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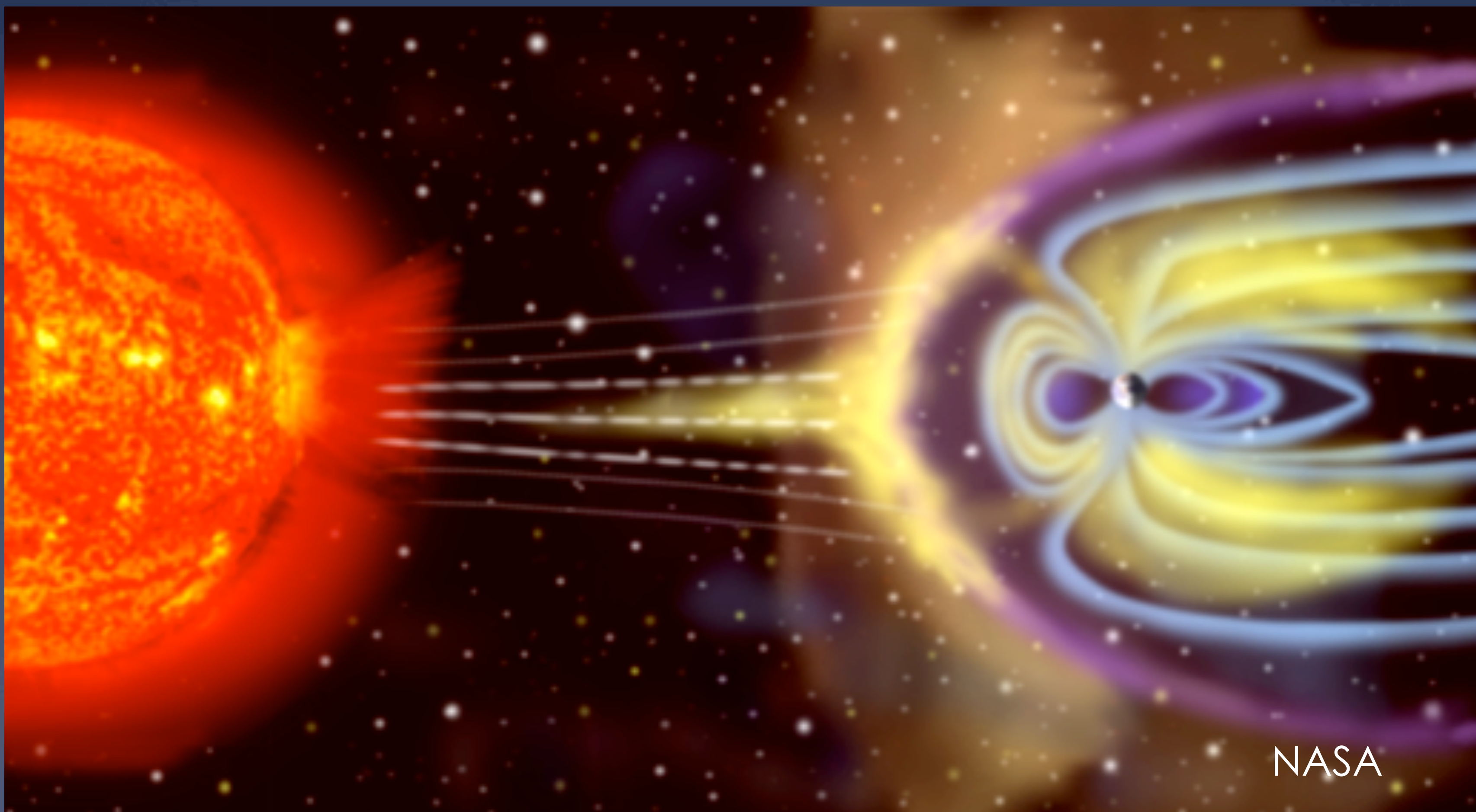
