Latitudinal and seasonal variations of O_2 on Mars using Herschel/HIFI

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Objective of the study

- With a mean mixing ratio above 0.1%, molecular oxygen is, after nitrogen and argon, the most abundant minor species. Still, its abundance and seasonal variations remain poorly studied, because of the weakness of its spectroscopic signatures. Oxygen was first detected at 0.76 μm by Barker (1972) and Carleton and Traub (1972), with a mixing ratio of 1300 ppm.
- A new disk-averaged measurement of 1400 ± 120 ppm has been recently inferred by Hartogh et al. (A&A 521, id. L49, 2010) using high-resolution heterodyne spectroscopy at 774 GHz with the HIFI instrument aboard *Herschel* (April 2010, Ls = 76°).
- As a non-condensible species, oxygen on Mars, like CO, is expected to show spatial and temporant variations, but these measurements have not been performed yet on O_2.
- We have been using HIFI aboard Herschel to study the latitudinal variations of O_2 on Mars for two different seasons, Ls = 47° (Dec. 23, 2011) and Ls = 108-115° (May 09-25, 2012). In addition, HDO and $H_2{}^{18}O$ transitions have been measured simultaneously for a retrieval of D/H. ^{13}CO and $C^{18}O$ transitions have been recorded simultaneously to infer CO mixing ratio and check the consistency of the GCM thermal profile.
- The present report describes the analysis of the O_2 and CO data.

The data set

Dates:

Dec 22, 2011 – Ls = 47°, Mars Diam = 8.3 arcsec

May 25, 2011 – Ls = 115°, Mars Diam = 8 – 9 arcsec

Transitions:

Simultaneous measurements:

- ^{13}CO 1870.141 GHz, $C^{18}O$ 1863.039 GHz, O_2 1870.018 GHz
- O_2 1812.405 GHz, HDO 1818.519 GHz
- HDO 1625.408 GHz, $H_2{}^{18}O$ 1633.483 GHz

Herschel FOV: 11.3 arcsec @ 1870 GHz, 12.9 arcsec @ 1633 GHz

Observation sequence:

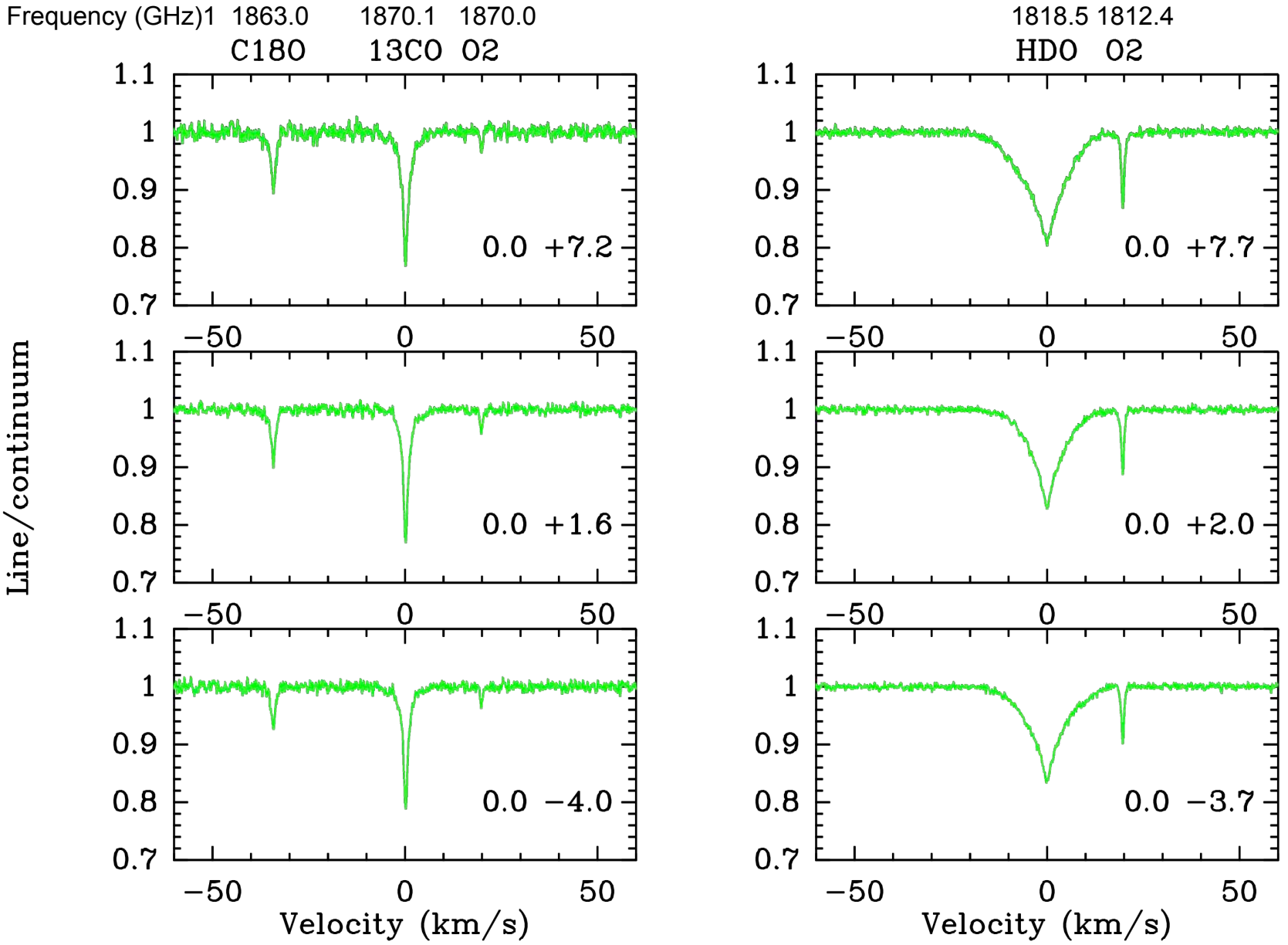
For each period, three observations were successively recorded, centered along the central meridian, at the south limb, the center and the north limb.

Total observing time: 27 hours

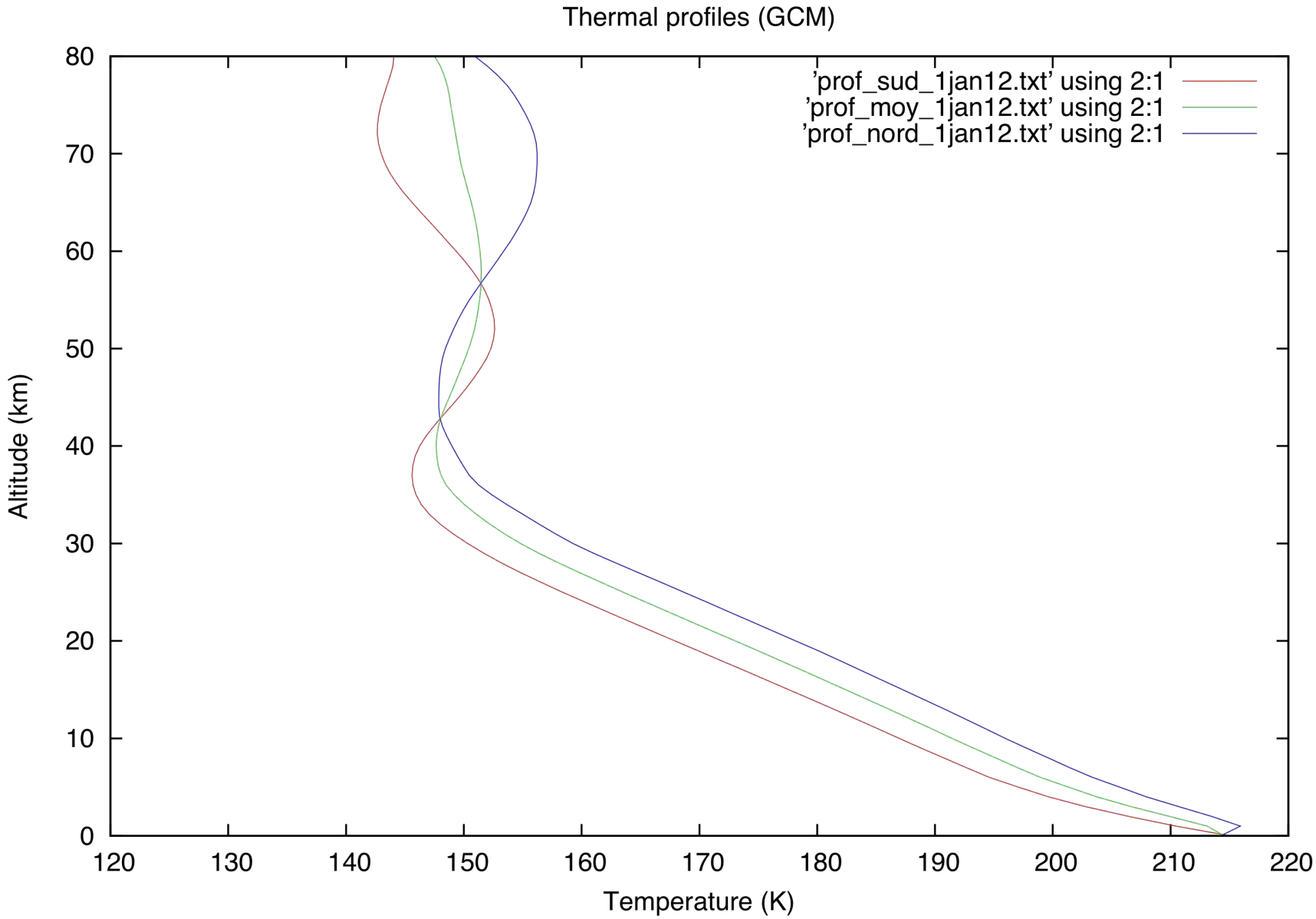
Data analysis

- Strong ripples are present in the raw data because Mars is a strong continuum source (Hartogh et al. A&A 521, id.L48, 2010)
- Ripple has been corrected from the known instrument standing wave frequency by removing sinusoidal baselines
- N-S offsets have been inferred using a radiometric model of Mars
- RT calculations have been made for the exact offsets of the observations, using the EMCD-GCM temperature profiles, for different values of the CO and O_2 mixing ratios
- Best fits are shown in the next figures, for the ^{13}CO and $C^{18}O$ lines and for the two O_2 lines, for the 3 disk positions and the two seasons.

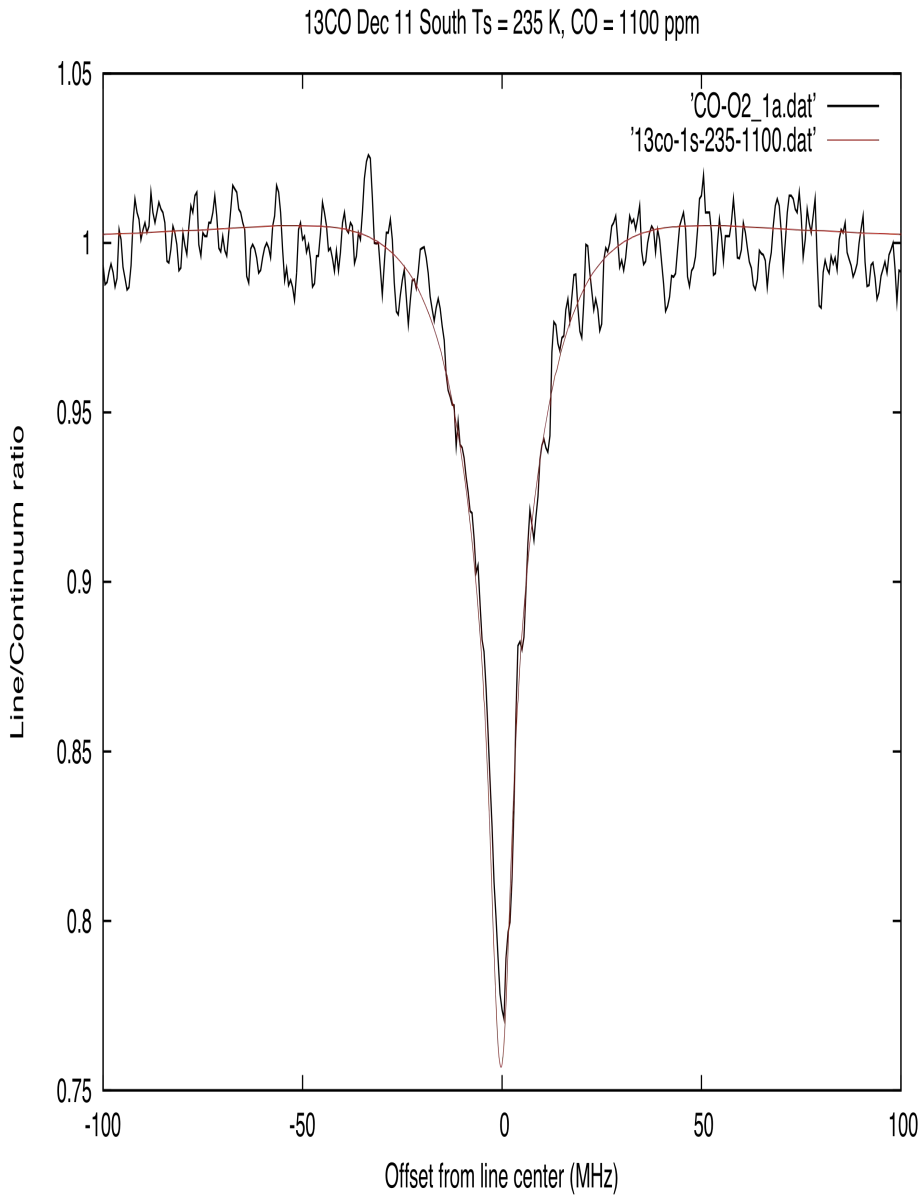
Herschel/HIFI data after ripple correction

