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A new study of circularly polarised emission from O2 molecules for Cosmic Microwave Background experiments at 18.2°N, 42.7°E

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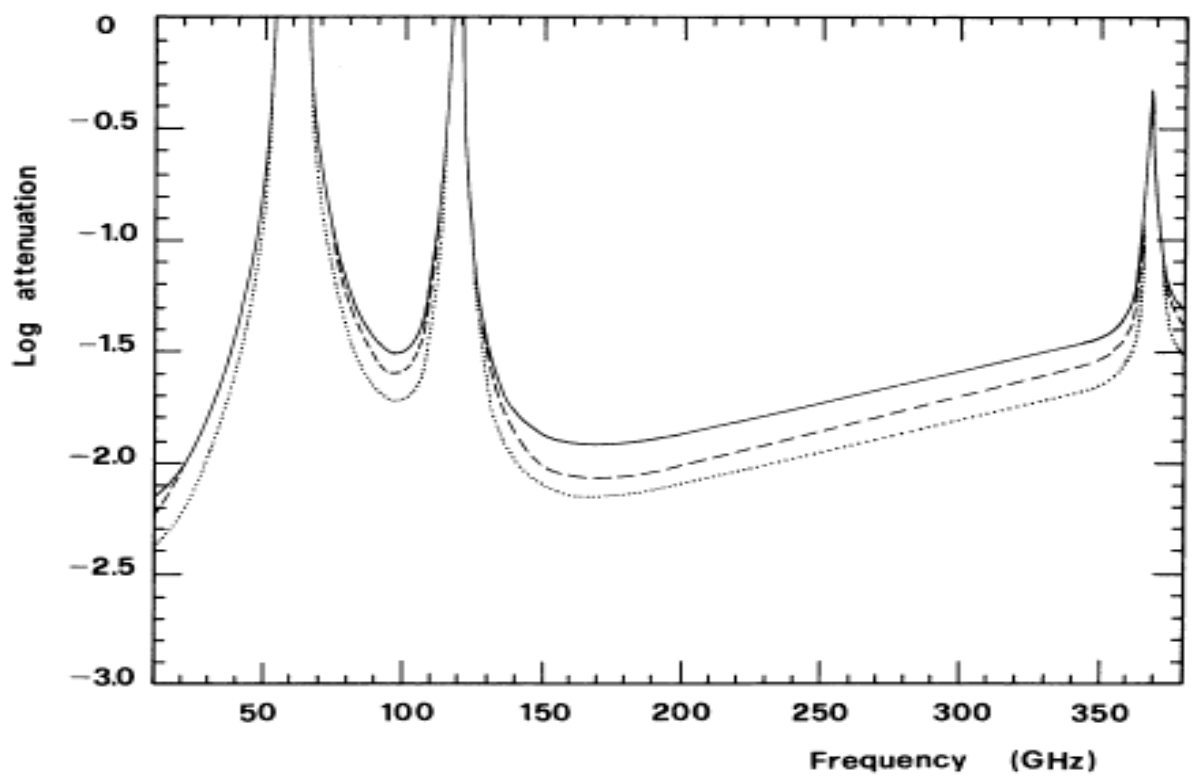
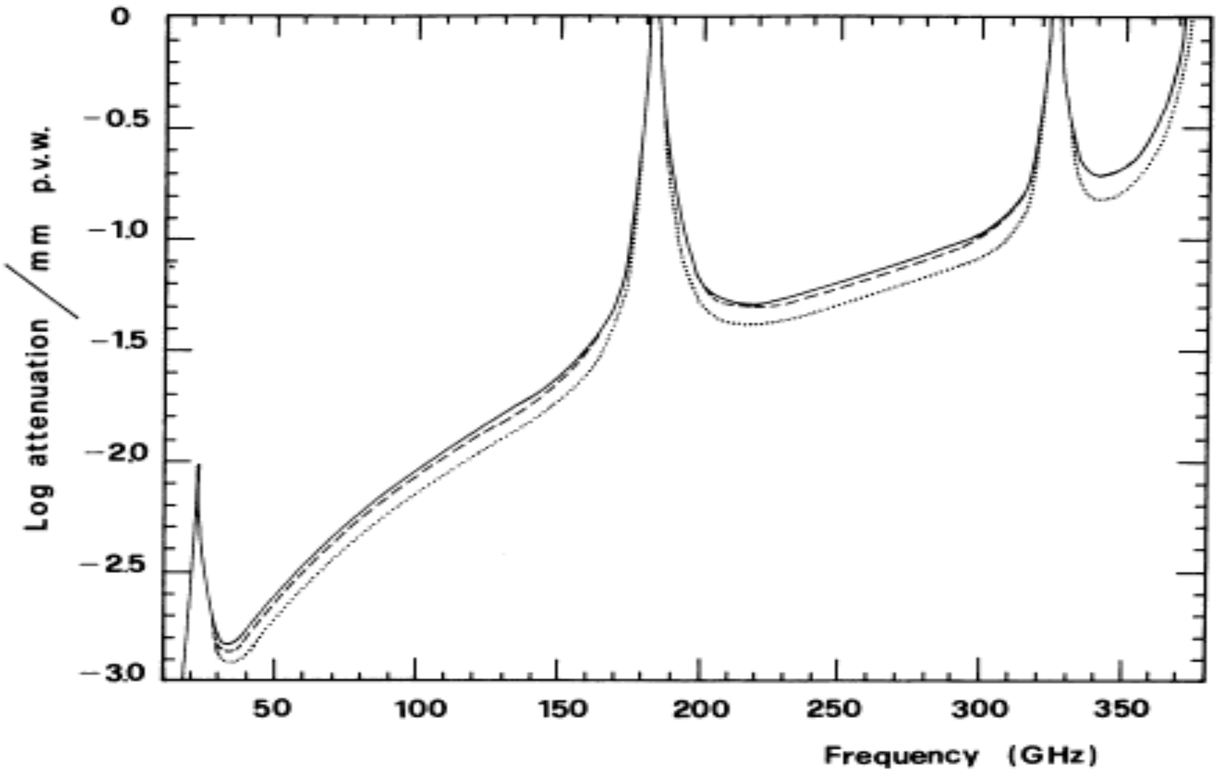
- Atmospheric emission/absorption contribution is a **serious** issue for **accurate** CMB measurements

