Department of Communication Systems

Skymap at 38.2 MHz as Measured by IRIS

Steve Marple

Lancaster University

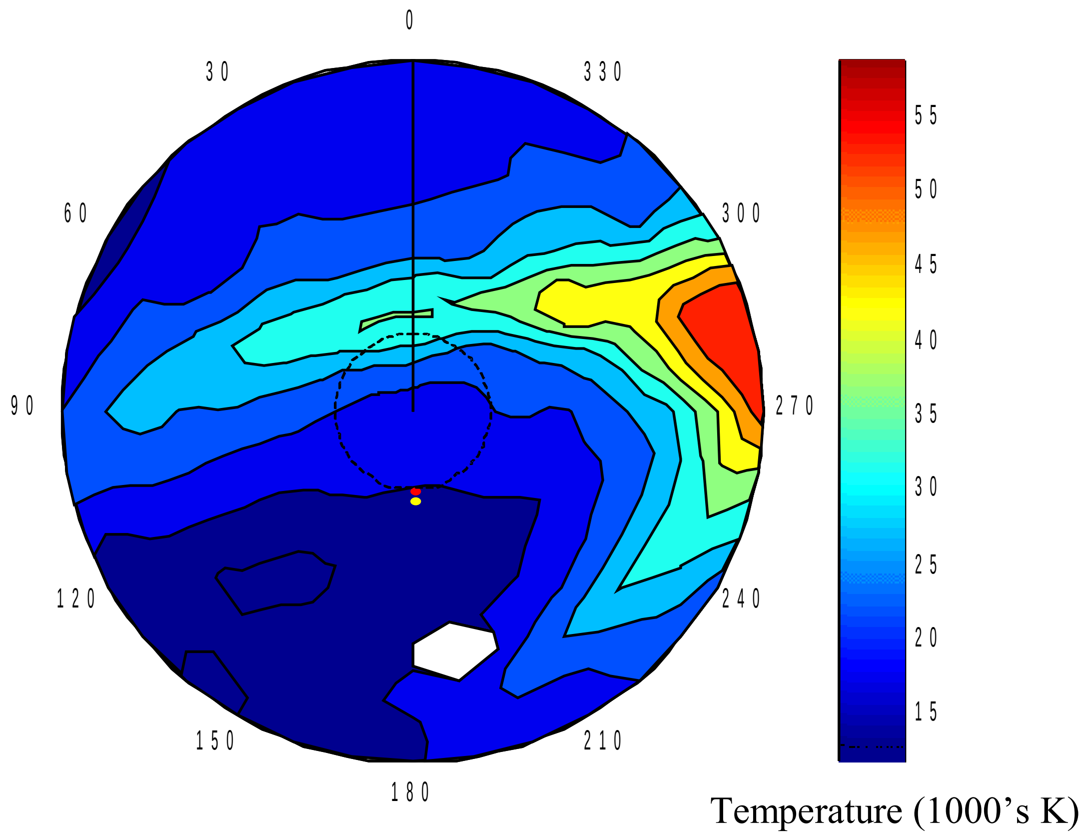
Skymap

A skymap is a map of cosmic noise level in all directions.