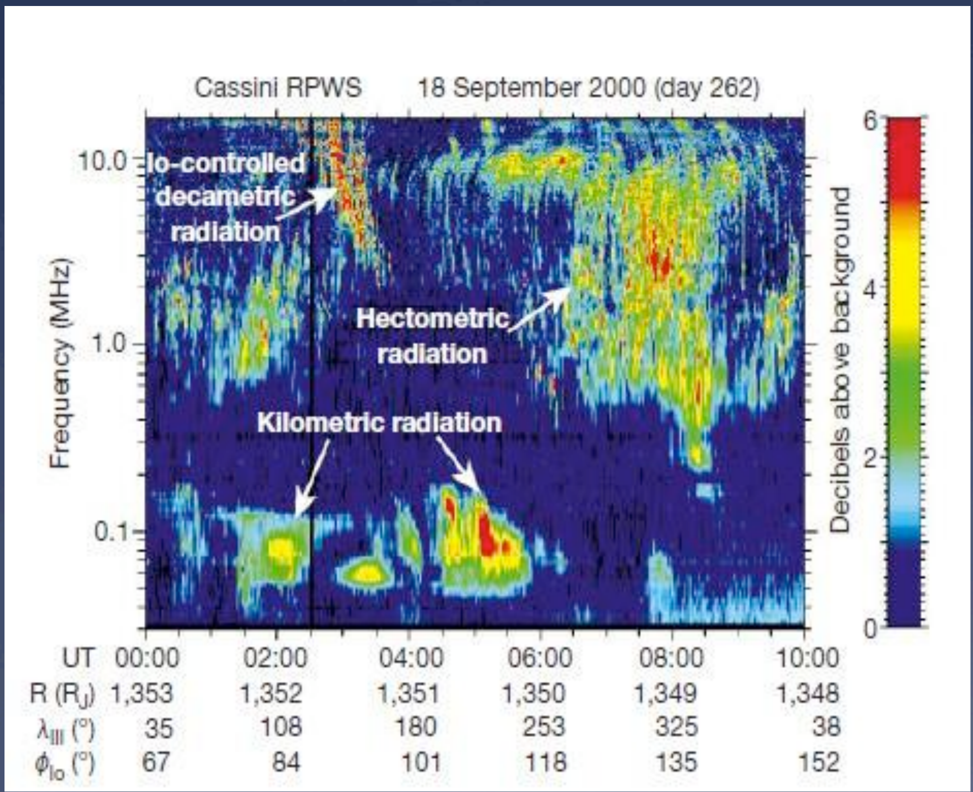
Radio emission from exoplanets