- Mainly $\mathbf{O_2}$ and $\mathbf{H_2O}$ at radio frequency range



Attenuation due to O_2 for Kitt Peak (solid line) at 2.040 km, the South Pole (dashed line) at 2.8 km and Mauna Kea (dotted line) at 4.2 km (Danese and Partridge, 1989).



Attenuation per mm of precipitable water vapour is shown for Kitt Peak (solid line) at 2.040 km, the South Pole (dashed line) at 2.8 km and Mauna Kea (dotted line) at 4.2 km and as a comparison for H_2O. Under the best conditions, the precipitable water vapour content at the South Pole can be 0.3 mm or less (Danese and Partridge, 1989).

• *The* ***attenuations*** *and the contributions to* T_{atm} *due to Oxygen and* H_2O *lines and continua (**e.g. Tenerife experiments**). The last row presents the liquid water droplet contributions*

• $\boldsymbol{T_{atm}}$ *is atmospheric emission at the zenith computed* ***neglecting*** *any contribution from* ***liquid water droplets***

	2.5 GHz	**4.75 GHz**	**9.4 GHz**	**10 GHz**	**33 GHz**	**90 GHz**
T_{atm} (mK)	949	993	1158	1180	4661	11575
T_{ph} (K)	250	250	251	251	251	253
$T_{Ox\ Lines}$ (mK)	8	28	121	129	2534	4782
$T_{Ox\ continuum}$ (mK)	938	948	956	956	1002	1320
$T_{wv\ Lines}$ (mK/mm)	0.5	2	10	12	146	309
$T_{wv\ continuum}$ (mK/mm)	1	3	13	14	158	1186
$T_{lw} \times 10^{-3}$ (mK/mm)	0.5	2	7	8	70	274