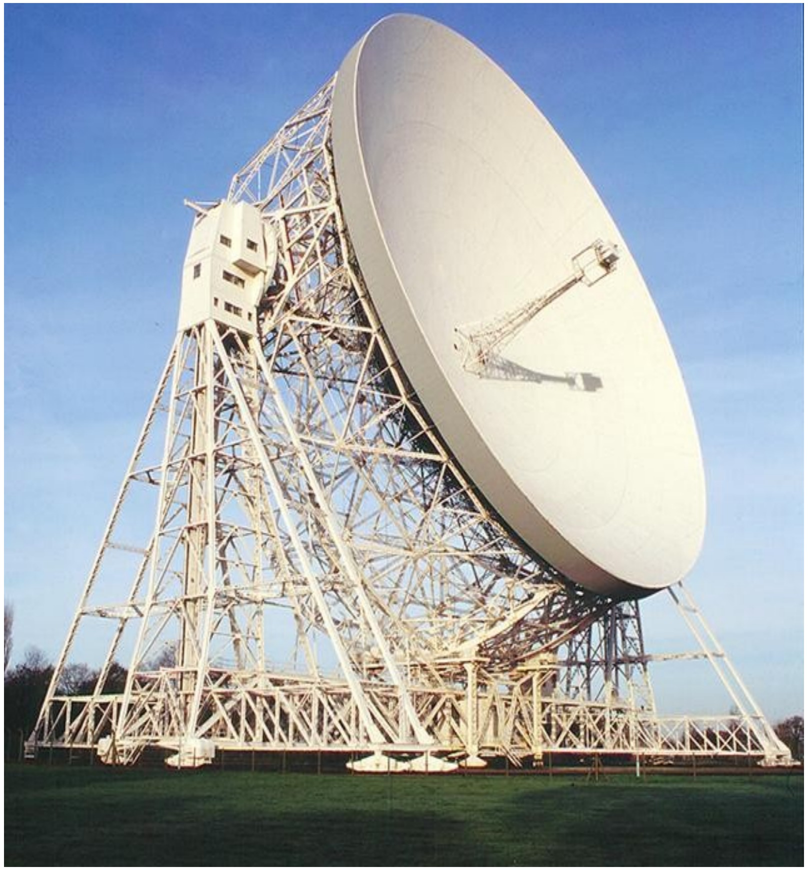
- Required to generate theoretical quiet day curves* (QDCs) for riometry and system design
- Uses in astronomy, e.g., observing large-scale galactic features

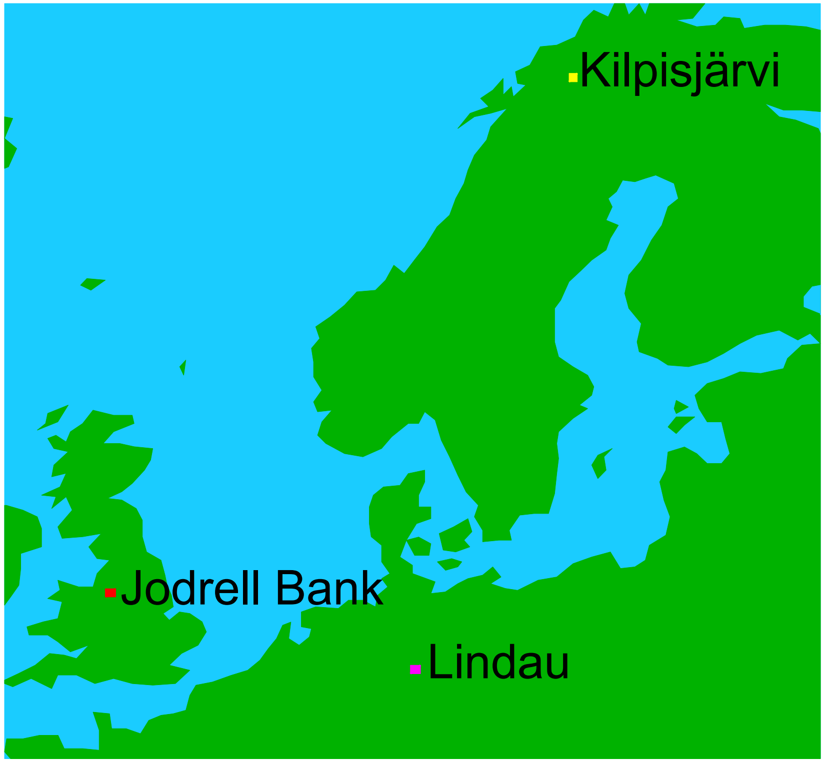
* QDC: background cosmic noise level in absence of absorption.

Skymap [Cane, 1978]