Matt Route & Alex Wolszczan (Penn State)



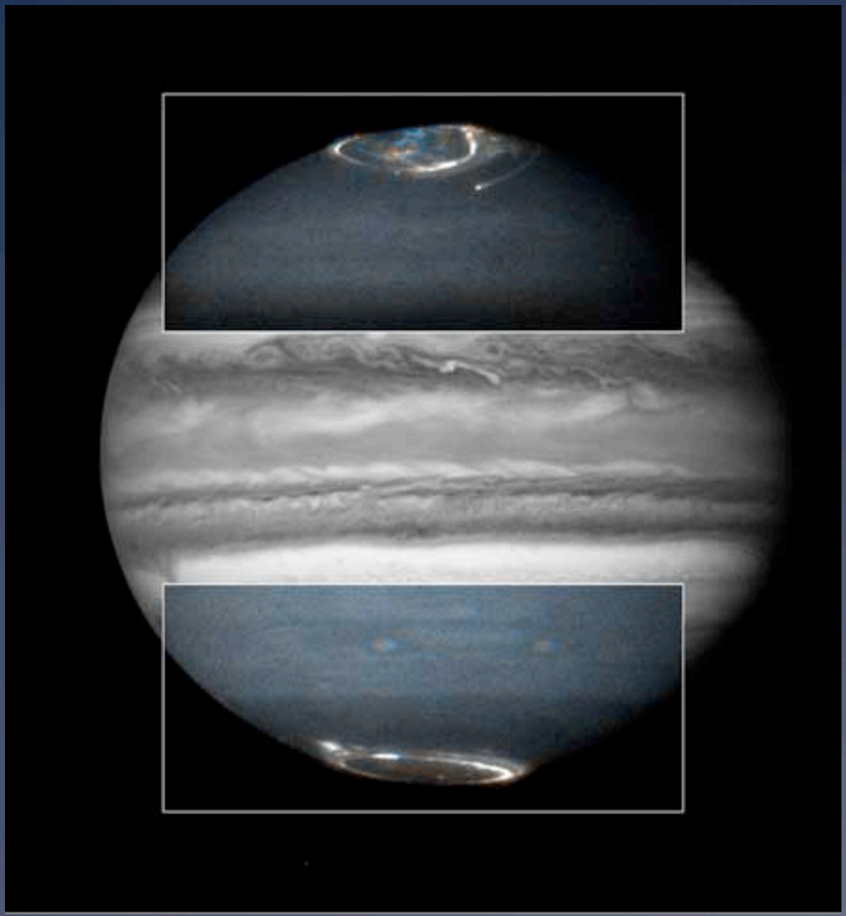
Motivation



Gurnett et al. (2002)

- Interaction of planetary magnetic fields with the solar wind produces observable electron cyclotron maser radiation
- With $\nu_c = eB/2\pi m$, and Jupiter's B~4G, the cutoff radio emission frequency is ~ 40 MHz
- Benefits from exoplanet detection:
  1. Diagnostic of magnetic fields from radio measurements → access to physics of planetary interiors (probe the planet-BD interface?)
  2. Measurement of planet rotation from radio flux variations
  3. Detection of satellites (e.g. Jupiter-Io system)
  4. Diagnostic of atmospheric stability (non-thermal loss due to stellar wind?)
  5. Constraints on planetary habitability

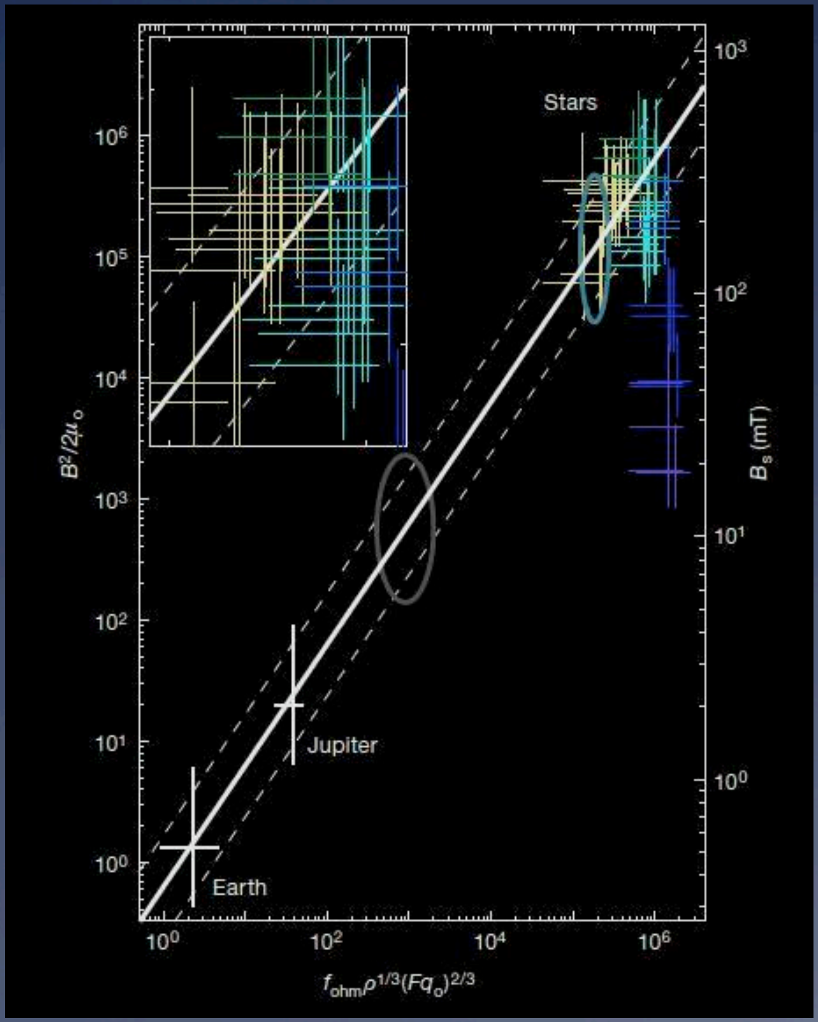
Energy supply for planetary radio emission



