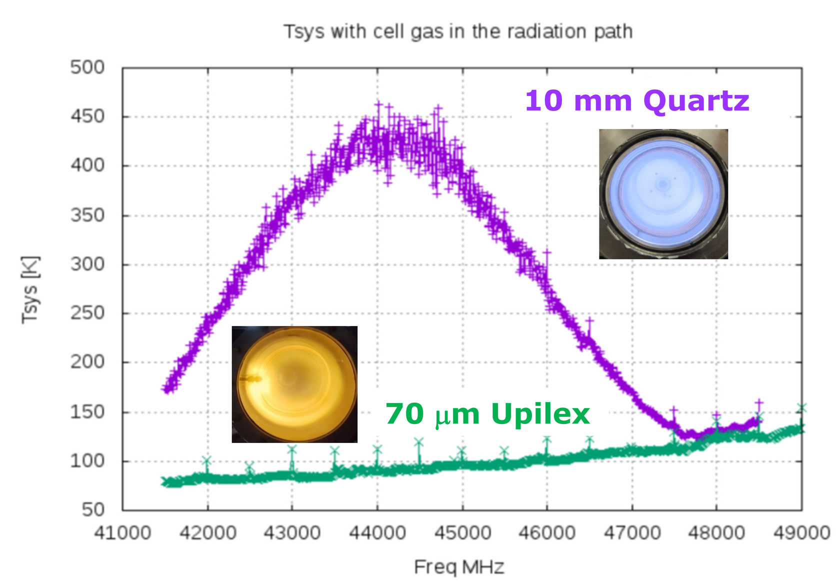
**Background for Thermal Emission Spectroscopy:**

Antenna towards the Zenith (clear blue sky) ⇒ 42 K at 45 GHz
Load of liquid $N_2$ (clouds or rainy weather) ⇒ 77 K

**Chamber windows:** Upilex®

75 μm thickness × 22 cm diameter.
Implosion risks due to their thinness.

Interference effects of the windows on the system temperature.

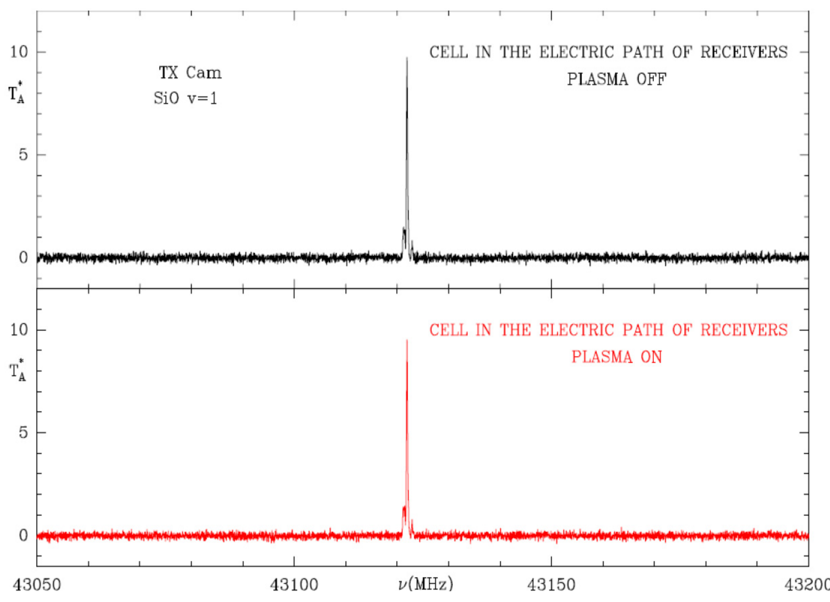



**MOLECULAR CLOUD**
**Size ~ $10^{19}$ cm**
**Density: ~ $10^4$-$10^5$ cm$^{-3}$**

Molecular cloud with $H_2$ ~ $10^{22}$ cm$^{-2}$ column density in the line of sight contains a column of CO ~ $10^{18}$ cm$^{-2}$ and HCN, $HCO^+$, HNC, CCH, CN, CS… ~ $10^{14}$ cm$^{-2}$

Plasma chamber: L = 42 cm, T=300 K
P = 10 Pa (0.1 mbar, 2.4 × $10^{15}$ cm$^{-3}$) } Column Density ~ $10^{17}$ cm$^{-2}$