Jodrell Bank Radio Telescope

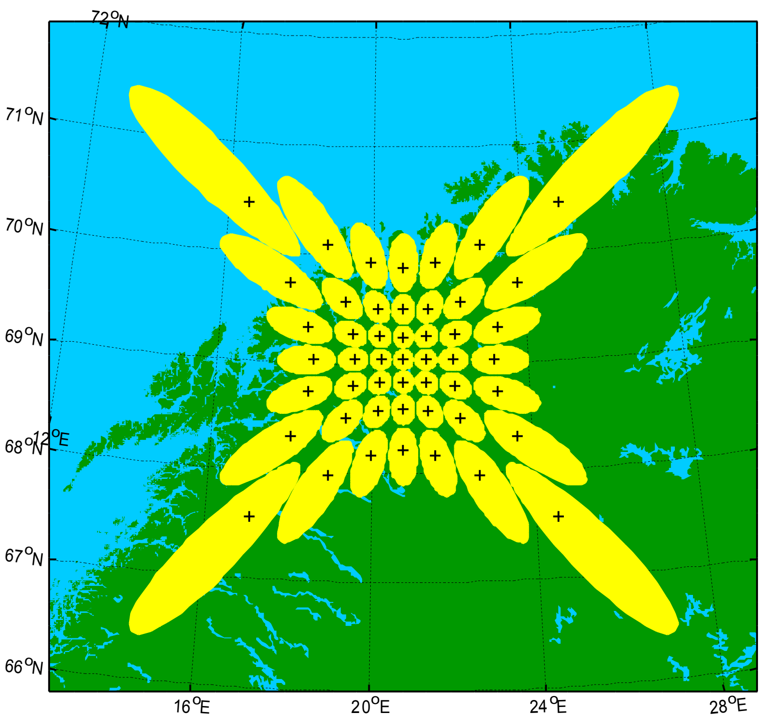


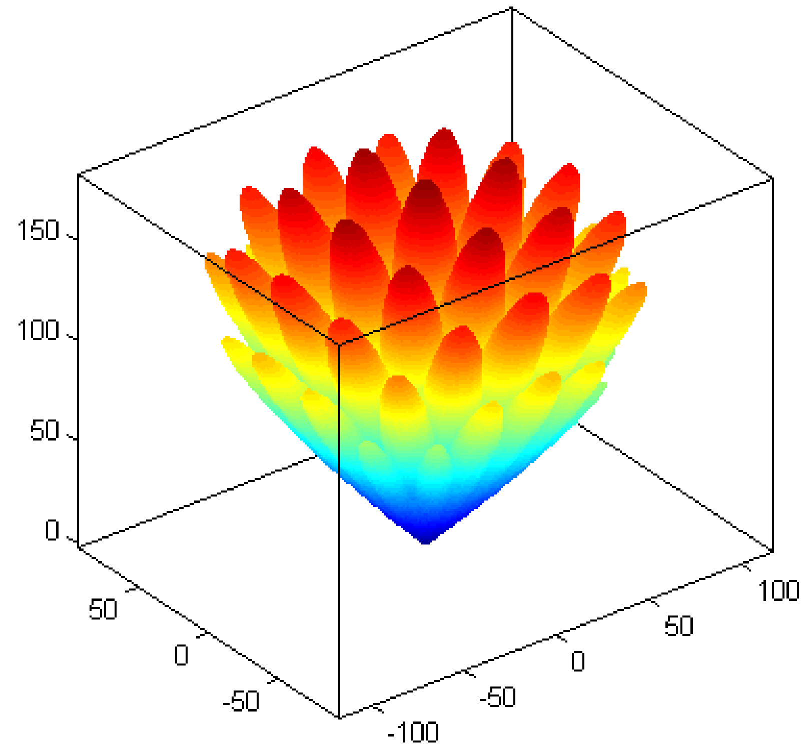


IRIS (Imaging Riometer for Ionospheric Studies)

- 64 crossed dipoles
- 49 imaging beams
- beam width 13° ~ 16°
- 6+ years of data
- Declination range: 14.1° - 83.3°N