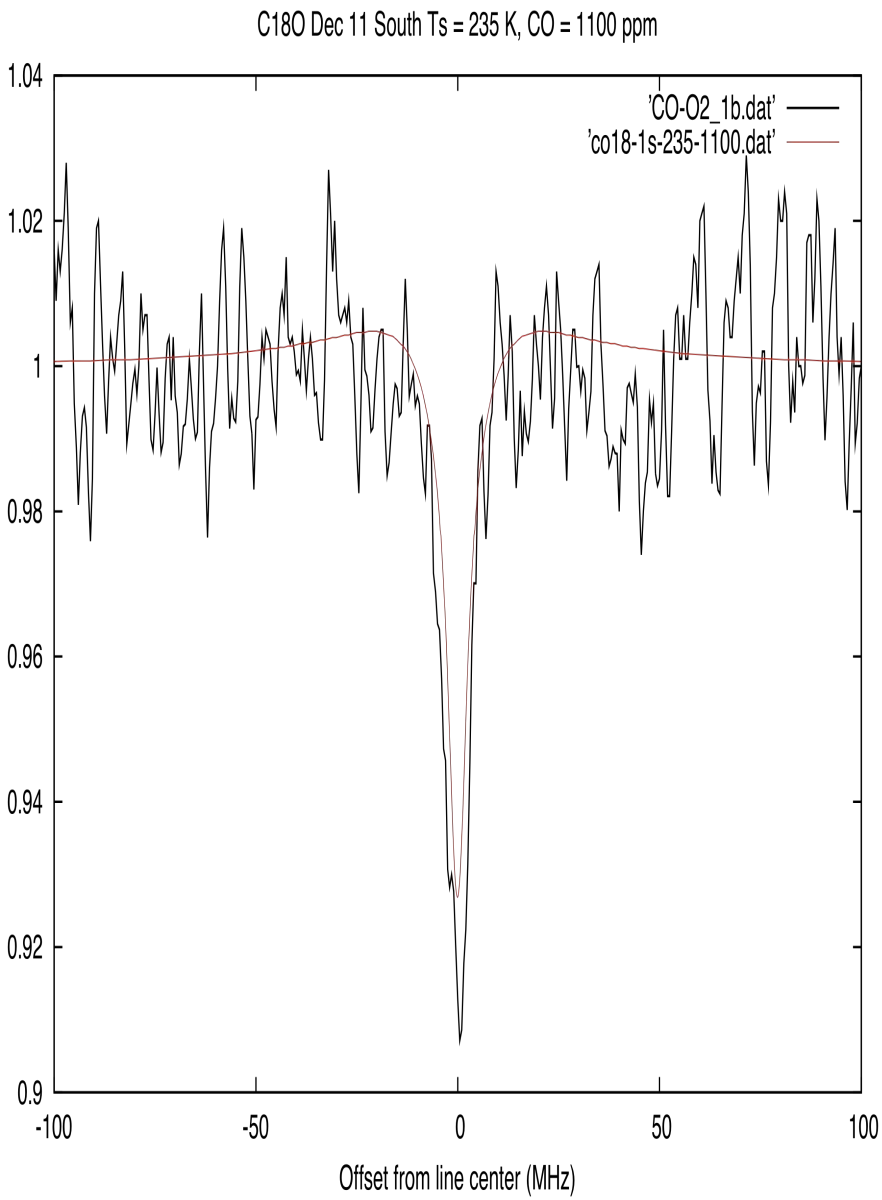


22 Dec 2011 Data – Thermal profiles

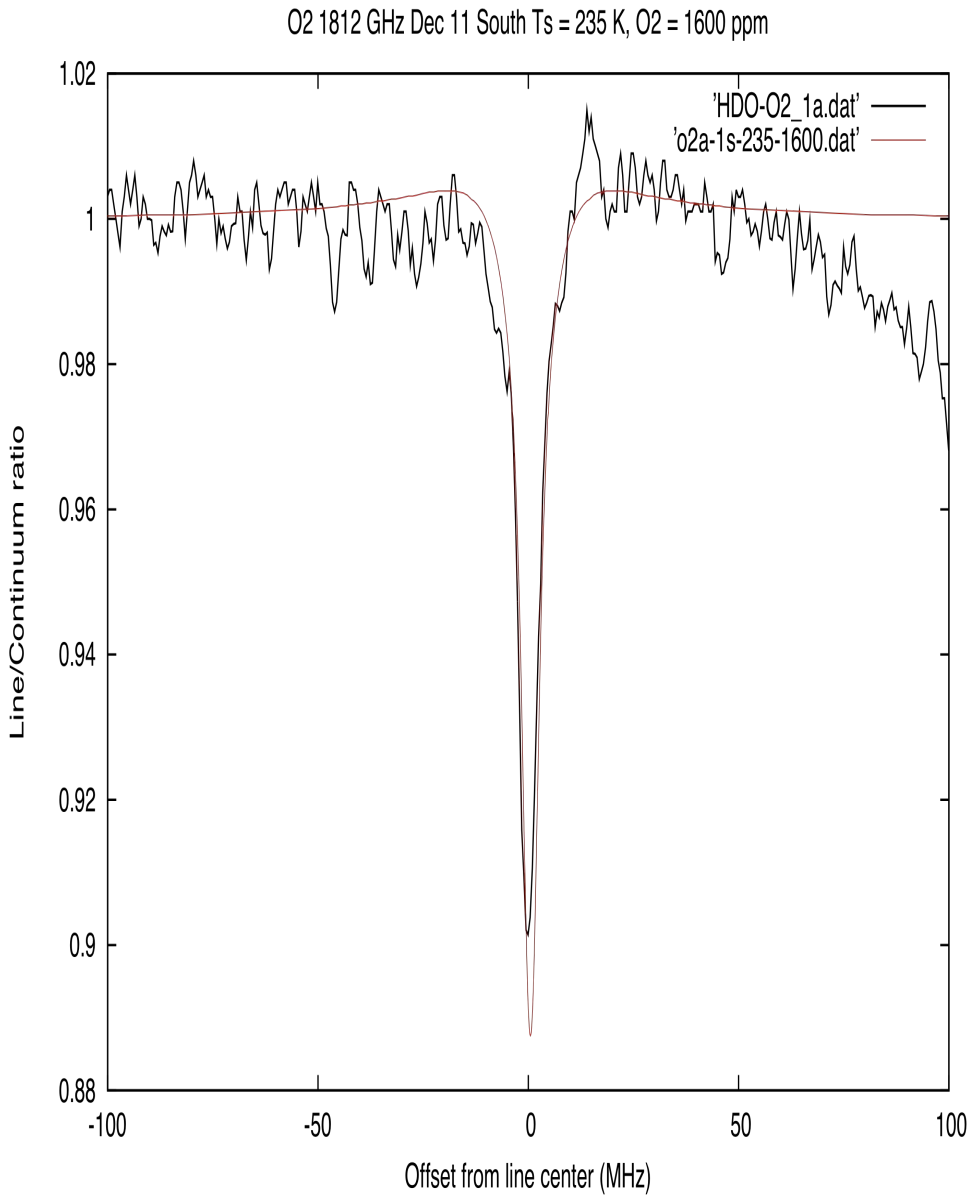


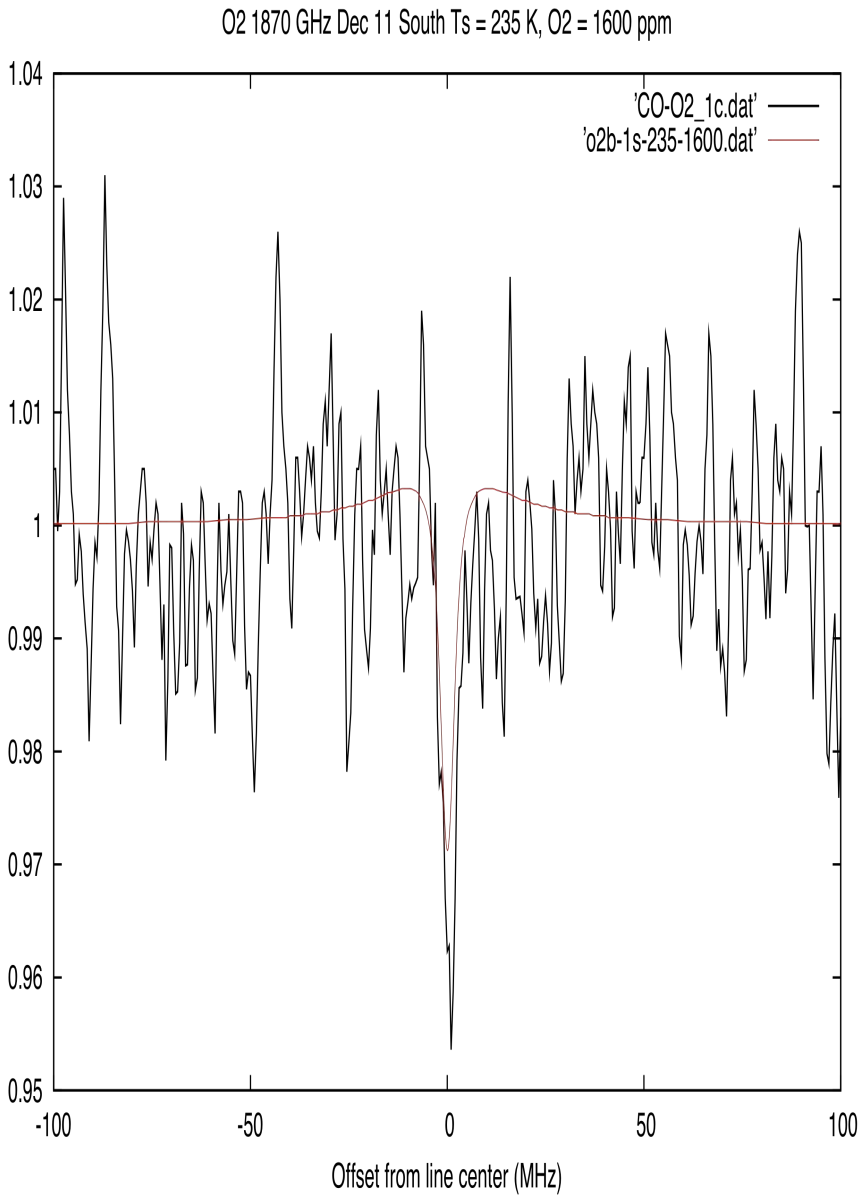
HIFI/Herschel, Dec 22, 2011, South – Ls = 47° - CO = 1100 ppm