NASA/HST

- Power generated depends on energy input into a planetary magnetosphere (Griessmeier et al. 2007)
- Kinetic: energy carried by stellar wind particles → $P_{inp} \sim n v_e^3 R_s^2$
- Magnetic: energy carried by fields in the wind → $P_{inp} \sim v_e B^2_{perp} R_s^2$
- Coronal Magnetic Eruption: like kinetic with n → n_{CME}
- Unipolar: Jupiter-Io mechanism → $P_{inp} \sim v_e B^2_{perp} R^2_{ION}$
- Observed radio flux: $\Phi = (\eta_{rad}\, \varepsilon\, P_{inp}) / (\Omega\, d^2\, \nu)$
- Need $f_p < f_c$; $f_p = (1/2\pi)(ne^2/\varepsilon_0 m)^{1/2}$

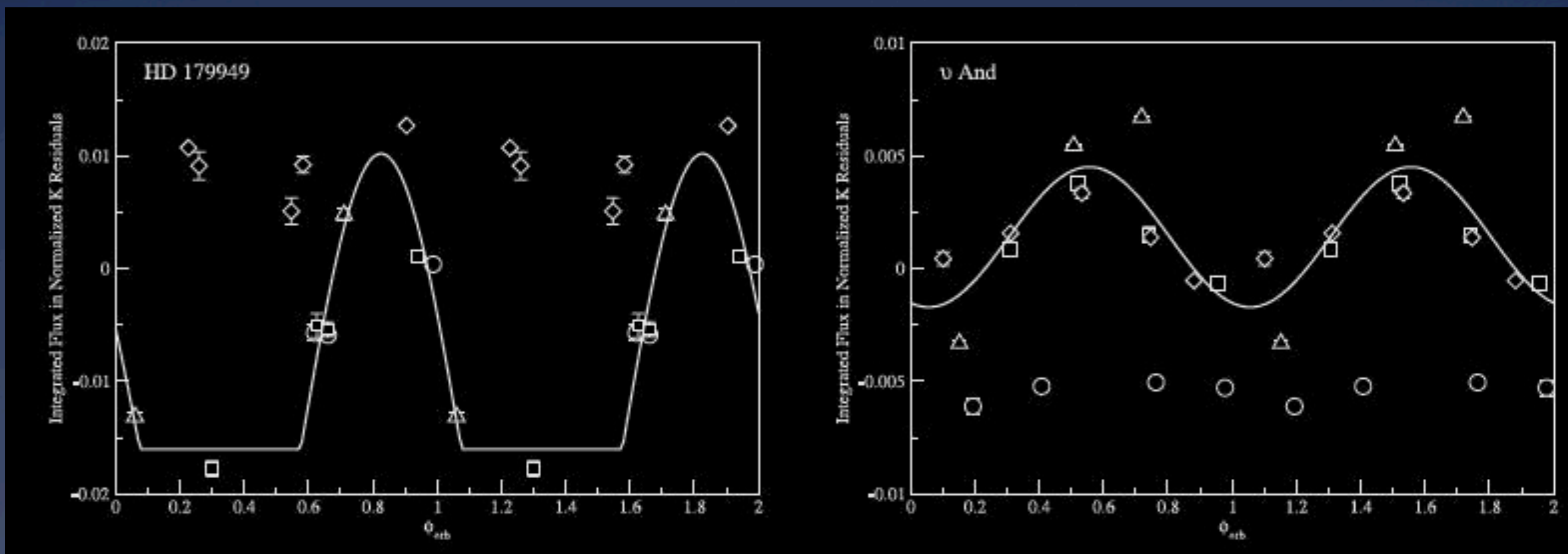
A generalized scaling law for magnetic fields in celestial bodies?