Beam projection

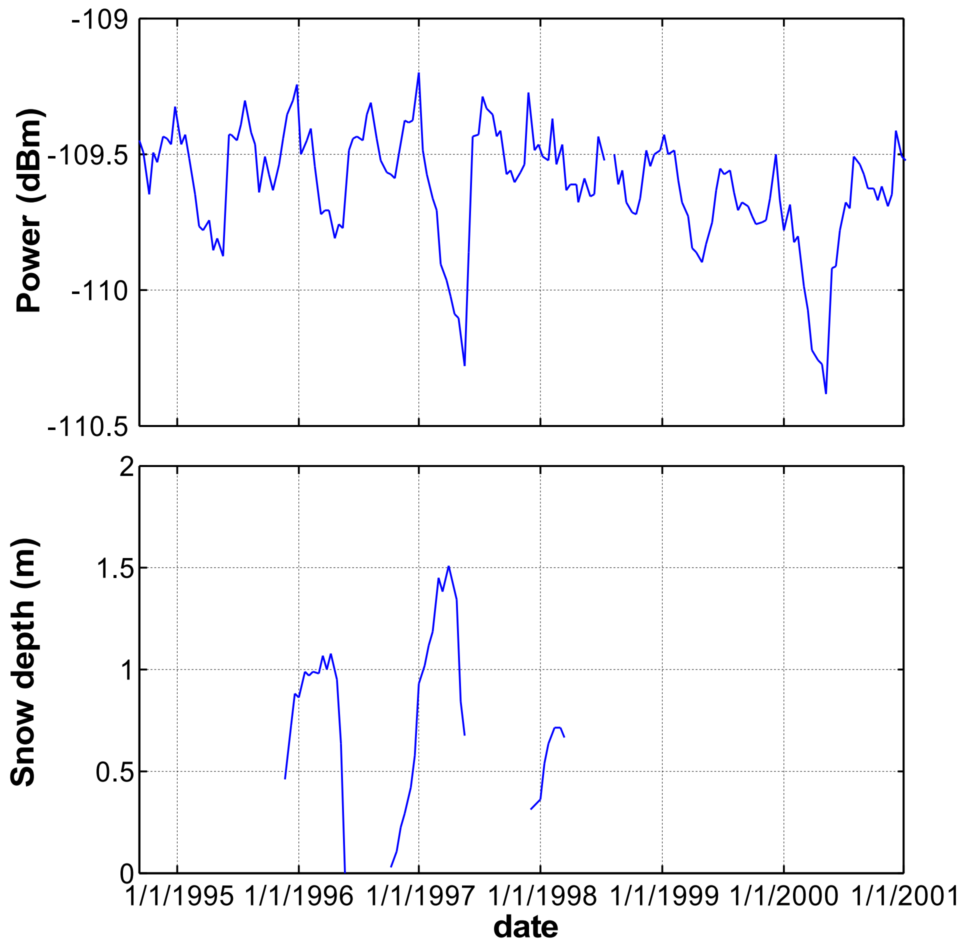




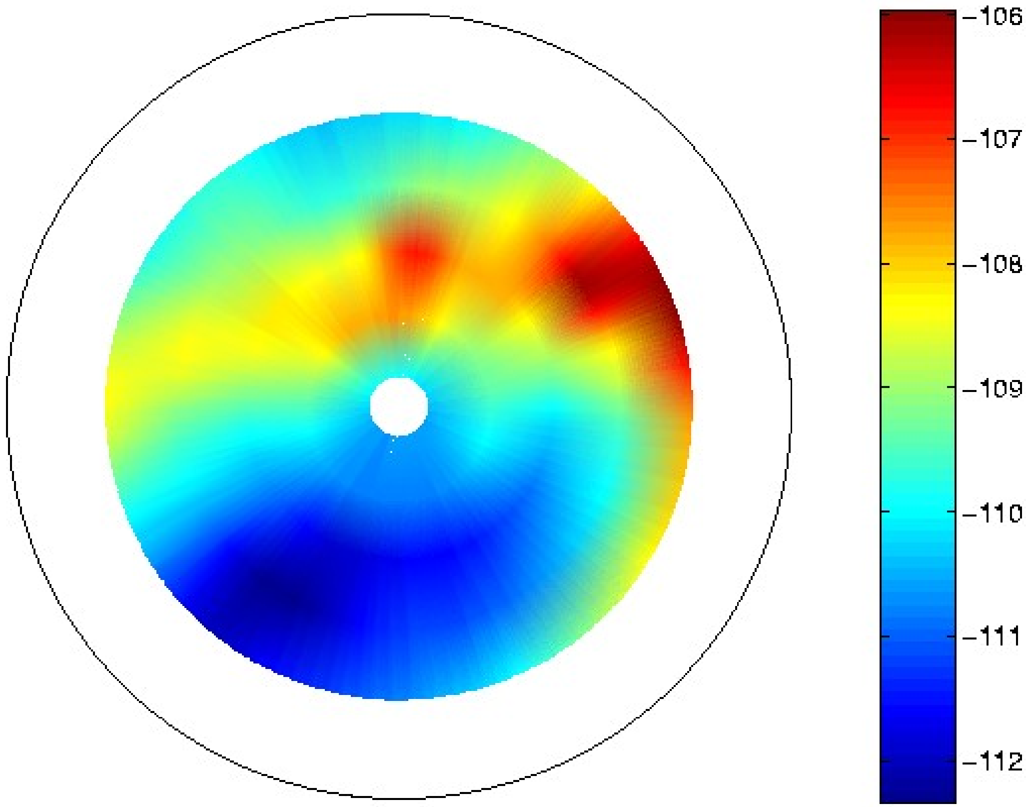
Received power affected by:

- Solar controlled D-region absorption
- Snow (modifies antenna performance)

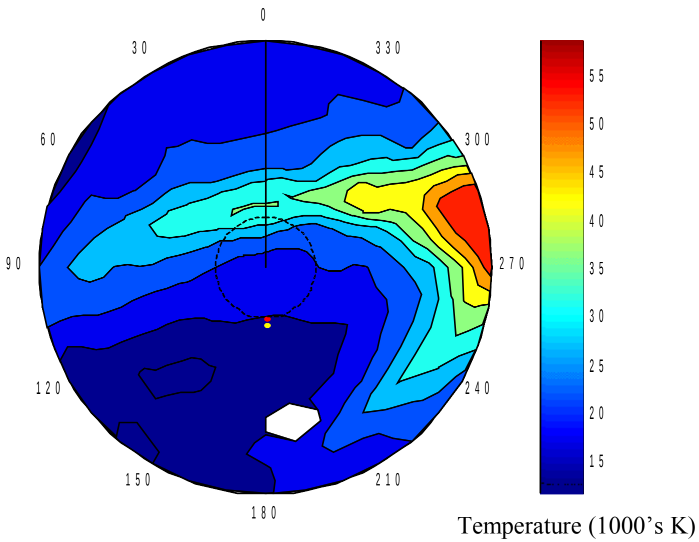
Mean QDC Power and Snow Depth
00:00:00 UT 02/09/1994 - 00:00:00 UT 01/01/2001
Kilpisjärvi, Finland (69.05° N, 20.79° E)

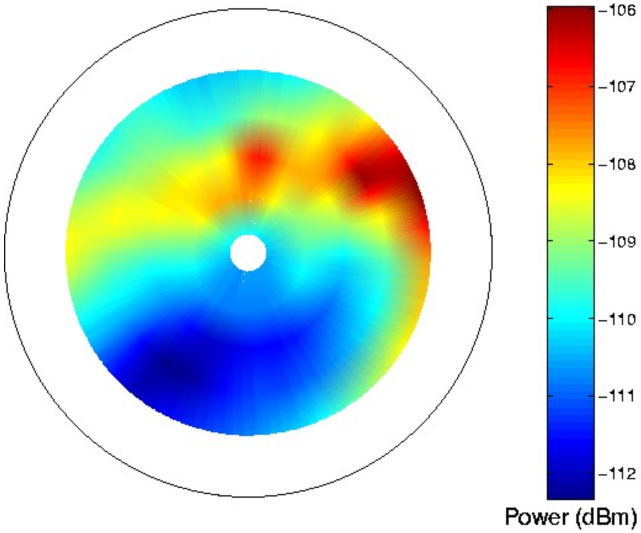


IRIS Skymap



Cane and IRIS skymaps





Summary

- Sky maps are needed for theoretical quiet day curves and system design
- An imaging riometer has been used as a radio telescope to produce a skymap
- Using riometer data from Antarctica a matching southern hemisphere map could be made

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Skymap at 38.2 MHz as Measured by IRIS

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My presentation is about some work I've been doing recently. I'll start by explaining what a sky map is, and briefly show some past work before presenting my own results.

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Skymap

A skymap is a map of cosmic noise level in all directions.

- Required to generate theoretical quiet day curves* (QDCs) for riometry and system design
- Uses in astronomy, e.g., observing large-scale galactic features

* QDC: background cosmic noise level in absence of absorption.