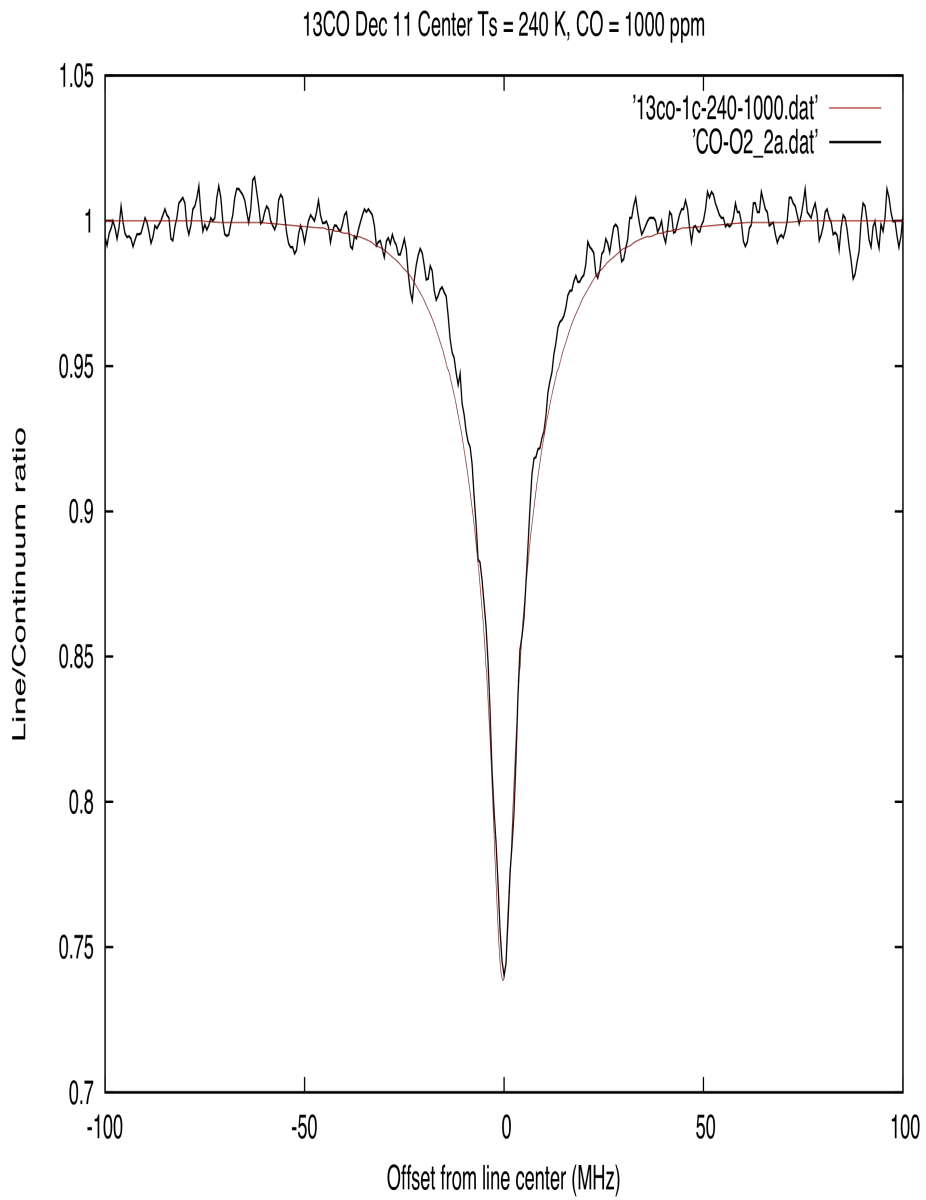


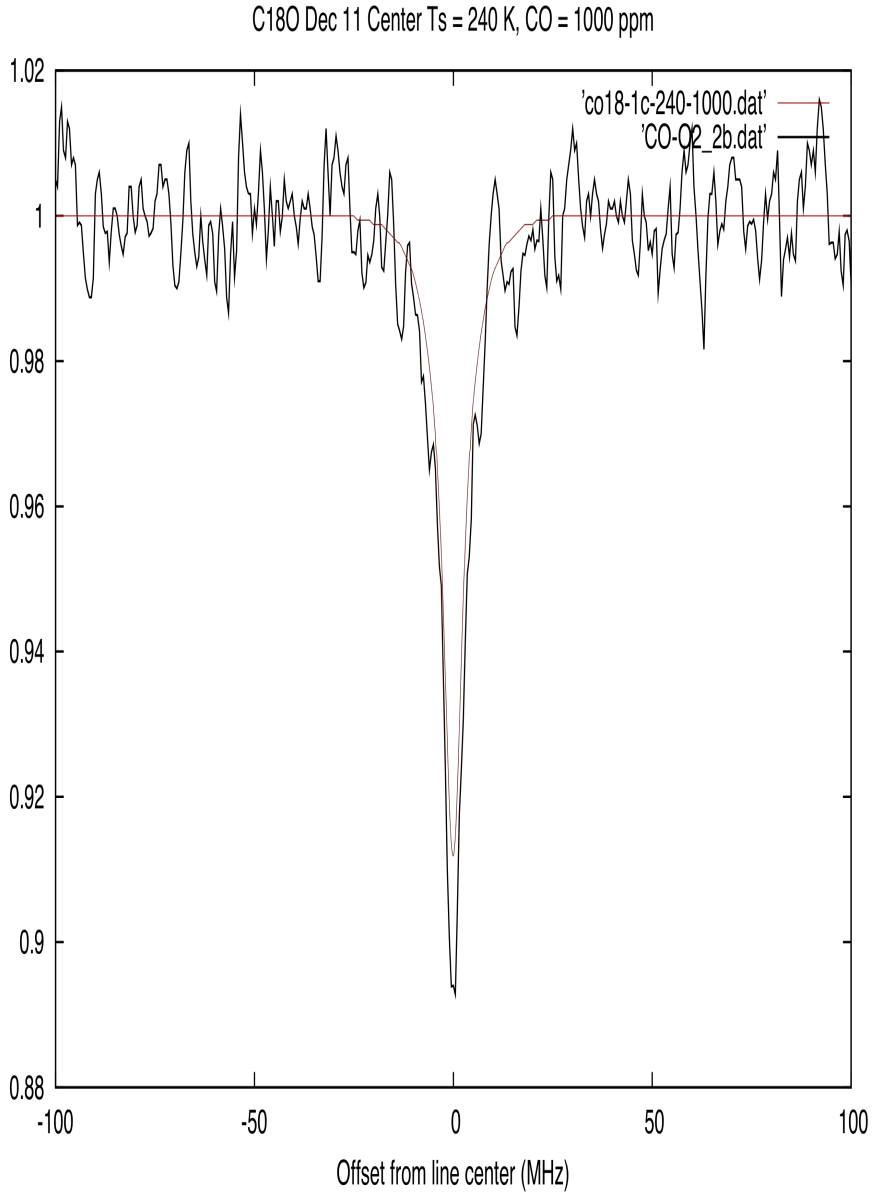
HIFI/Herschel, Dec 22, 2011, South – Ls = 47° - O_2 = 1600 ppm



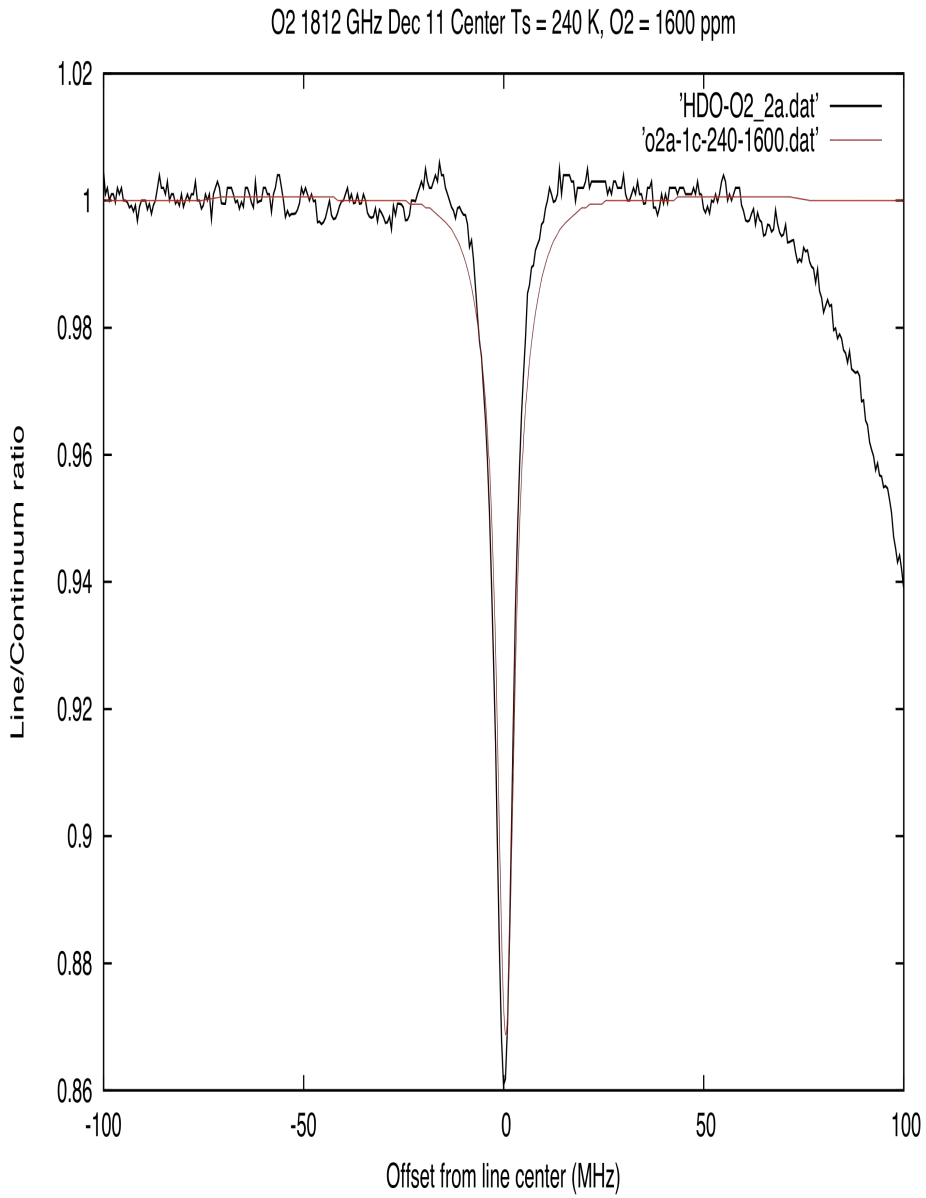


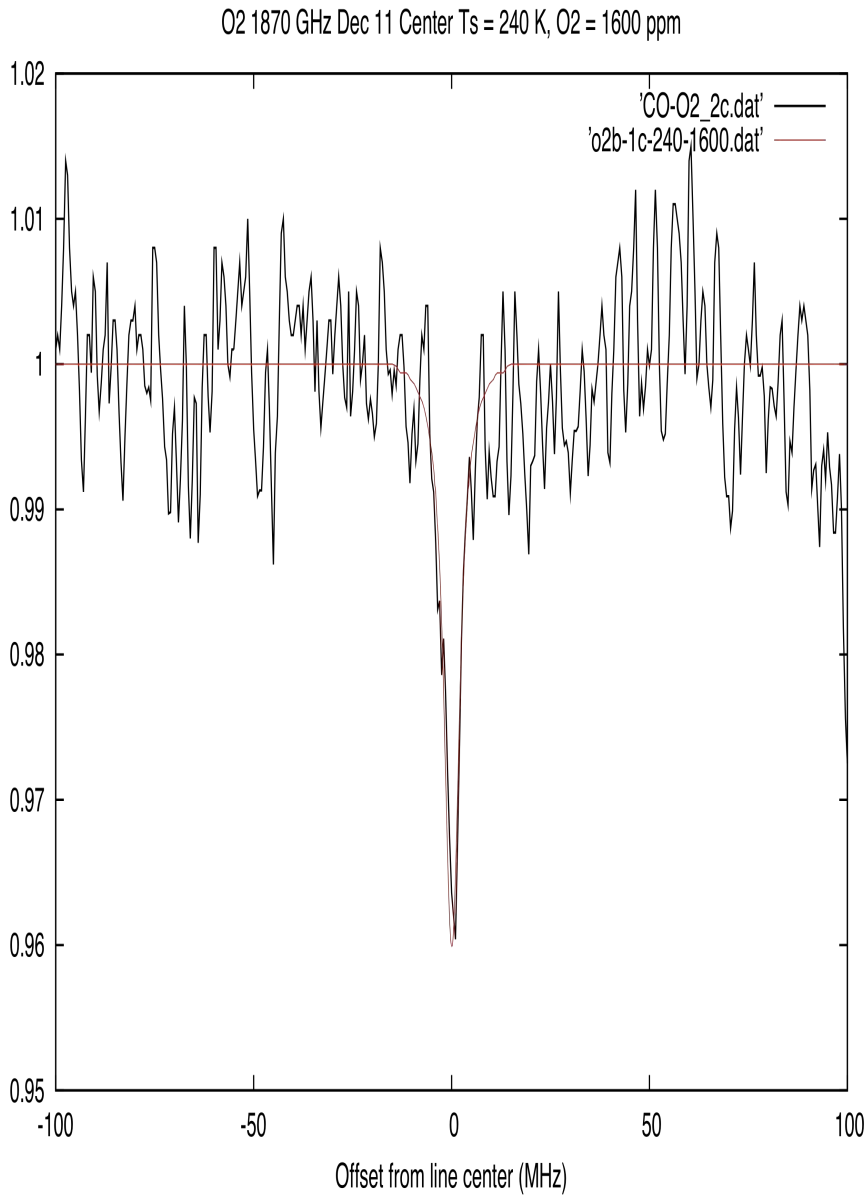
HIFI/Herschel, Dec 22, 2011, Center – Ls = 47° - CO = 1000 ppm



