Probing Stellar and Substellar Magnetospheres with Next Generation Radio Instruments

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• EVLA – Continuum point-source sensitivity better than 1 microJy between 2 and 40 GHz.

• Operation at any frequency between 1.0 and 50 GHz, with up to 8 GHz bandwidth per polarization and a minimum of 16,384 channels.

• EVLA will revolutionize stellar radio astronomy.
RSRO – Resident Shared Risk Observing

Early access to the growing capabilities of the EVLA as it is being commissioned, in exchange for a period of residence in Socorro to assist with the commissioning.

RSRO 10B-209: ‘Broadband Periodic Dynamic Spectra of Ultracool Dwarf Pulsars’ - 38 hours on two brown dwarfs

RSRO 10C-210: ‘Broadband Spectra of Radio Emission from M Dwarf Stars and Brown Dwarfs’ - 16 hours on 2 flare stars and two brown dwarfs
UV Ceti

Duration ~25 mins
Frequency = 1-2 GHz
1 GHz total bandwidth
RMS noise ~ 50 µJy

Duration ~25 mins
Frequency = 4.8-5.8 GHz and 6.8-7.8 GHz
2 GHz total bandwidth
RMS noise ~ 9 µJy

Duration ~25 mins
Frequency = 18.7-19.7 GHz and 23-24 GHz
2 GHz total bandwidth
RMS noise ~ 14 µJy
V374 Peg

The images show different views of V374 Peg, a variable star. The graphs illustrate the flux of the star as a function of frequency, with a power law index $\alpha = 0.3$. The data points are shown with error bars, indicating the variability and uncertainty in the measurements.
Detecting thermal radio emission from solar type stars (F8V-K2V) with activity levels comparable to the Sun is now possible.

Excellent method to measure coronal magnetic field strengths low in the corona and chromosphere.

Solar radio flux at distance of Alpha Centauri compared to VLA and EVLA sensitivity.
Combining Radio and Zeeman Doppler Imaging

Zeeman Doppler Imaging (ZDI) enables the mapping of the large-scale magnetic fields of stars.

Donati et al. (2006) – Fully convective dwarf stars have large-scale axisymmetric dipolar fields.

Simultaneous observations can map the radio corona to the stellar magnetic field.

- Work done in collaboration with Julien Morin, J.F. Donati & Moira Jardine.
- Quiescent emission is strongly periodic with rotation of the dwarf.

- Two peaks per period if rotation when the large-scale magnetic field is perpendicular to our line of sight.
Peterson et al. Nature 2010: Coronal Loop on Algol
Simultaneous Zeeman Doppler Imaging and VLBI
Brown Dwarfs Pulses!

The M9 dwarf TVLM 513-46546 - Hallinan et al. (2006, 2007)
Radio Emission from Solar System Planets

- All the magnetized planets in our solar system produce extremely bright radio emission at low frequencies (MHz and kHz).

- 1-5 % of auroral input energy converted into electron cyclotron maser emission.

- Produced at the electron cyclotron frequency - Field strength (Gauss) = Frequency (MHz) / 2.8

Credit: Soho
Peak to peak amplitude variation in r' band is ~ 7%
TVLM 513-46546 → M8.5
Period: 1.96 hours
Surface B > 3015 G
Log($L_{H\alpha}/L_{bol}$) = -4.8
Log($L_X/L_{bol}$) = -5.1 (marginal)

LSR J1835+3259 → M8.5
Period: 2.84 hours
Surface B > 3015 G
Log($L_{H\alpha}/L_{bol}$) = -4.85
Log($L_X/L_{bol}$) < -5.7

2MASS J0746+20 → L0+L1.5
Period: 2.07 hours
Surface B > 1735 G
Log($L_{H\alpha}/L_{bol}$) = -4.85
Log($L_X/L_{bol}$) < -4.7

2MASS J0036+18 → L3.5
Period: 3.08 hours
Surface B > 1735 G
Log($L_{H\alpha}/L_{bol}$) = -4.7
Log($L_X/L_{bol}$) < -6.65
Jovian Radio Components

- DAM arcs
- S-bursts
- HOM
- nKOM
- bKOM
- QP-bursts

Time or CML

Frequency (MHz)

Adapted from Zarka, P. 1998, J. Geophys. Res., 103, 20159
• 5 hours of test data with 2 GHz bandwidth.
• RMS noise ~2.3 μJy
EVLA: First results...

- Phase folded light curves.
- Clear difference in time of arrival at higher frequencies.
- First slice of the spectrum
- Spectral Index $\alpha \sim -2$: steep
Conclusions

- EVLA will enable the definitive detection of the thermal radio emission from the atmospheres of main sequence stars for the first time.

- Broadband spectra of individual active stars should establish the various mechanisms at work in non-thermal and thermal radio coronae.

- Combining radio observations with Zeeman Doppler Imaging is a powerful method for diagnostics of stellar coronae.

- The study of ultracool dwarf pulsars indicates the presence of planet-like behaviour at the lower end of the main sequence.

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