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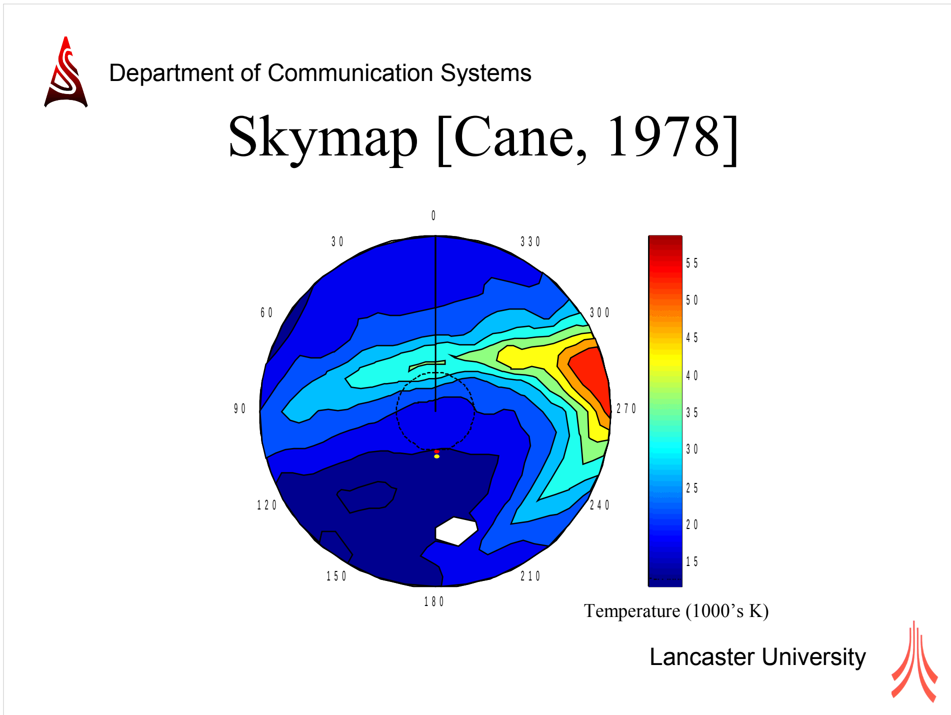
A skymap is a map of the cosmic noise level, looking in all directions of the sky. In addition to many uses in astronomy skymaps are also important for riometry. They're needed for the preparation of theoretical quiet day curves and system design.



This is the northern hemisphere section of a sky map by Cane. The centre of the map shows the sky above the north pole, the outer edge is the sky above the equator. Colour is used to indicate sky temperature. The plane of the milky way is along here, and the centre of the galaxy is about here.

The quiet day curve is a locus around the sky map at constant declination. Declination is the astronomical version of latitude. The equivalent of longitude is *right ascension*. By combining sufficient quiet day curves we can map the northern hemisphere sky. The circle in the centre of the map is the locus that an infinitely narrow zenithal beam located at Tromsø would trace over 1 sidereal day.

This is actually a composite map created from maps at frequencies 30, 38 and 178 MHz. Most of the northern hemisphere data is taken from the 1973 survey at 38MHz by Milogradov-Turin and Smith, who used the Jodrell Bank telescope…

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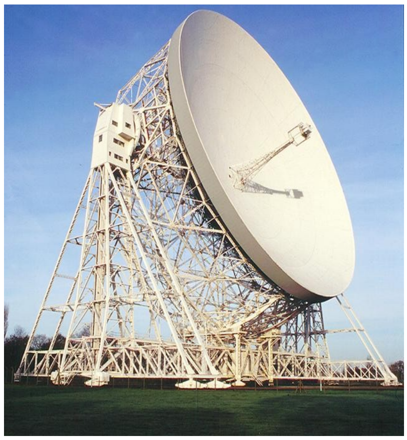
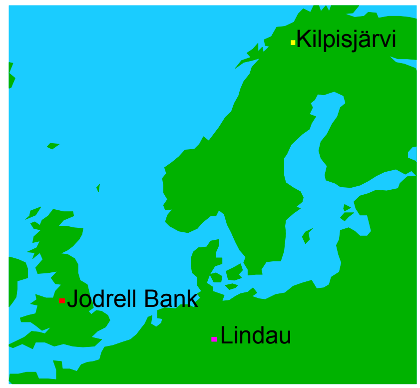
Jodrell Bank Radio Telescope





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Jodrell Bank radio telescope uses a fully steerable 76m dish. With a crossed-dipole antenna placed at the focal point the beamwidth was found to be 8°. Unfortunately they did not have a riometer so Milogradov-Turin and Smith used the data from a riometer in Lindau to ensure their measurements were free of ionospheric absorption. Lindau is about 830km from Jodrell Bank.

