Water Vapour Radiometry

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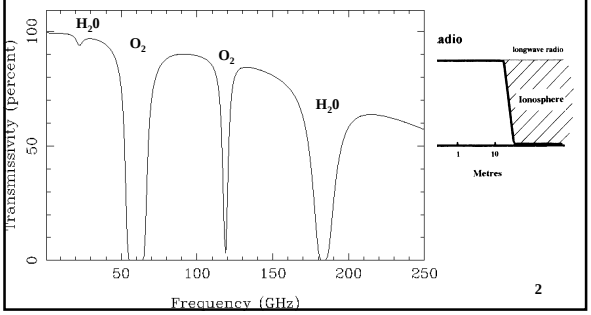
The Neutral Atmosphere

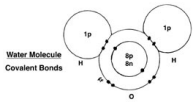


Microwave Radiometry

- Radiative transfer: A lossy medium will emit thermal radiation in proportion to its physical temperature and its attenuation coefficient.
- For an atmosphere, the attenuation coefficient will depend on its composition, temperature and pressure. It will also be a function of frequency.
- Atmospheric radiometry is the study of the radiation emitted by the atmosphere.
- Microwave radiometry is extensively used to infer properties of the Earth's atmosphere, as well as the atmospheres of other planets.

Water

- Its dipolar structure means that its melting and boiling points are much higher than other simple molecules (e.g. CO_2, O_2, N_2).
- Whereas CO_2, O_2 and N_2 are distributed in the lower atmosphere as ideal gases (e.g. they are distributed according to ideal gas law and gravity), water is "clumpy".



Atmospheric transmission

- When receiving celestial emission at radio frequencies, O_2, N_2 (the "dry") components of the atmosphere introduce a excess path of approximately 2.2 metres over a vacuum.
- Water vapour introduces 50-300cm of excess path.
- Whereas the dry components are well-mixed, water vapour is clumpy.
- At microwave wavelengths, water vapour fluctuations is the predominant cause of changes in the excess path lengths at different antennas.

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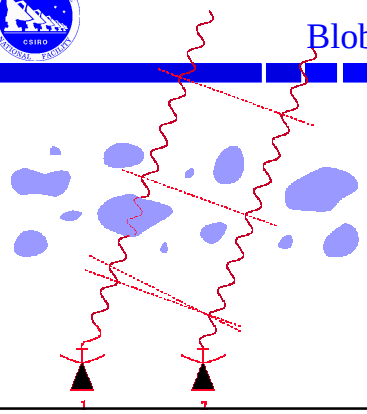
Blobs of water



- Blobs exist on all size scales.
- Follow a so-called Kolmogorov spectrum of sizes.
- Typically the water vapour column for two sites 1 km apart are 99% the same – the so-called turbulent component consists of just 1% of the water.

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Water vapour radiometry

- Meteorologists have long used radiometry to study the water content of the atmosphere.
- The use of the technique in radio interferometry has been suggested for 10-20 years.
- Interferometry is a very different application that meteorology.
  - Path lengths of interest are much smaller (~100 μm).
  - It is a differential system (absolute path is not relevant).
- Main problems: systematics!

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Continuum vs Line systems

- "Continuum" water vapour radiometers measure fluctuations far from water lines
- Line systems work near either of the two water lines: 22.3 GHz or 183 GHz.
- Line systems much more robust to systematics. The water line shape acts as a filter to remove systematics.

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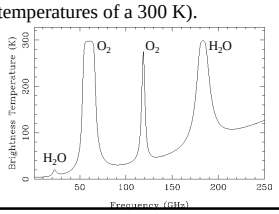
ATCA Water Vapour Radiometer

- A radiometer near 22.3 GHz, which takes measurements at 4 bands.
- Required sensitivity is to measure fluctuations of 10 mK in the sky brightness of about 30 K (and uncooled receivers with system temperatures of a 300 K).



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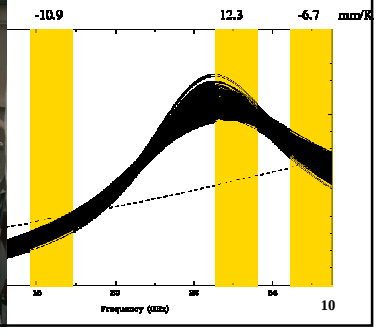
ATCA Water Vapour Radiometer



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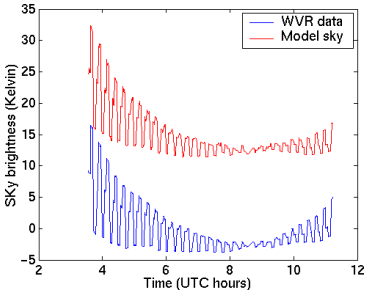
Fluctuations in sky brighness



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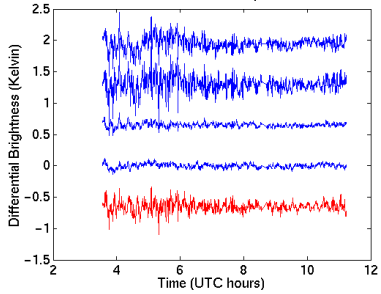
Compare the channels



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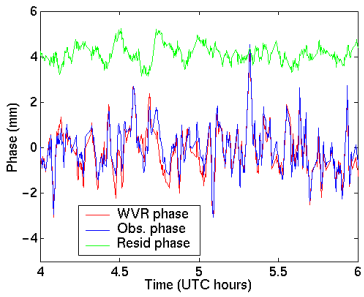
Results of the WVR



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