Danese and Partridge, 1989

Emission from O_2 molecules

- **Weaker** than that from H_2O molecules (molecules have **no electric dipole moment**)

- Important: only for molecules in the atmosphere with **strong magnetic dipole moment** having two electrons coupled with parallel spin in the highest energy level. So O2 spectral lines ‘at microwave frequencies’ result from magnetic dipole transitions

- Good : O_2 distribution in the atmosphere is almost **constant** in space and time → easier to study

Emission from H_2O molecules

- Bad: Distribution in the atmosphere is **<u>Non-uniform and variable</u>** in space and time → harder to study and it is a **major source of statistical error** or 'noise' in the measurement of T_{atm}

- Although H_2O (mainly water vapour) is a **<u>minor component</u>** of the Earth's atmosphere, absorption in the H_2O lines **<u>equals</u>** to that in O_2

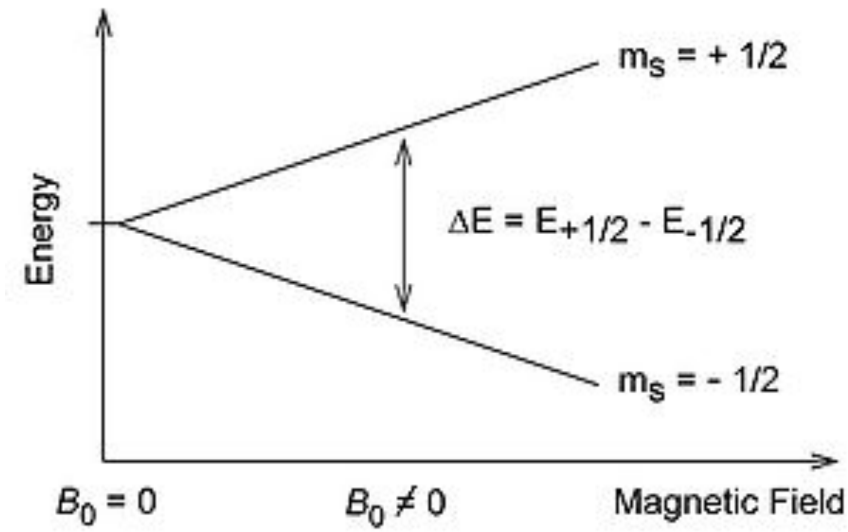
- Wide study of water vapour effect on CMB measurements has been made by **<u>VSA</u>** (Hafez et al., 2008) **<u>ignoring</u>** ice crystals

- However **ice crystals** in the upper troposphere can generate polarisation signals at μK level (**electric** dipole moment, **polarisation** lines due to the **<u>wind</u>**!), and so might contribute significantly to sensitive ground base measurements of the CMB polarisation (Pietranera et al., 2002)