Cane found discrepancies between the 30 and 38MHz surveys, even after adjusting for frequency. She increased the measurements of Milogradov-Turin and Smith by about 8%.

Most skymaps have been made by radio telescopes, I'll now show an alternative approach, which uses the imaging riometer at Kilpisjärvi.

8% ~ 0.35dB

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IRIS (Imaging Riometer for Ionospheric Studies)

- 64 crossed dipoles
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- beam width 13° ~ 16°
- 6+ years of data
- Declination range: 14.1° - 83.3°N

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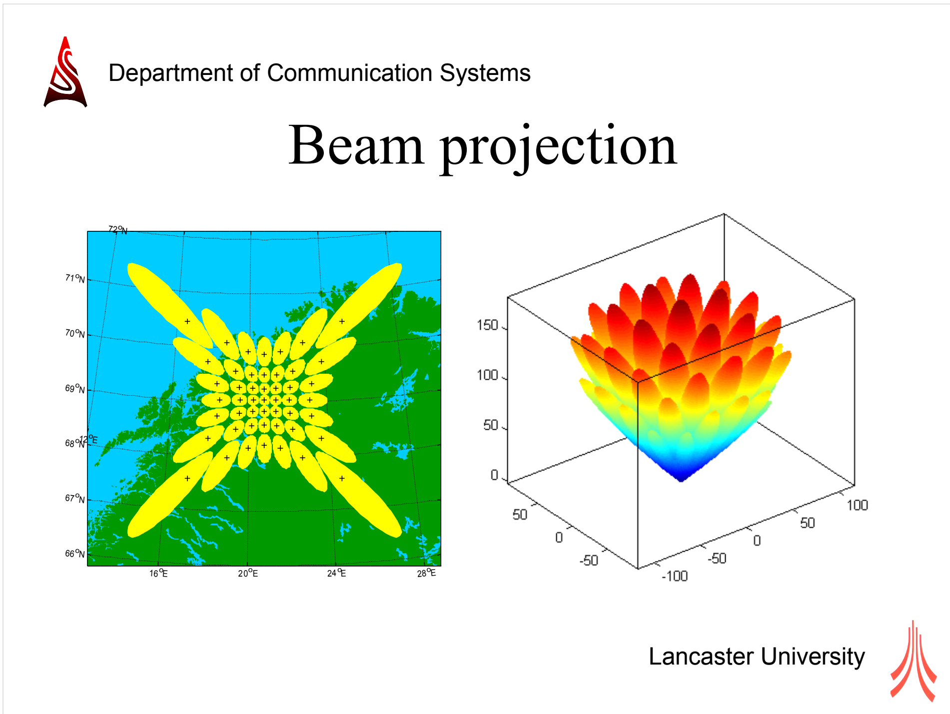
A riometer is designed to measure ionospheric absorption of radio waves by observing the deviation of received power from the expected level, or *quiet day curve*. By *quiet* I mean lack of particle precipitation, solar radio emissions and lightning.

As IRIS is an imaging riometer we have 49 spatially-distributed beams.



In plan the beam projection looks like this. (Here the beams have been projected onto the ionosphere at 90km altitude.) If I discard the corner beams (which contain grating lobes) and any declinations which differ from others by less than 1º there are 20 unique declinations, in the range 14.1° - 83.3°N. That covers about 80% of the northern hemisphere.

In the 3 dimensional view you can see that beams vary both in width and sensitivity. Before combining the quiet day curves into the skymap the values must be corrected for this variation. That work is still in progress, so my skymap currently uses only 5 beams.

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Received power affected by:

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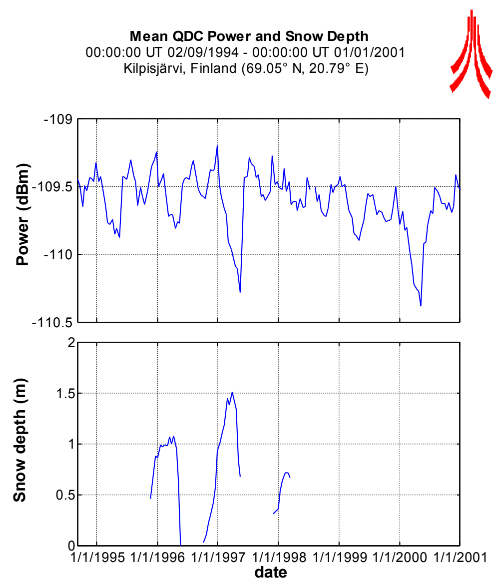
There are 2 other factors which have to be included. The first is absorption caused by solar UV energy. Our algorithm for generating the quiet day curves removes the irregular absorption events caused by particle precipitation, but it doesn't remove the daily solar-controlled absorption.