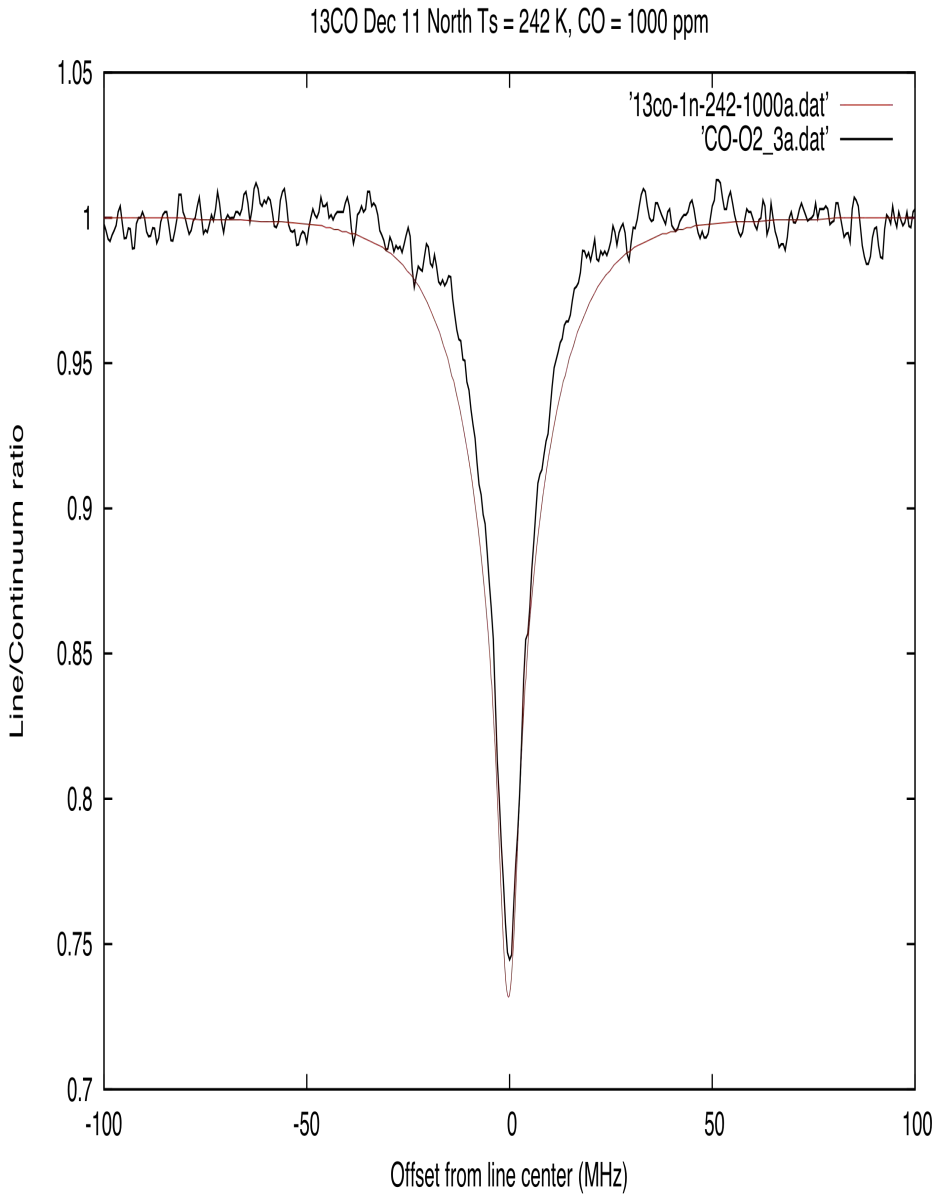


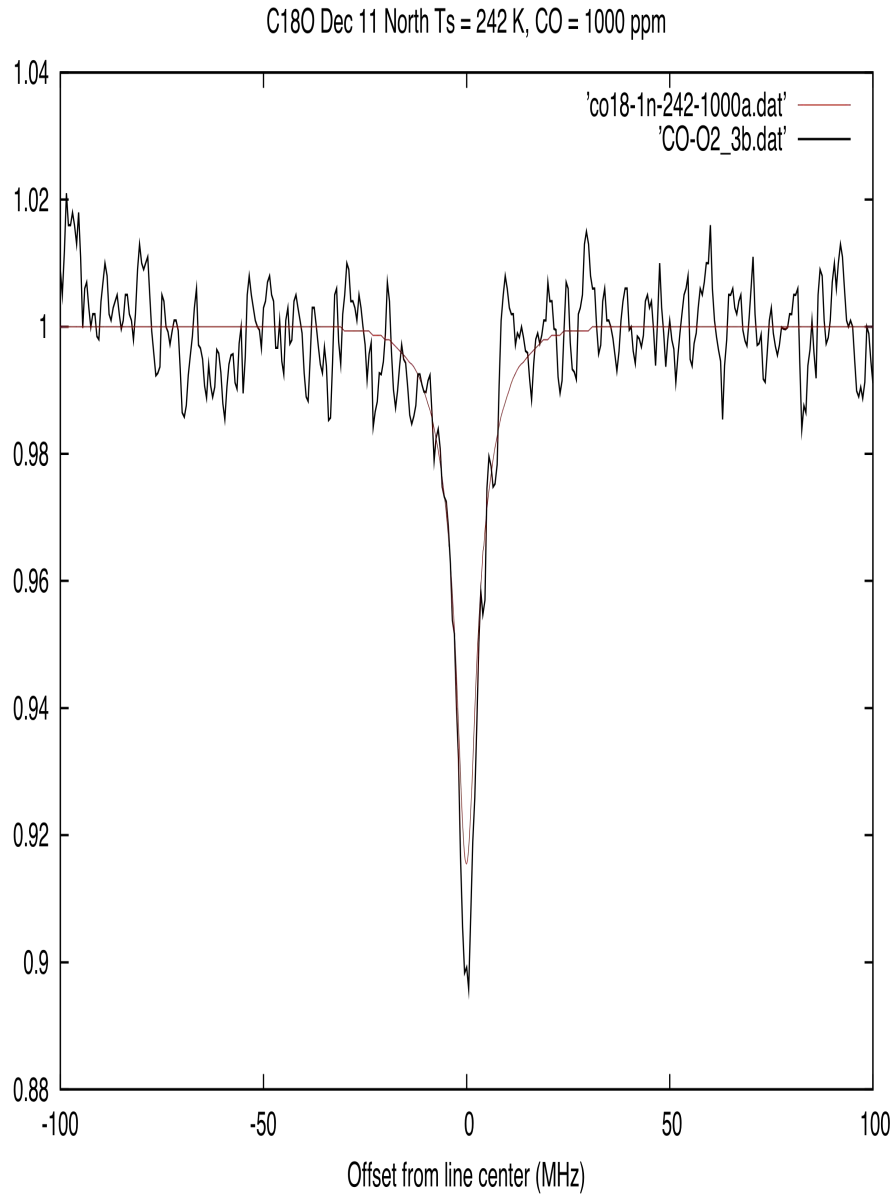
HIFI/Herschel, Dec 22, 2011, Center – Ls = 47° - O_2 = 1600 ppm