Polarisation

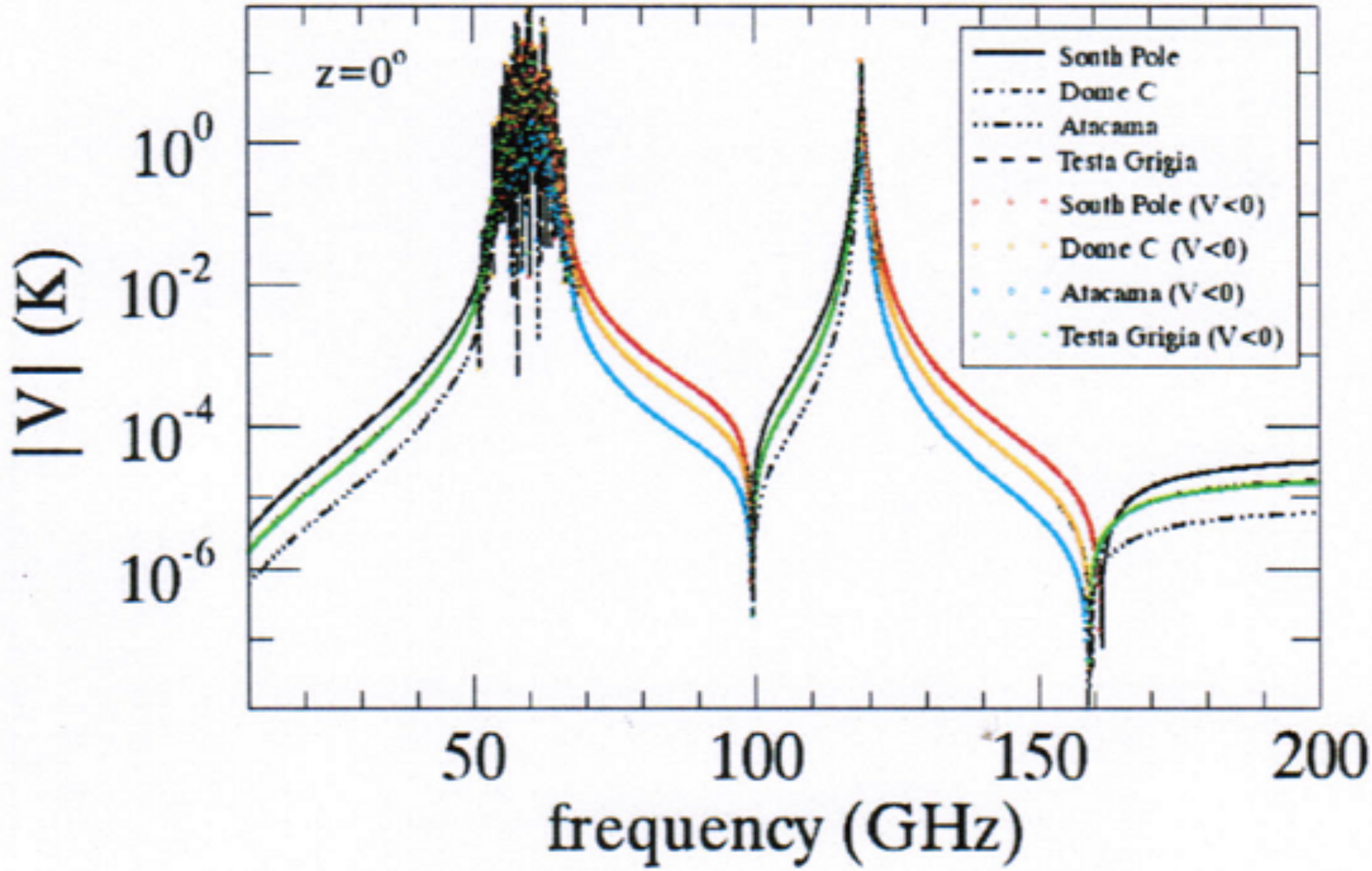
- **<u>Our study</u>** will focus mainly on **circular** polarisation emissions from the **Oxygen** molecules and their **contribution** to the CMB measurements for accurate measurements. **No measurements of the ice crystal polarisations** will be made at this stage.

- Polarisation emission from O_2 in the Earth magnetic field (due to **Zeeman Splitting**):