**1% Plasma Radicals ~ 0.1 Pa ⇒ ~ $10^{15}$ cm$^{-2}$**

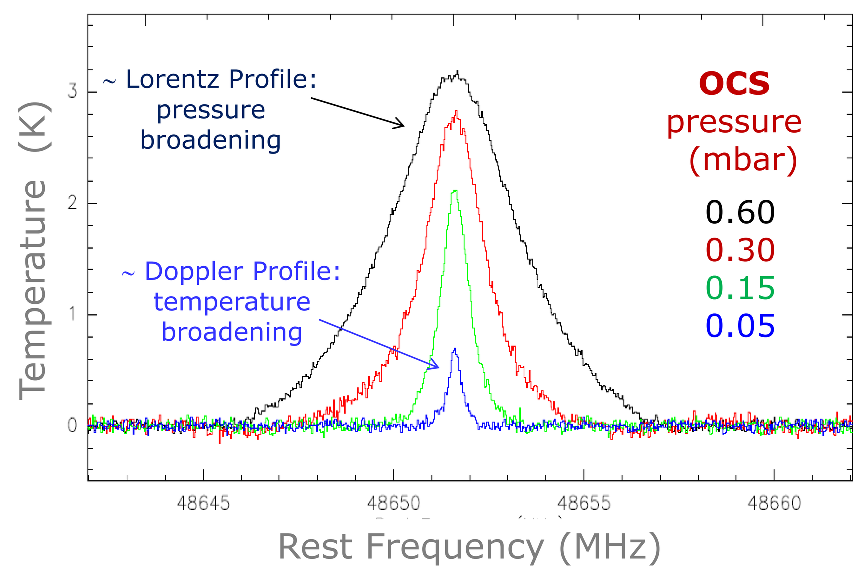



### Tests with the HEMT receiver

With plasma ON, no spurious signals have been induced in the spectra from any coupling of the RF discharge and the receivers.

Radioastronomical observations of a SiO maser in TX Cam have shown identical results with plasma ON or OFF.

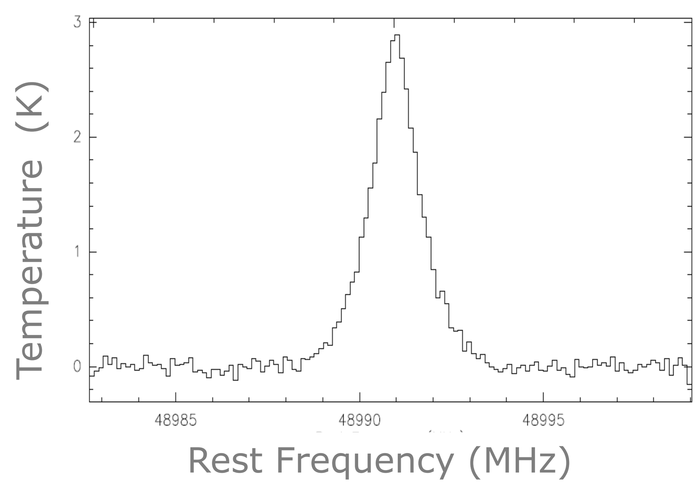
## Results




### OCS Gas

Carbonyl Sulfide (OCS) emission vs. gas pressure.

Very good baselines (gas cell with OCS – empty gas cell). $OC^{34}S$ and $v_2$ lines detected