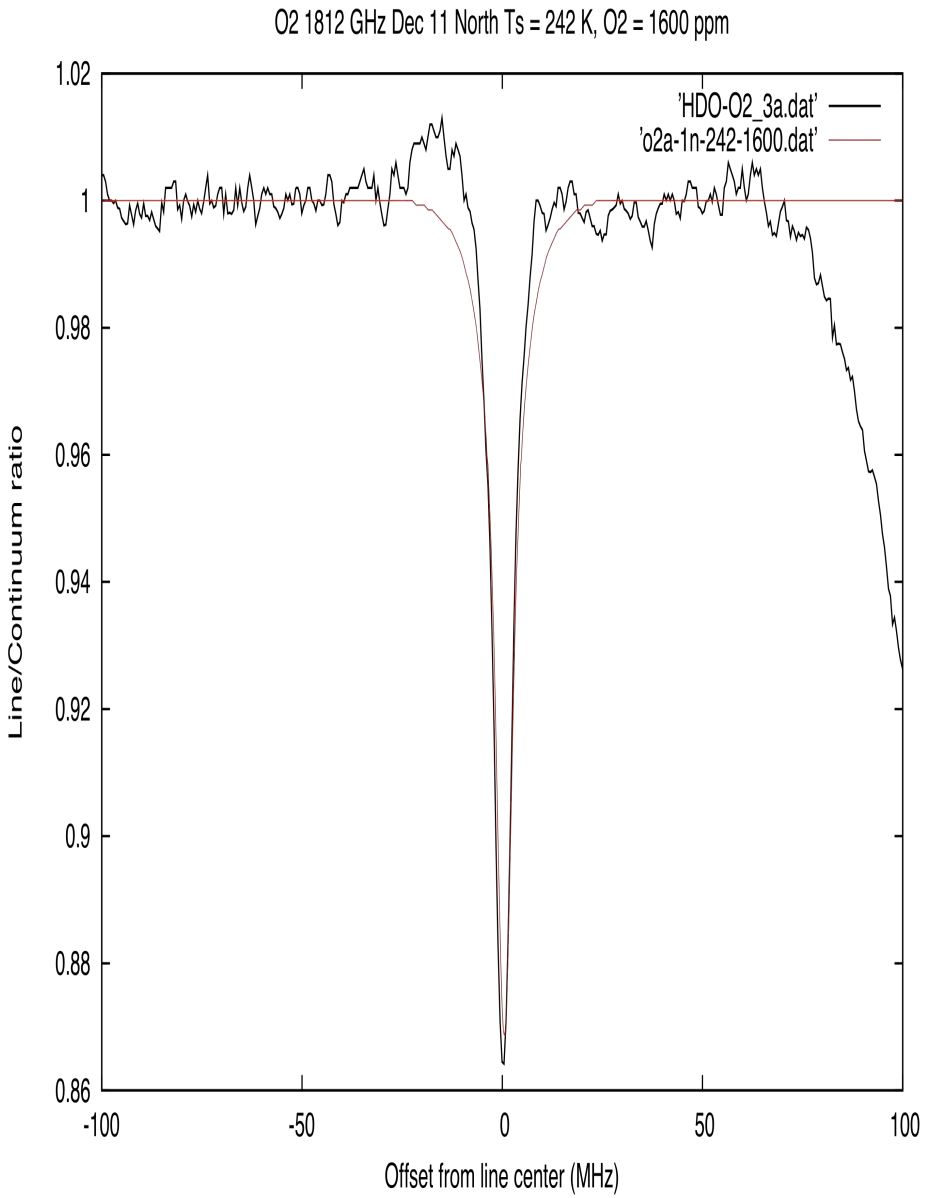


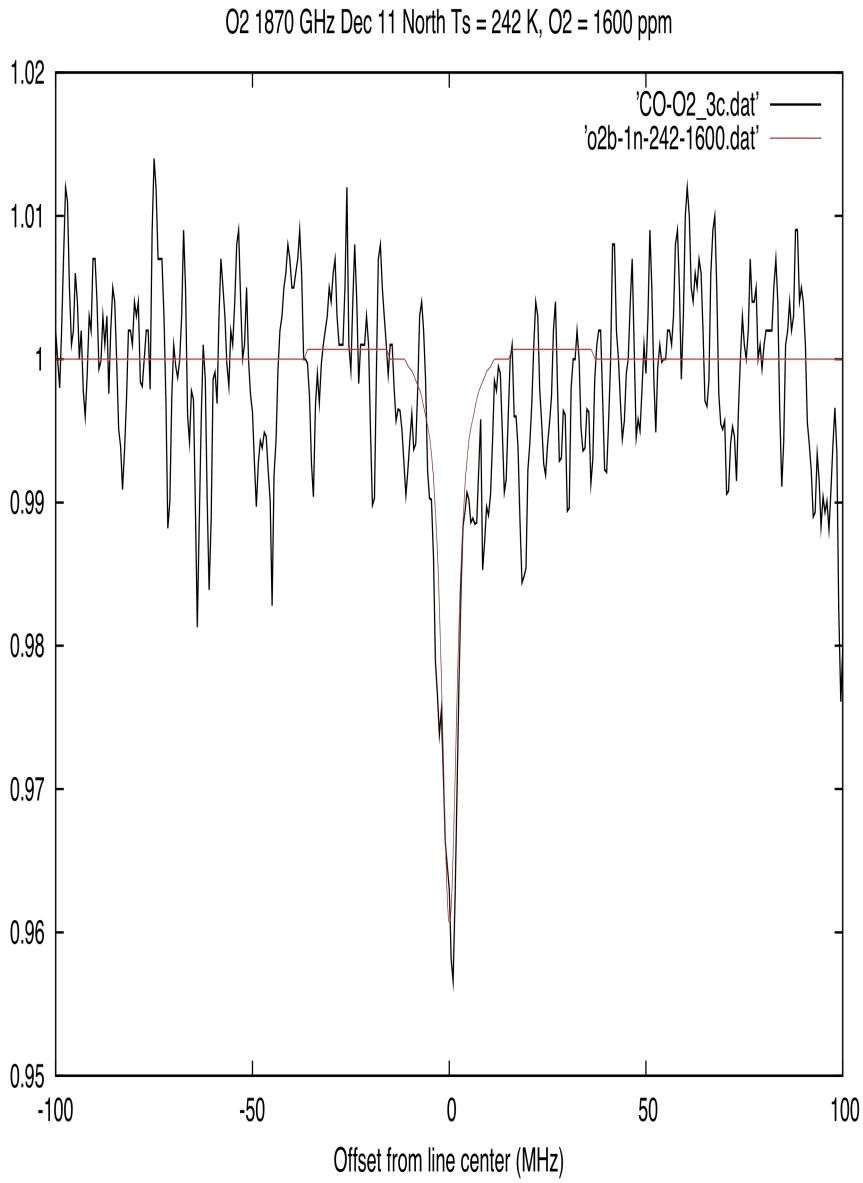
HIFI/Herschel, Dec 22, 2011, North – Ls = 47° - CO = 1000 ppm