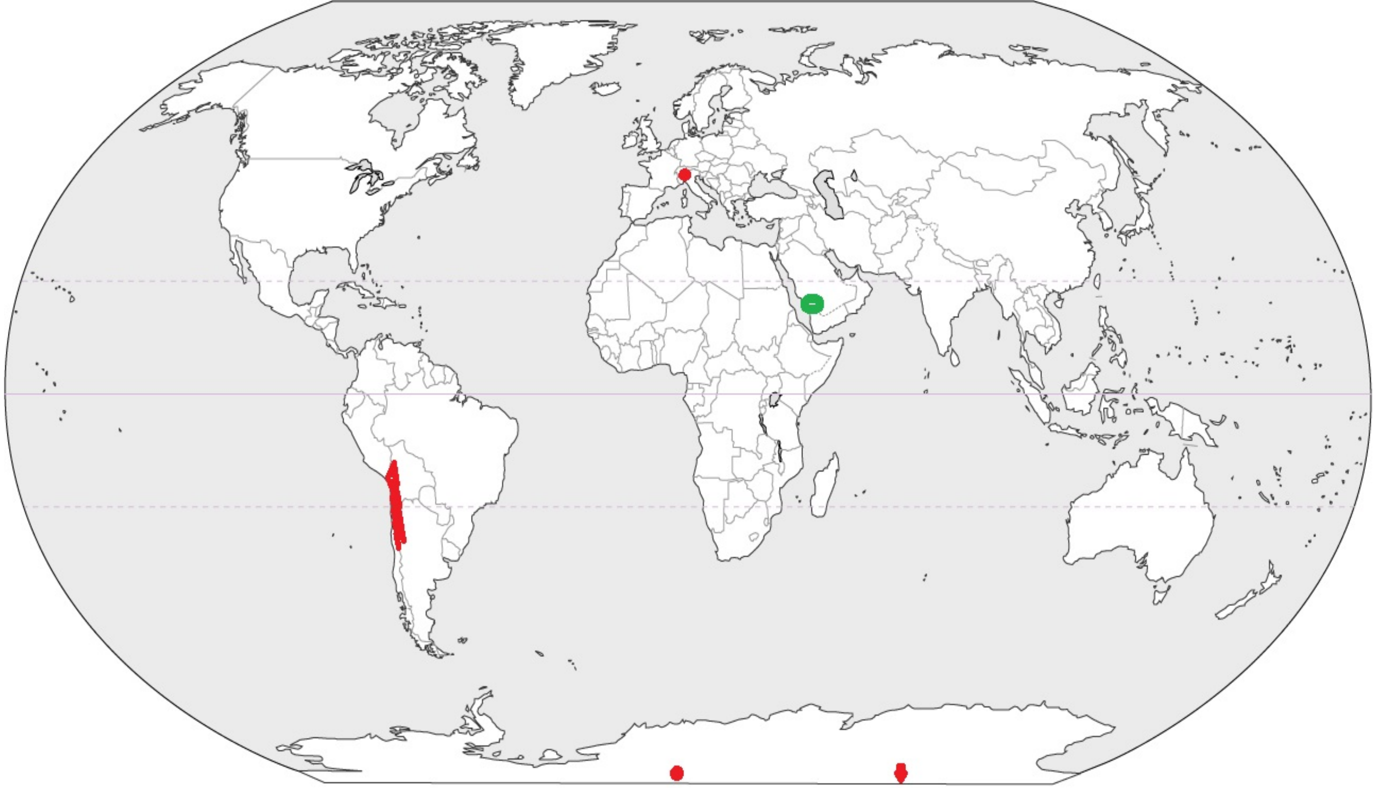


- computation made for different locations:

Fabbian et al., 2012: **<u>Calculated</u>** for South Pole, Dome C (Antarctica) and Atacama desert (Chile) and Testa Grigia …**Abha (Asir area) → Experement**