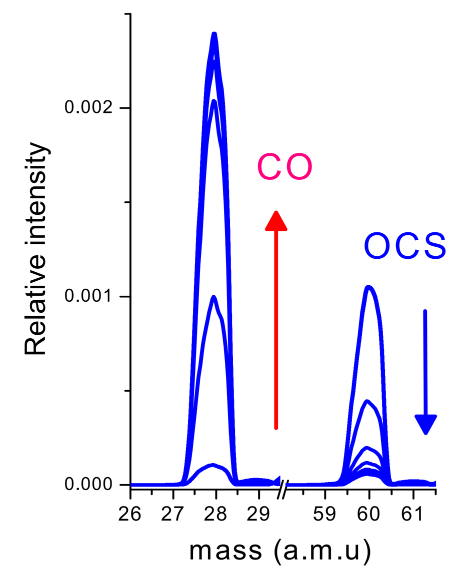

### OCS Plasma

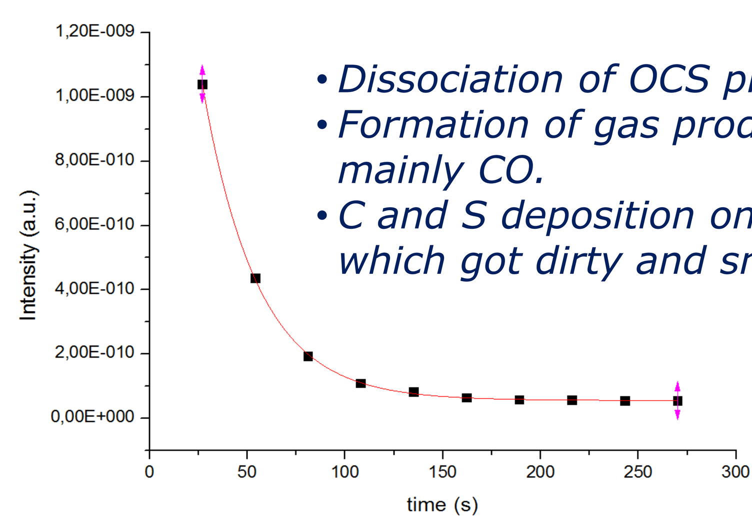
*0.15 mbar, 5 W, $t_{residence}$ ~ 2 min*

Very net and clear spectral emission of generated CS radical detected succesfully!

### Mass Spectrometer Results

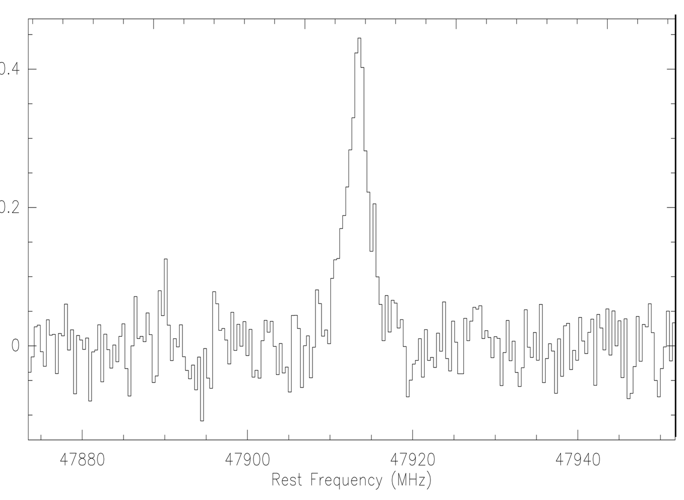
**Time evolution of OCS after plasma ignition**

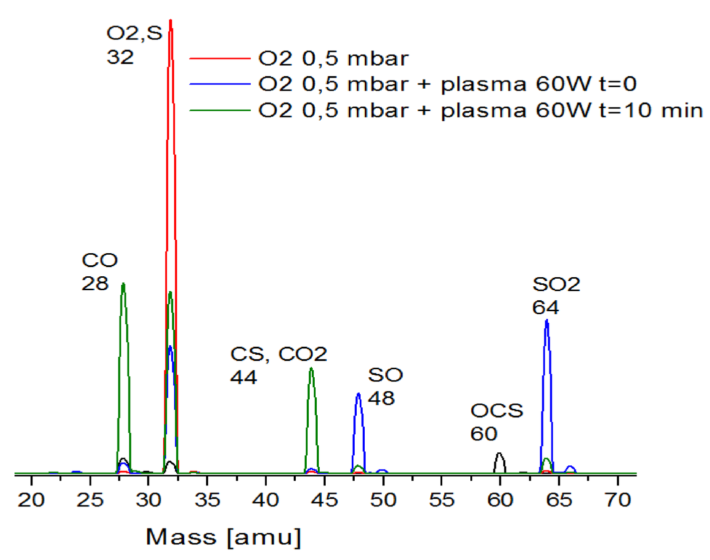



- *Dissociation of OCS precursor.*
- *Formation of gas products, mainly CO.*
- *C and S deposition on the walls, which got dirty and smelly.*

### $O_2$ discharge after S & C wall deposition by previous OCS and $CS_2$ plasmas: $SO_2$ and CO production






- $O_2$, 0.5 mbar, 60 W.
- $SO_2$ produced first and disappeared in 5-10 min in favor of CO and $CO_2$.
- $SO_2$ emission: different vibrational states, $v_2$ = 0,1,2 observed, depending on RF power.

## Summary & Conclusions

- Radioastronomical receivers can be used to perform spectroscopy and chemical simulations in a cell of moderate size.
- Sensitivity can be as good as 0.0001 mbar of CS in 20 sec at 49 GHz.
- HEMT receivers are extremely stable. Baselines can be corrected with a systematic instrumental baseline (stable for periods of ~1 hours).
- No coupling observed between receivers and the power supply source of RF Plasmas.

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