The second factor is snow affecting the antenna performance.

I just want to stress that these effects don't cause **any** problems for absorption measurements. The received power and quiet day curve are affected equally, and since absorption is the difference between the two the effect is removed.



The top panel of this graph shows the mean quiet day received power for the central beam. Several seasonal variations can be seen, such as the received power decreases in Spring. Two years stand out, 1997 and 2000 – both years with extremely high snowfall. The lower panel shows the average snow depth for 3 winters, with the expected anti-correlation.

The effects of snow and solar controlled absorption can be eliminated by using only the highest received power levels for a given declination and right ascension.

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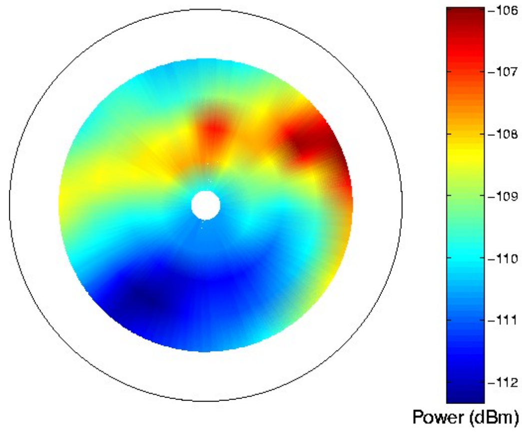
IRIS Skymap



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This is my skymap of the northern hemisphere. Some areas are missing because the declination range is not complete.

You can see the milky way across here. When I include the remaining 15 declinations the resolution will be *much* better. The colour scale is power, I haven’t yet converted it to temperature.

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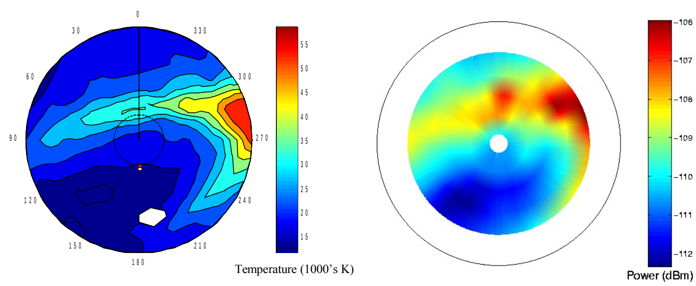
Cane and IRIS skymaps



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You can see the IRIS skymap is very similar to Cane's, the scaling is different since the correction for the different beam widths and sensitivities hasn't yet been applied. The results so far look very promising.

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Summary

- Sky maps are needed for theoretical quiet day curves and system design
- An imaging riometer has been used as a radio telescope to produce a skymap
- Using riometer data from Antarctica a matching southern hemisphere map could be made

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Sky maps are essential for riometry.

Imaging riometers can be used as a radio telescope. The resolution is much worse than modern instruments, but the field of view is much greater.

As far as I am aware this is the first time anyone has produced a skymap with an imaging riometer.

We were limited to a northern hemisphere survey, but a similar skymap could be generated using a southern hemisphere riometer.

J. Milogradov-Turin, F. G. Smith. A Survey of the Radio Background at 38 MHz. Monthly Notices of the Royal Astronomical Society. ISSN 0035-8711. 161 pp. 269-279. 1973.

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R. S. Roger, C. H. Costain, T. L. Landecker, C. M. Swerdlyk. Radio Emission from the Galaxy at 22 MHz. Astronomy and Astrophysics Supplement Series. ISSN 0365-0138. 137 pp. 7-19. 2nd May 1999.

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M. C. Rose, M. J. Jarvis, M. A. Cliverd, D. J. Maxfield, T. J. Rosenburg. The Effect of Snow Accumulation on Imaging Riometer Performance. Radio Science. ISSN 0048-6604. 35(5) pp. 1143-1153. September-October 2000.