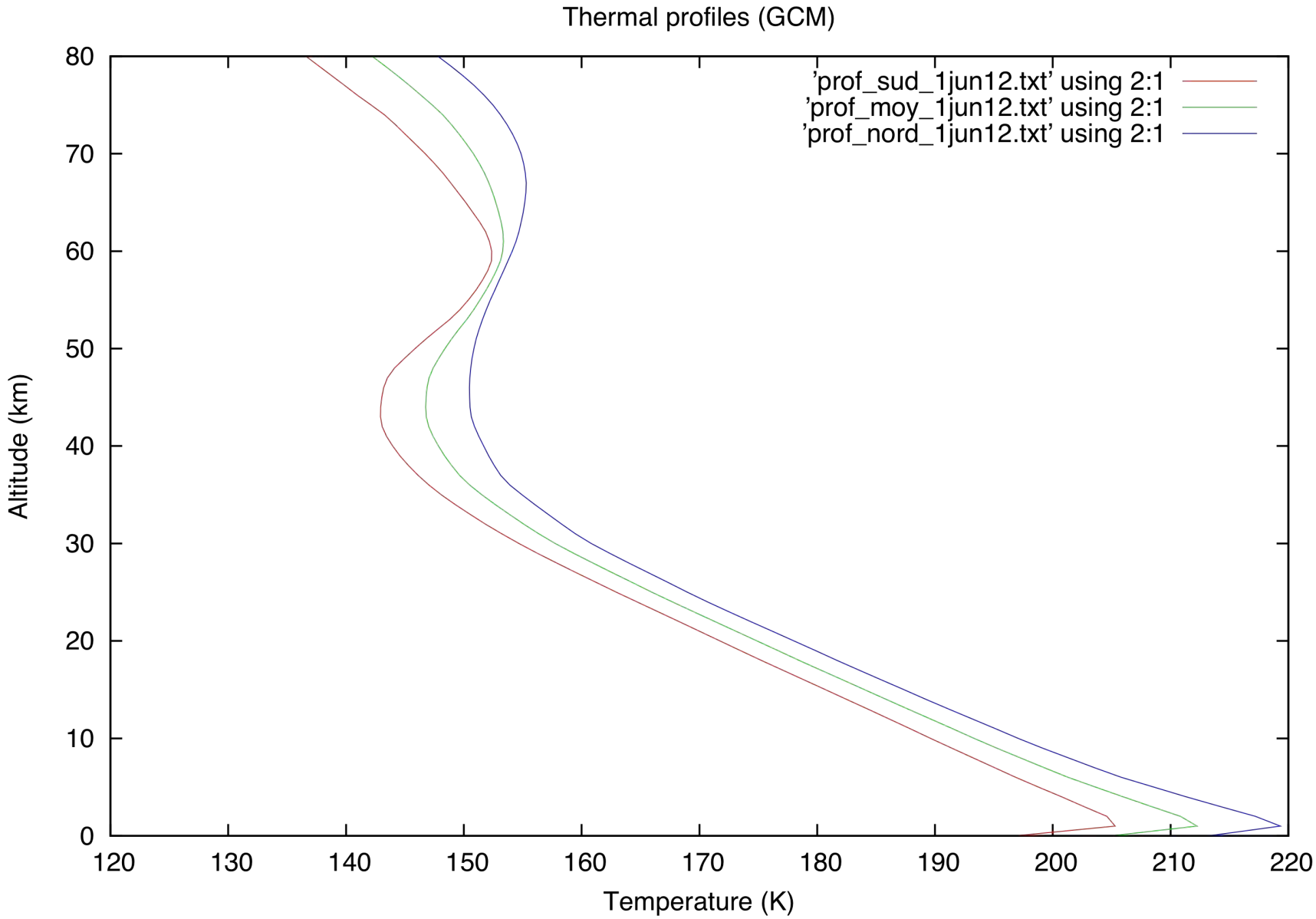


HIFI/Herschel, Dec 22, 2011, North – Ls = 47° - O_2 = 1600 ppm

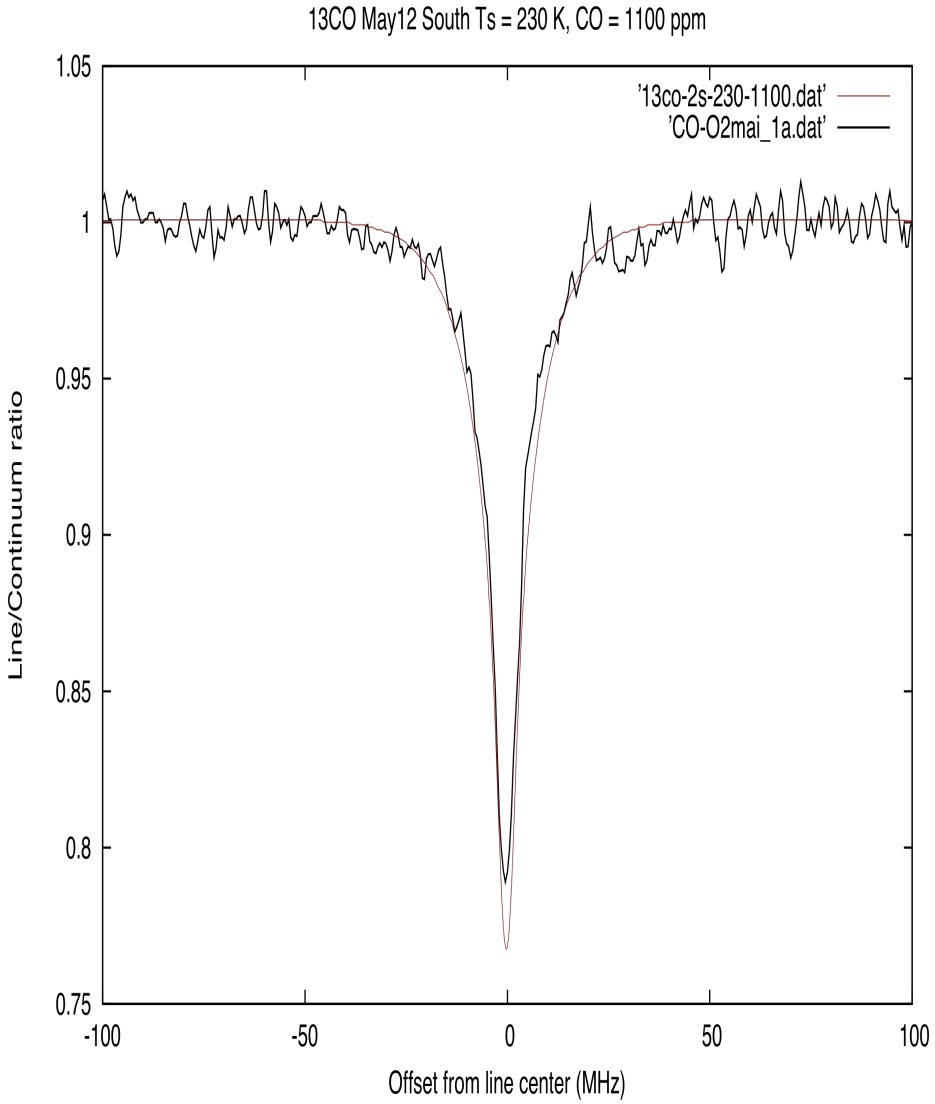


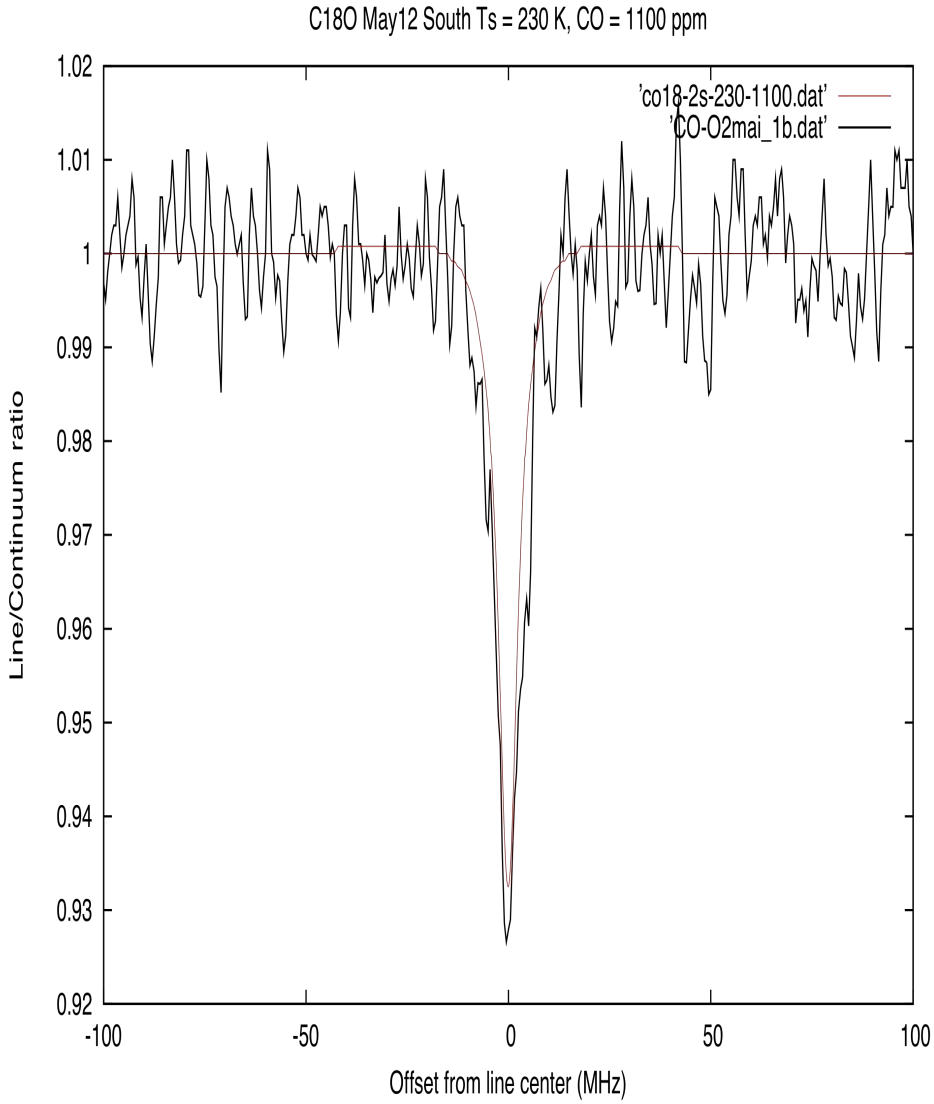


25 May 2012 Data – Thermal profiles

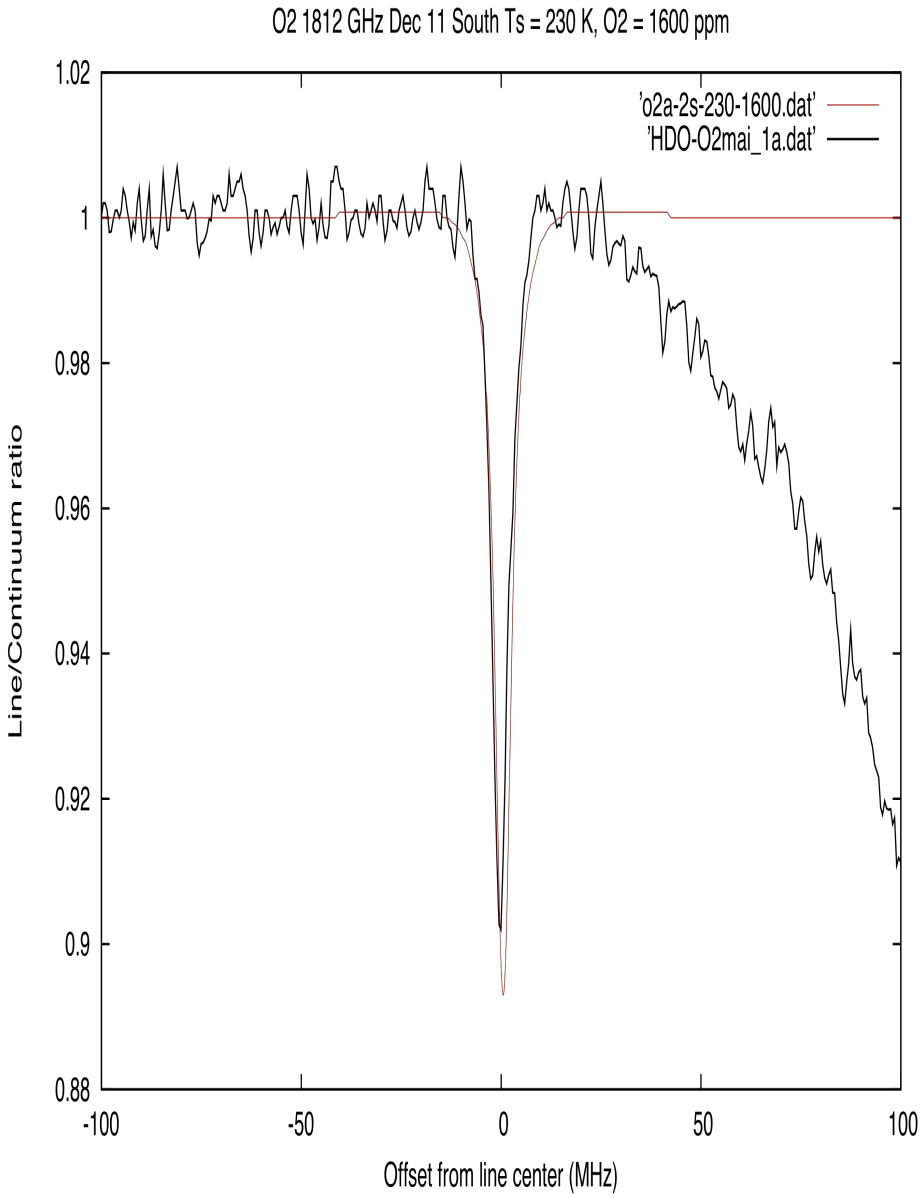


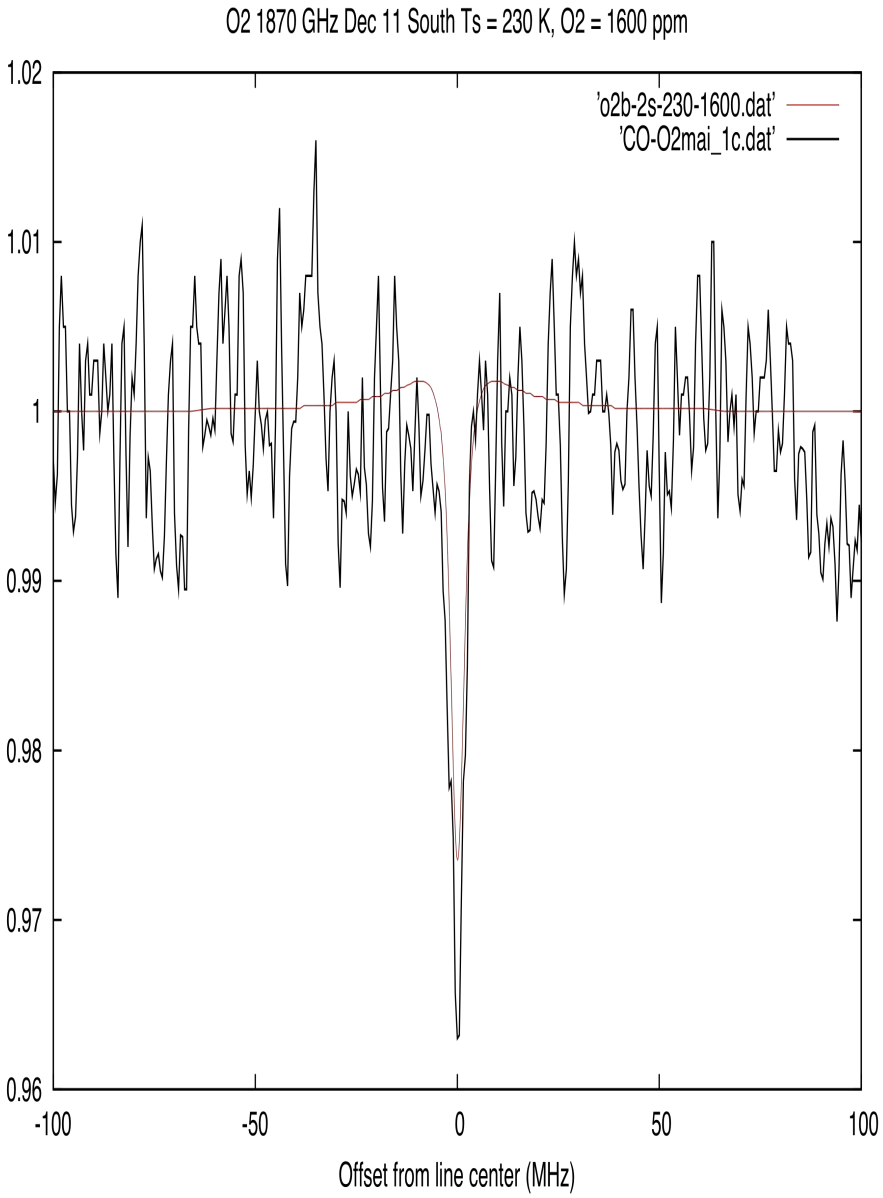
HIFI/Herschel, May 25, 2012, South – Ls = 115° - CO = 1100 ppm



