


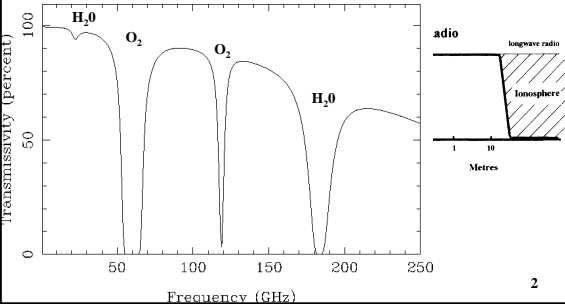
Water Vapour Radiometry

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The Neutral Atmosphere




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Microwave Radiometry

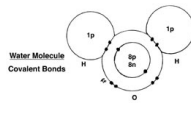
- Radiative transfer: A lossy medium will emit thermal radiation in proportion to its physical temperature and its attenuation coefficient.
- For an atmosphere, the attenuation coefficient will depend on its composition, temperature and pressure. It will also be a function of frequency.
- Atmospheric 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.

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Water

- Its dipolar structure means that its melting and boiling points are much higher than other simple molecules (e.g. CO₂, O₂, N₂).
- Whereas CO₂, O₂ and N₂ are distributed in the lower atmosphere as ideal gases (e.g. they are distributed according to ideal gas law and gravity), water is "clumpy".




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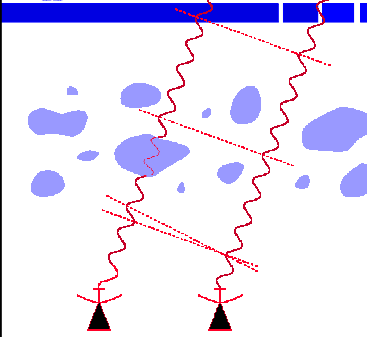
Atmospheric transmission

- When receiving celestial emission at radio frequencies, O₂, N₂ (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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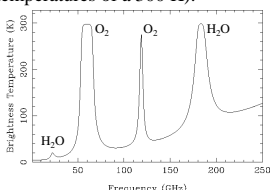
Continuum vs Line systems

- “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

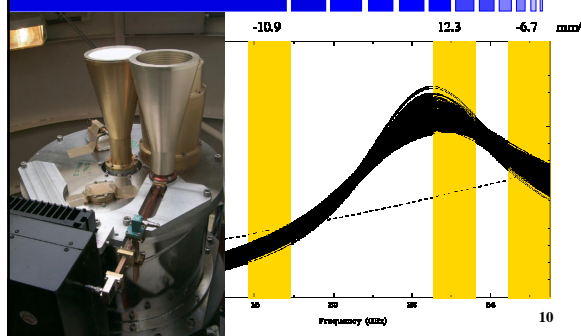
- A radiometer near 22.3 GHz, which takes measurements at 4 bands.
- Required sensitivity is to measure fluctuations of 10 mK in the sky brightness of about 30 K (and uncooled receivers with system temperatures of a 300 K).



The plot shows brightness temperature (K) on the y-axis (0 to 300) versus frequency (GHz) on the x-axis (50 to 250). It features three distinct peaks labeled H₂O, O₂, and H₂O.

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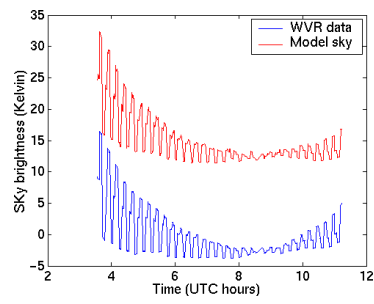
ATCA Water Vapour Radiometer



The image shows the physical radiometer instrument on the left and a spectral plot on the right. The plot displays a broad peak with a dashed line indicating a fit. Three vertical yellow bars are overlaid on the plot, with values -10.9, 12.3, and -6.7 mK/K above them. The x-axis is labeled 'Frequency (GHz)' with values 30, 20, 10, and 10.

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Fluctuations in sky brightness

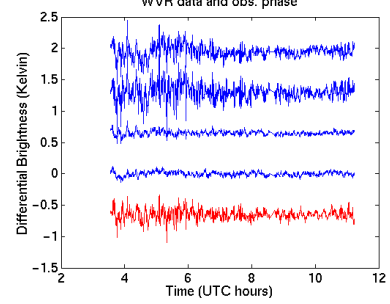


The graph plots 'Sky brightness (Kelvin)' on the y-axis (ranging from -5 to 35) against 'Time (UTC hours)' on the x-axis (ranging from 2 to 12). Two data series are shown: 'WVR data' (blue line) and 'Model sky' (red line). Both series show a similar trend of decreasing brightness over time, with the WVR data exhibiting more high-frequency noise.

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Compare the channels

WVR data and obs. phase



The graph plots 'Differential Brightness (Kelvin)' on the y-axis (ranging from -1.5 to 2.5) against 'Time (UTC hours)' on the x-axis (ranging from 2 to 12). It shows multiple channels of data as distinct horizontal lines with high-frequency noise, representing the difference between channels.

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