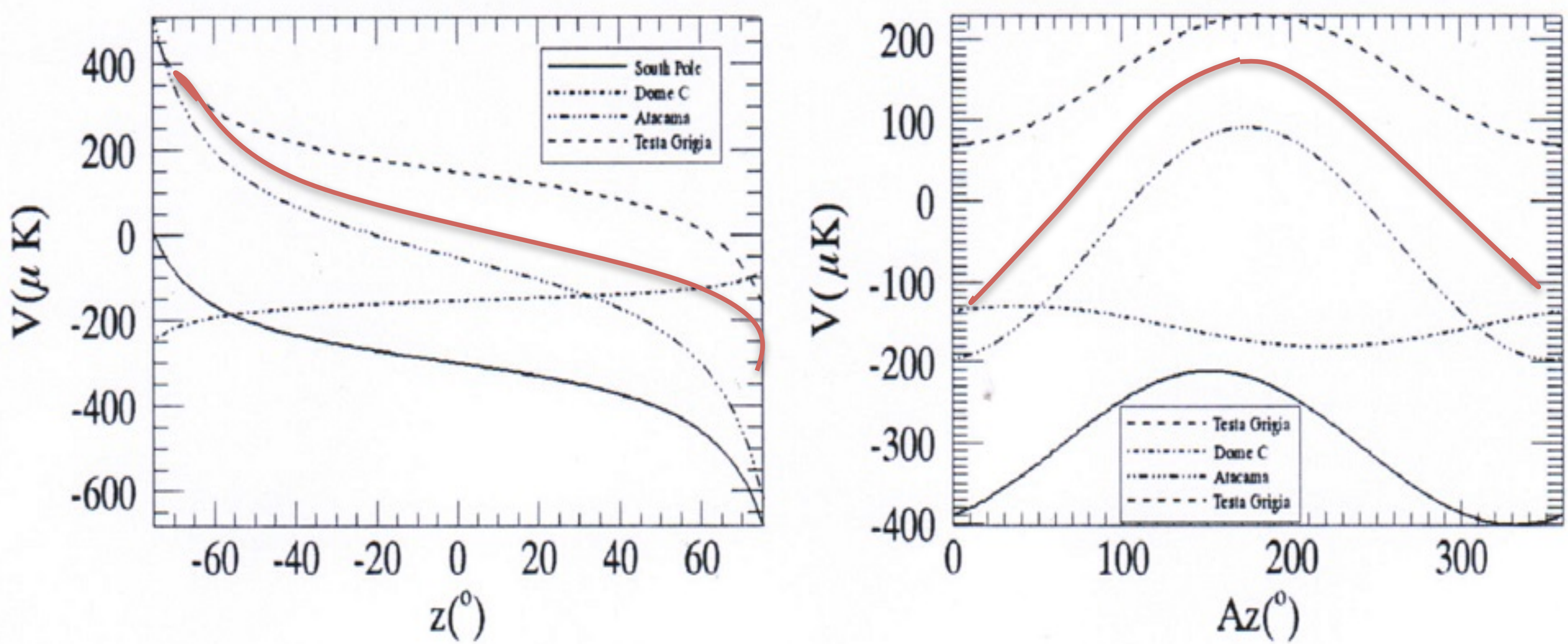


Absolute value of polarized atmospheric signal at the zenith for various sites as a function of frequency. Colored lines denote negative values



Location	Average Altitude	Latitude (°)	Longitude (°)
Testa Grigia	3479 m	+45.6	+007.60
Abha (Asir area)	2200 m	+18.2	+042.66
Atacama Desert	5000 m	-24.5	+069.25
Dome Circe	3233 m	-75.0	+123.30
South Pole	2835 m	-90.0	000.00

Suitable Location: Near Abha Asir Area 18.2°N, 42.7°E



North-South elevation scans (left) and azimuthal scans at constant elevation of 45°(right) of O_2 polarized signal for different sites at 90 GHz.

Conclusion

-T_{atm} contribution is a **serious** issue to the sensitive CMB measurements a some (the effect **increases** with radio frequencies (Mainly due to O_2 and water vapor)

- Polarised emission from O_2 molecules **can not be negligible** for ground-base observations of the CMB polarisation due to Zeeman splitting in Earth magnetic field (**Circular polarisation, no electric dipole, has strong magnetic dipole moment).**

- Ice crystals in the upper troposphere **could be also an issue** for the CMB ground-base measurements and produced polarisation signals at μK level (**Linear polarised due to the wind)**

- We suggest a **new experiment** (by Aug2014t) to study the effect of the polarised emission from O_2 molecules at 18.2 N, 42.7 E

-Results from this experiment will be **compared to** the computed results obtained from other locations in the world. This better understanding of its contribution **to improve** the measurements of CMB polarisation emission. Polarisation of Ice Crystals **may be studied** later. **Expected result from new experiment was shown → does it confirm the computed results given in Fabbian et al., 2012?**

Note: The experiment will be **one of our CMB expremental plan to study the CMB polarisation and what is affected by.** We already started this, e.g. C-Bass project with Caltech/JPL, University of Oxford, University of Manchester, HartRAO and KACST