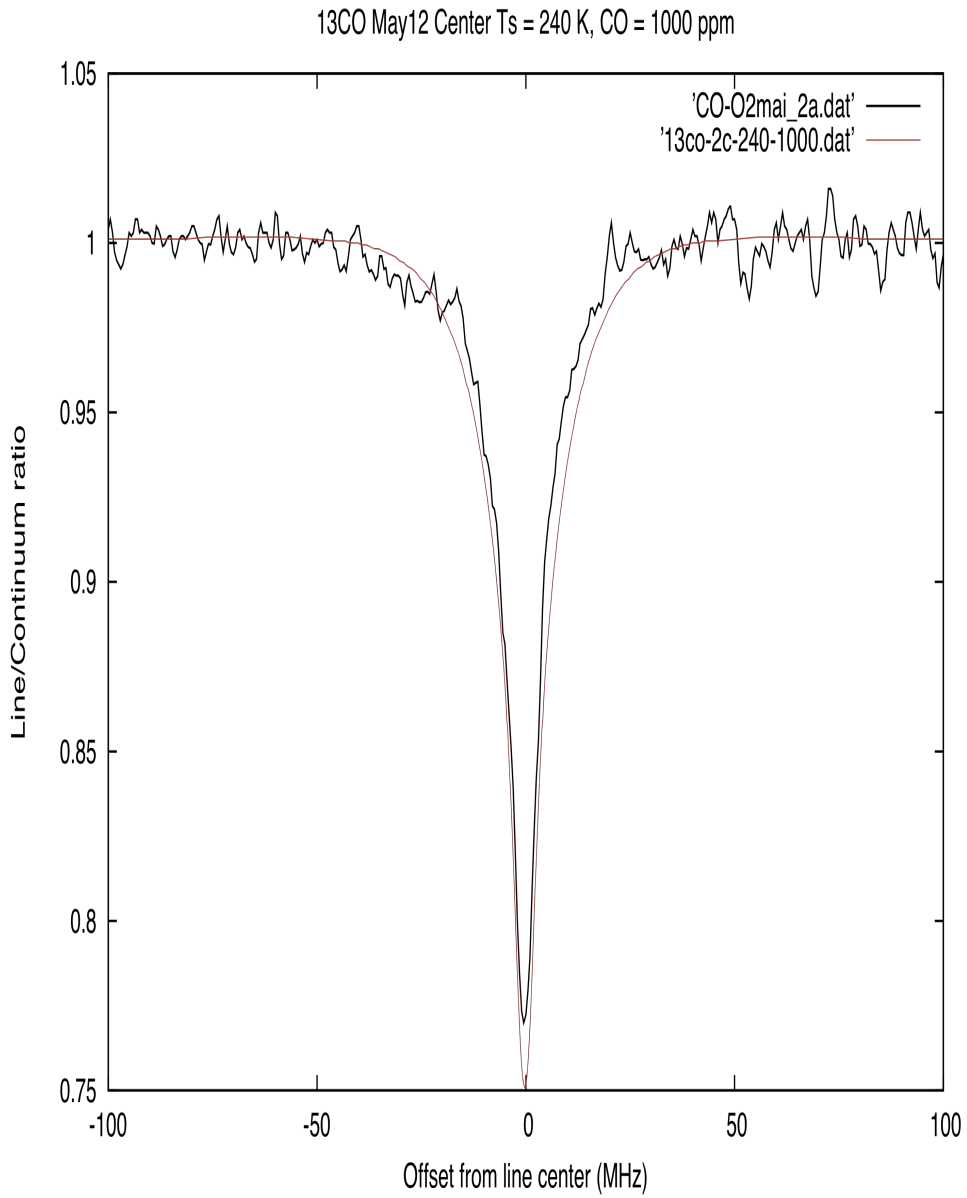


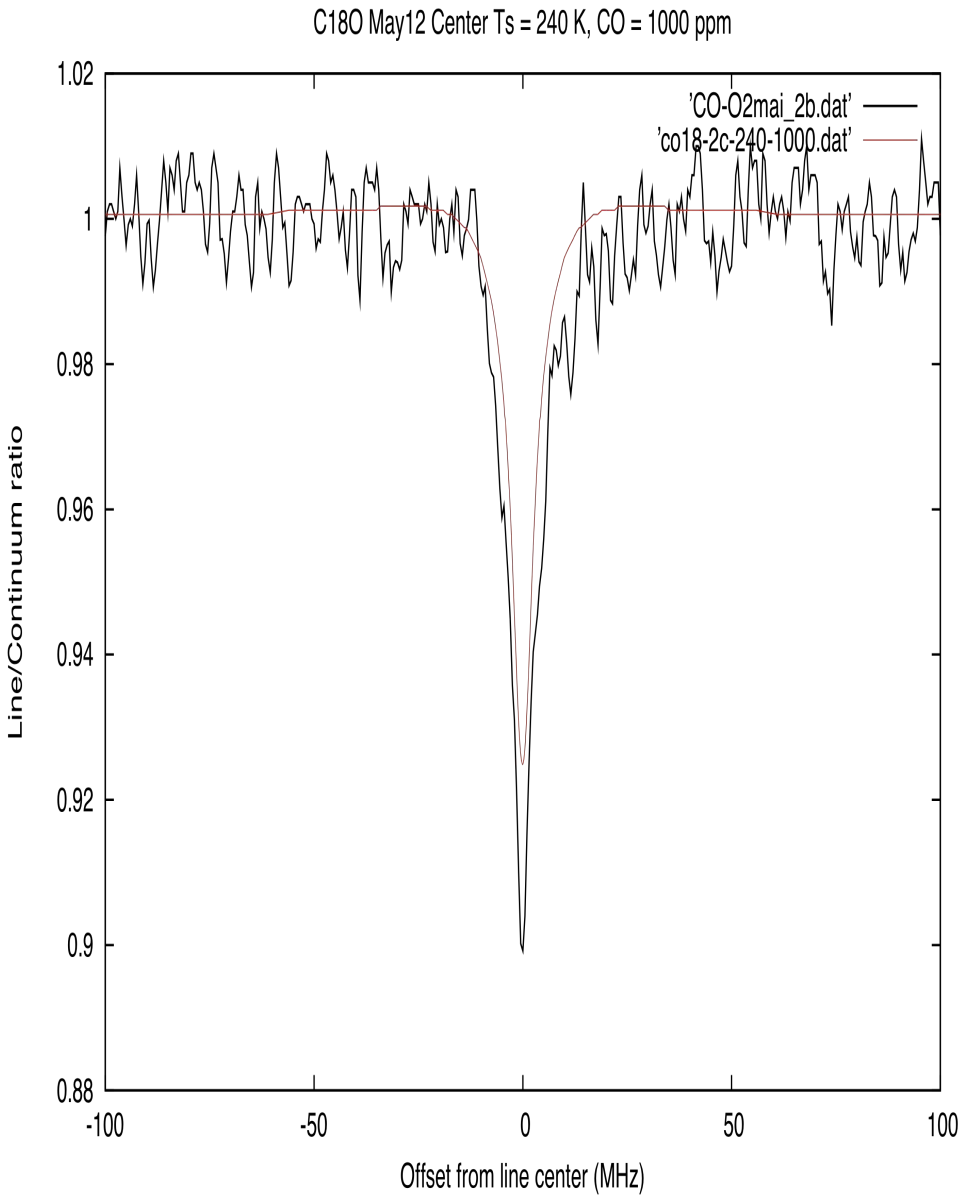
HIFI/Herschel, May 25, 2012, South – Ls = 115° - O_2 = 1600 ppm



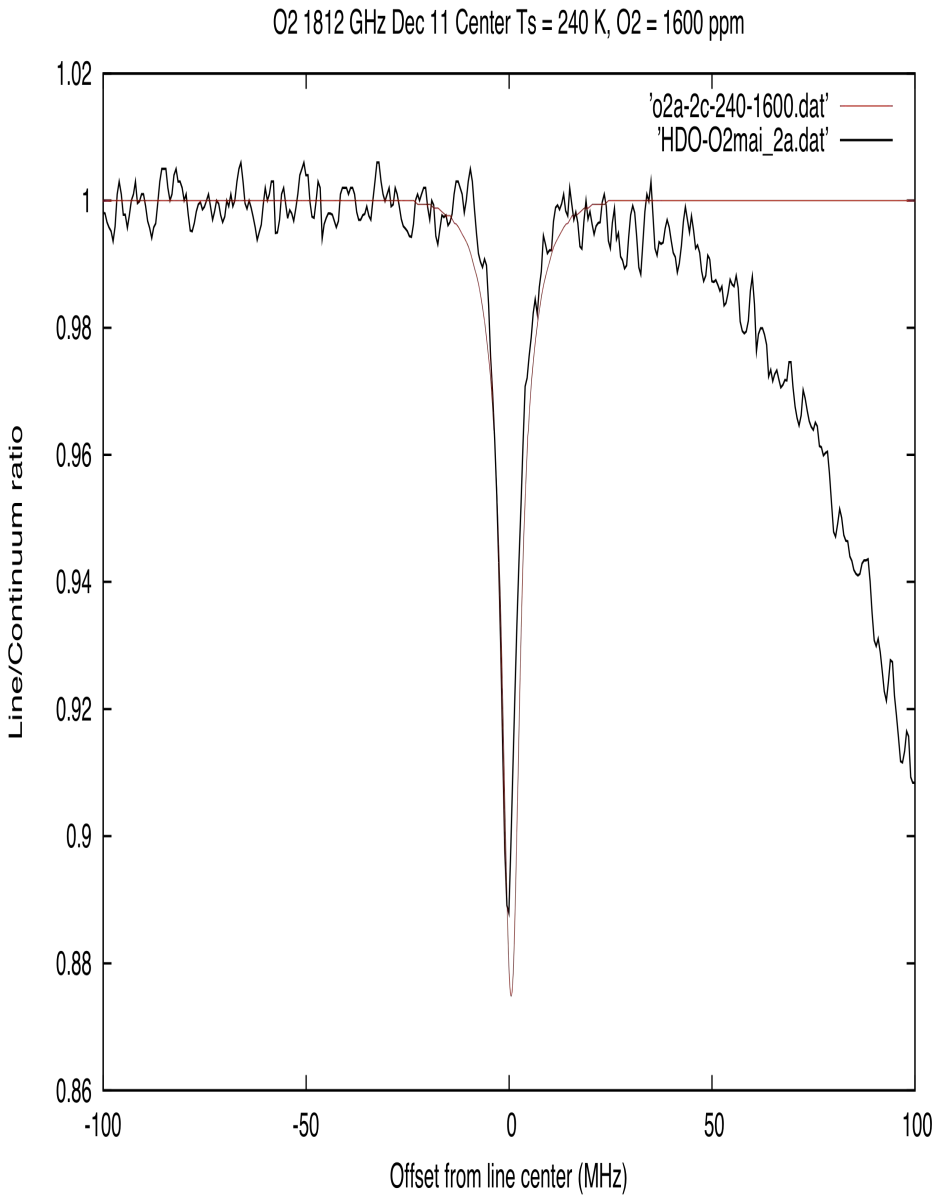


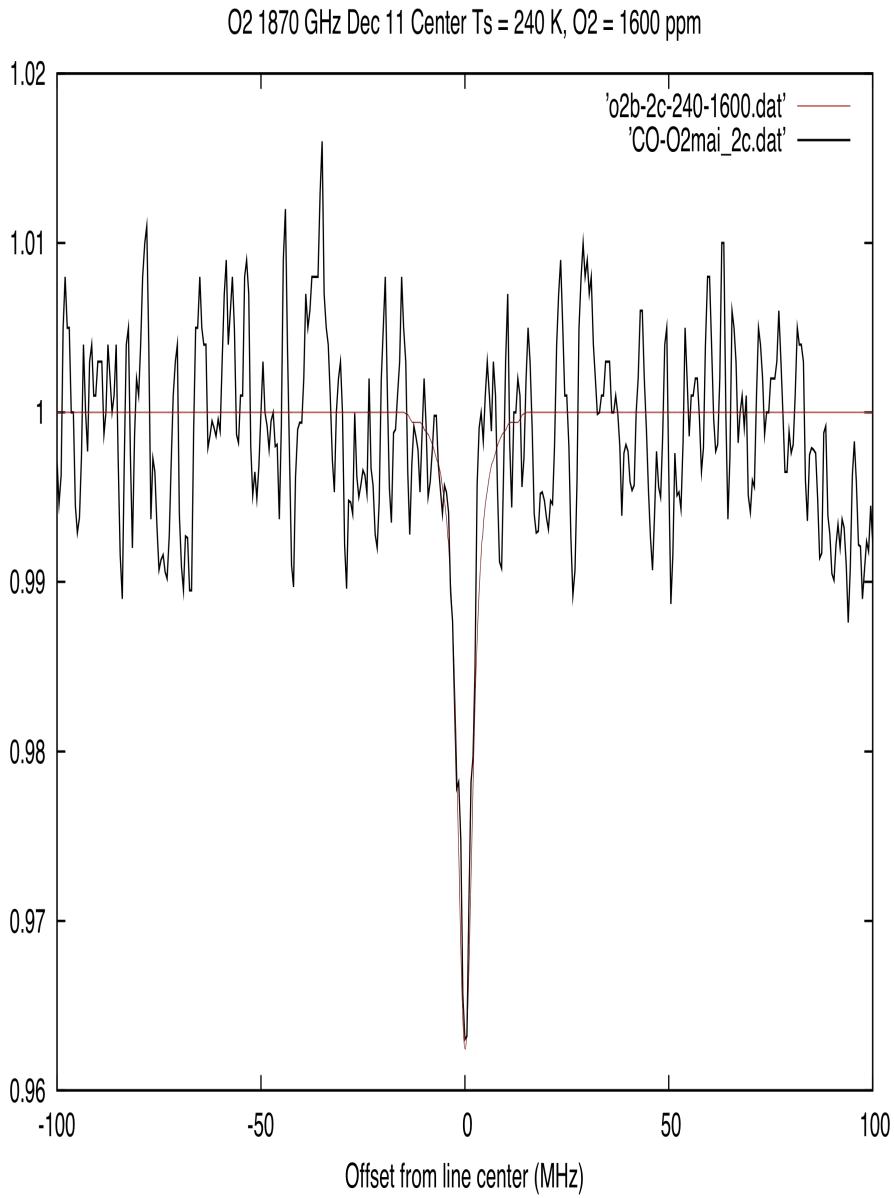
HIFI/Herschel, May 25, 2012, Center – Ls = 115° - CO = 1000 ppm



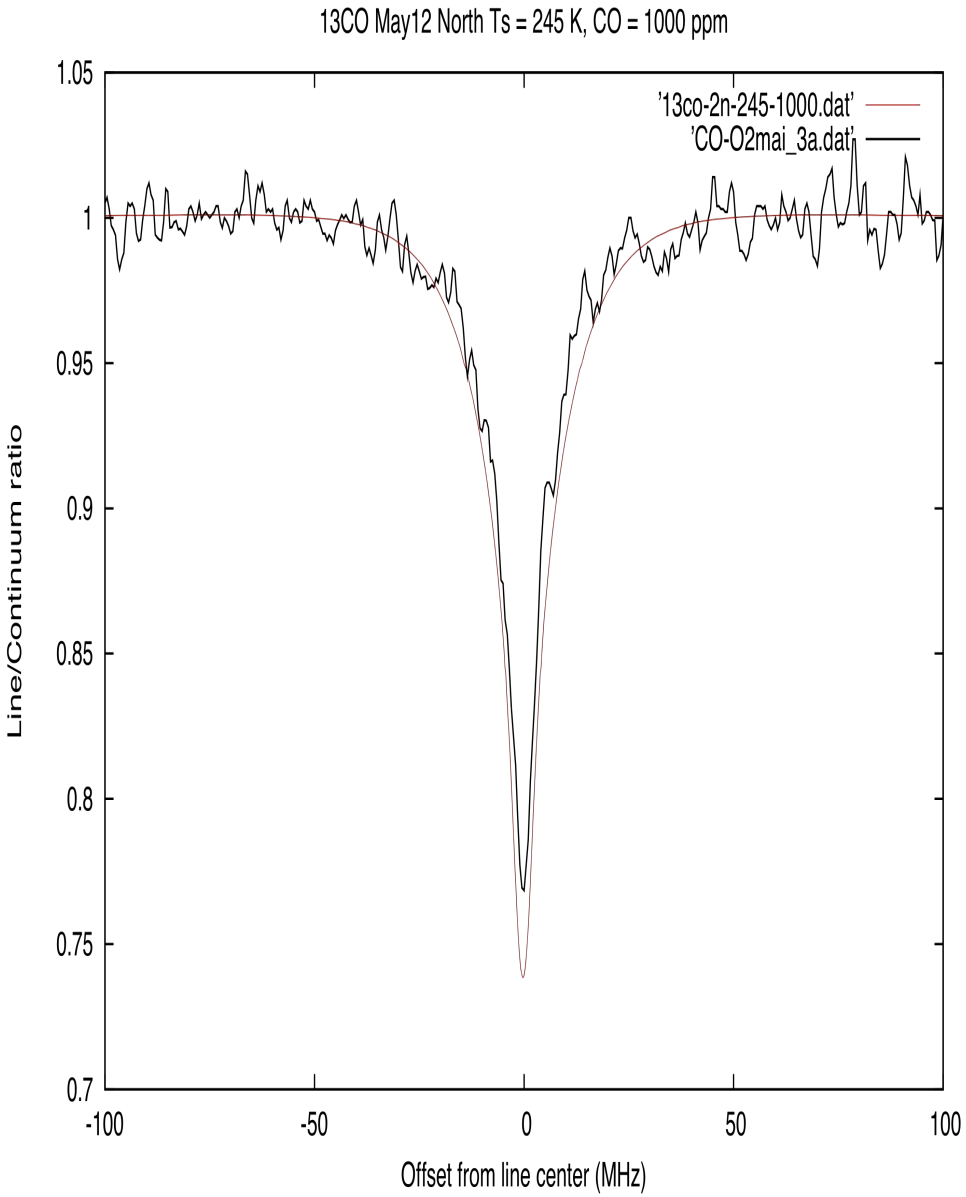


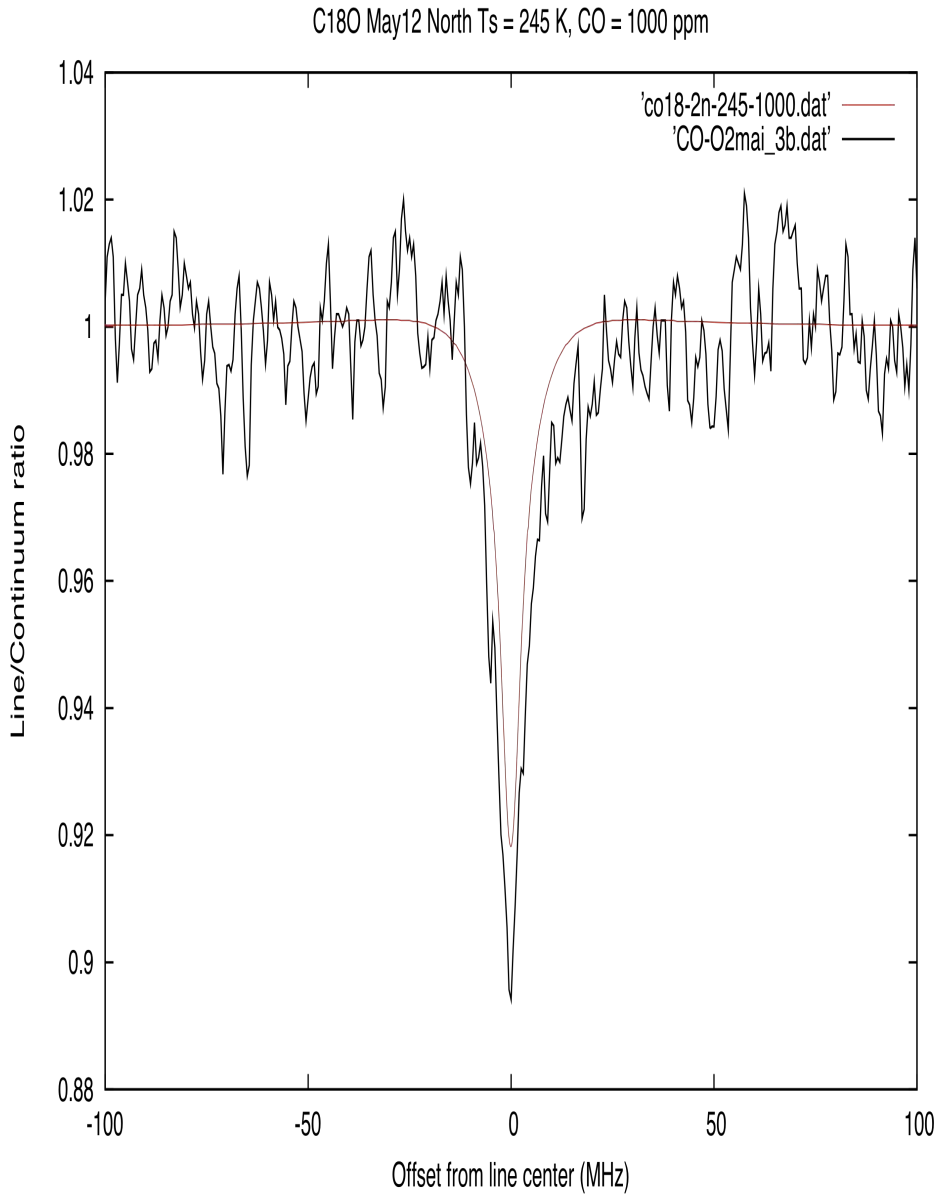
HIFI/Herschel, May 25, 2012, Center – Ls = 115° - O_2 = 1600 ppm



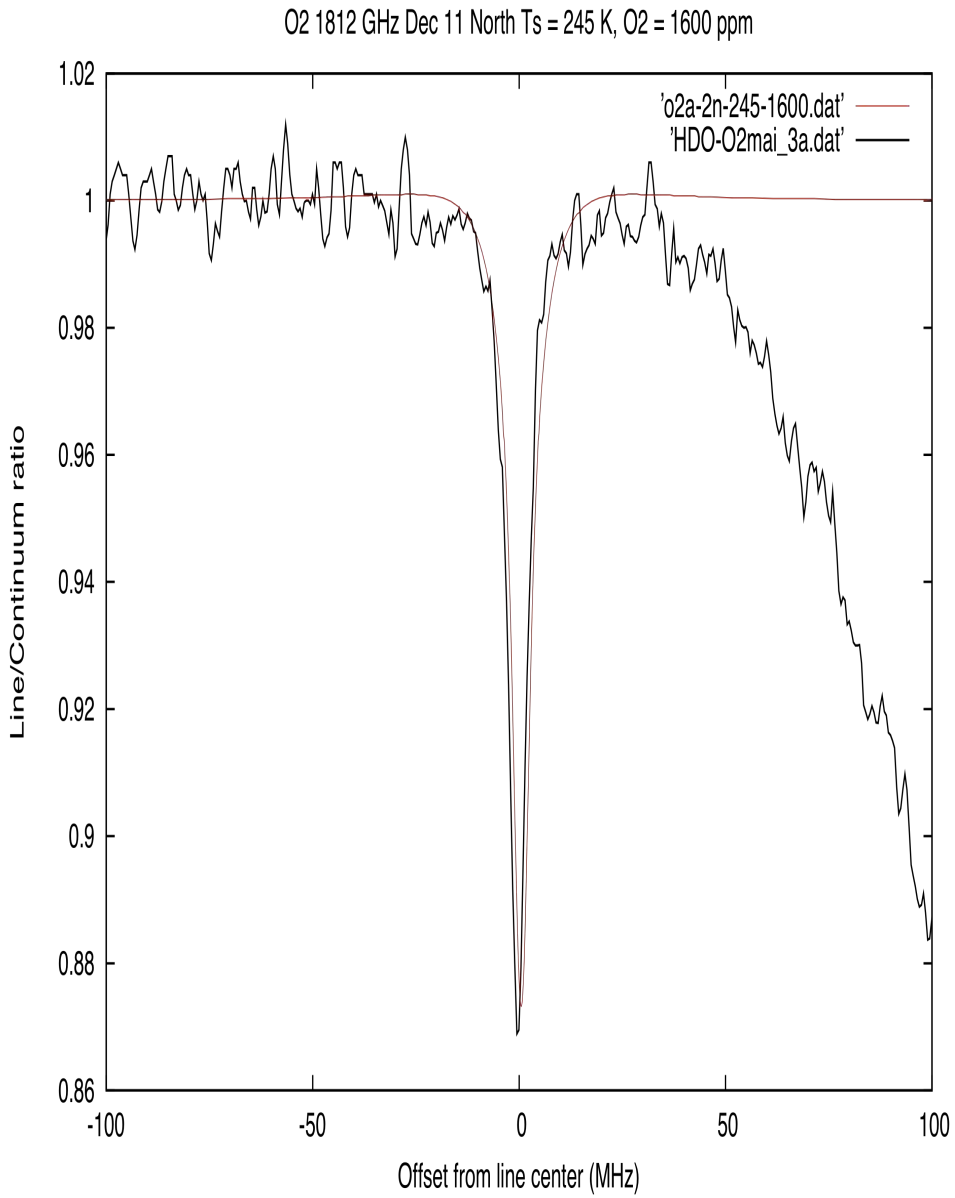


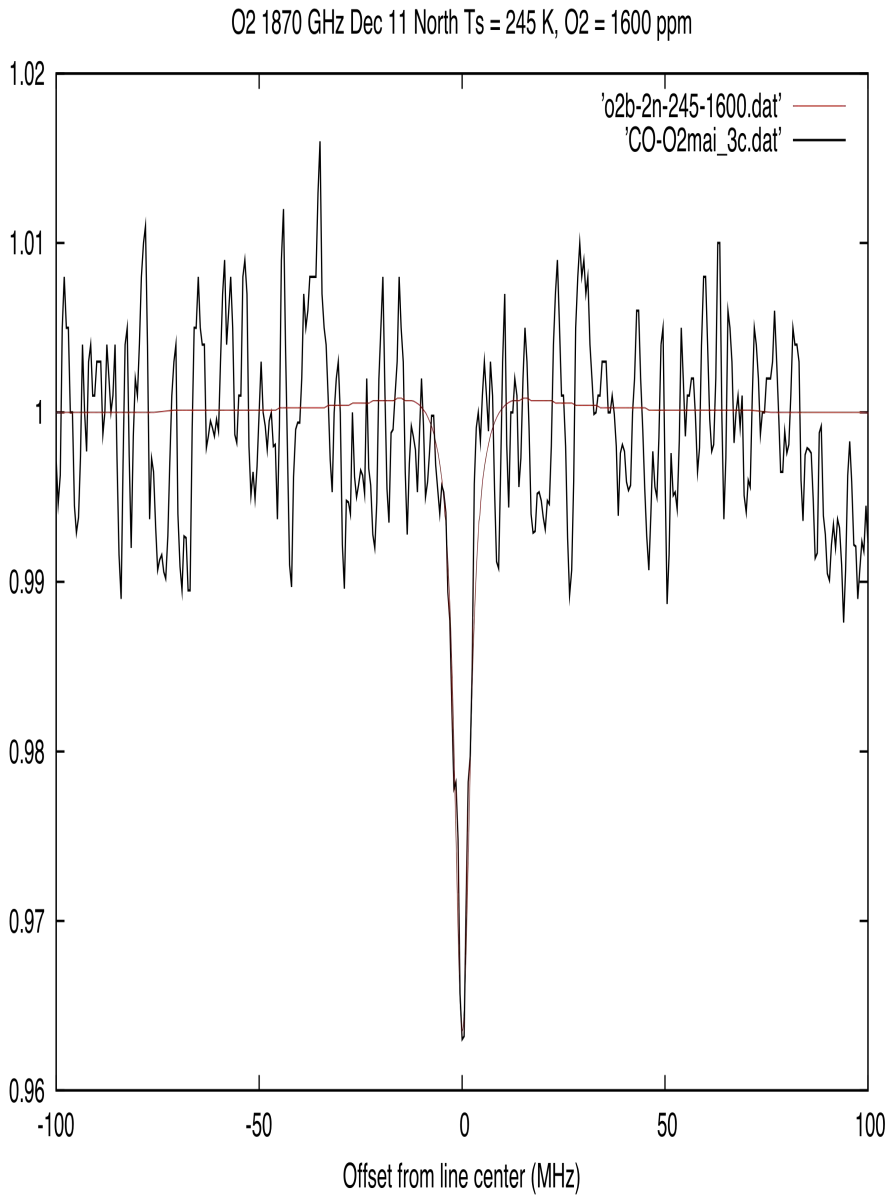
HIFI/Herschel, May 25, 2012, North – Ls = 115° - CO = 1000 ppm





HIFI/Herschel, May 25, 2012, North – Ls = 115° - O_2 = 1600 ppm





Conclusions

- Best fits are obtained for the following mixing ratios of CO and O_2 (ppm):

	CO			O_2		
	N	C	S	N	C	S
Dec. 2011 (Ls = 47°)	1000	1000	1100	1600	1600	1600
May 2012 (Ls = 115°)	1000	1000	1000	1600	1600	1600

- For both seasons, there is no evidence for a latitudinal variation in the mixing ratios of CO and O_2

- There is a systematic discrepancy in the fits of the CO lines, with the synthetic ^{13}CO line being stronger than the data and the synthetic $C^{18}O$ line being weaker
  - Possible origin: Uncertainty in USB/LSB gains

- For both CO and O_2, the inferred mixing ratios tend to be larger than measured by Hartogh et al. (A&A 521, id. L48 and id. L49, 2010) for Ls = 77°
  - Possible origin: Change in T(z) profile? Seasonal effect?