* Extension of geodynamo models to rapidly rotating stars
* Energy contained in the magnetic fields generated by convection
* Young, warm planets should have stronger fields
* Giant exoplanets with 20-200x Jupiter's luminosity should have field strengths 5-12x Jupiter's
* Giant exoplanets should have detectable radio emission

Christensen et al. 2009

Measurable planet-star interaction?



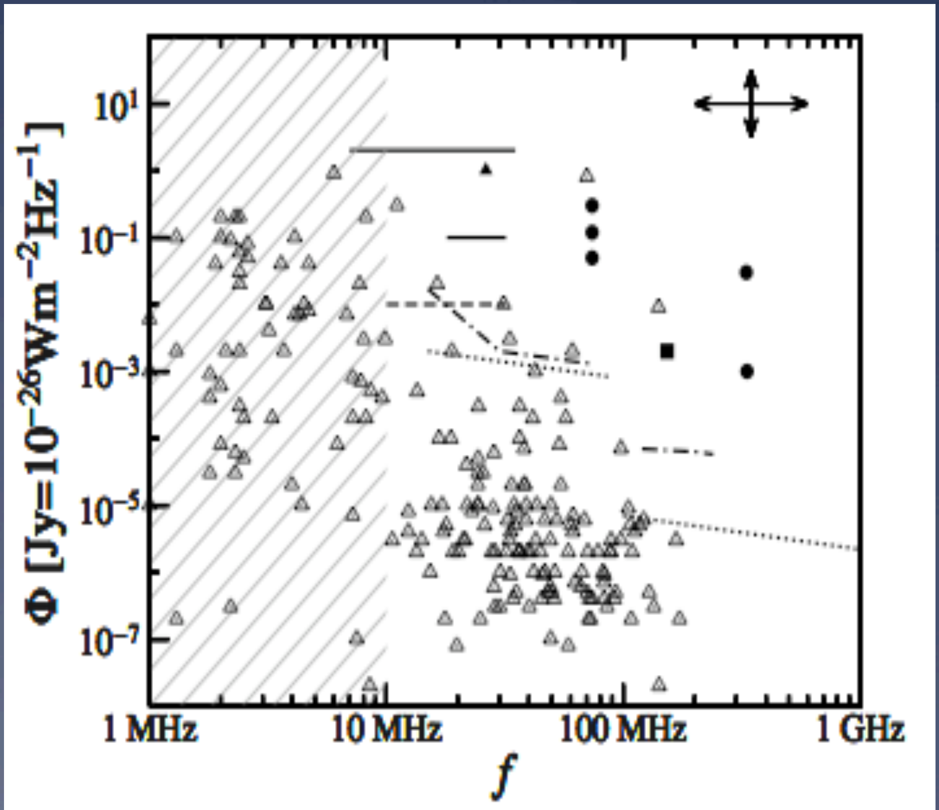
- Analogy to RS CVn stars and induced chromospheric activity (Cuntz et al. 2000)
- Measurements of Ca II H and K lines for 13 stars
- HD 179949 and ν And may exhibit cyclic variation

Shkolnik et al. 2005

Searches for radio emission from exoplanets

- VLA at 74, 330, 1465 MHz (Bastian et al. 2000, Farrell et al. 2003, Lazio & Farrell 2008)
- GMRT at 150, 235, 244, 330, 610, 614 MHz (Majid et al. 2005, Hallinan et al. 2009, Lecavelier des Etangs et al. 2009, Winterhalter et al. 2009)
- UTR-2 at 23-27 MHz (Ryabov et al. 2004, Zarka 2007)

Griessmeier et al. (2007) predictions



Sensitivity requirements and current detection limits
(Lazio et al. 2009)

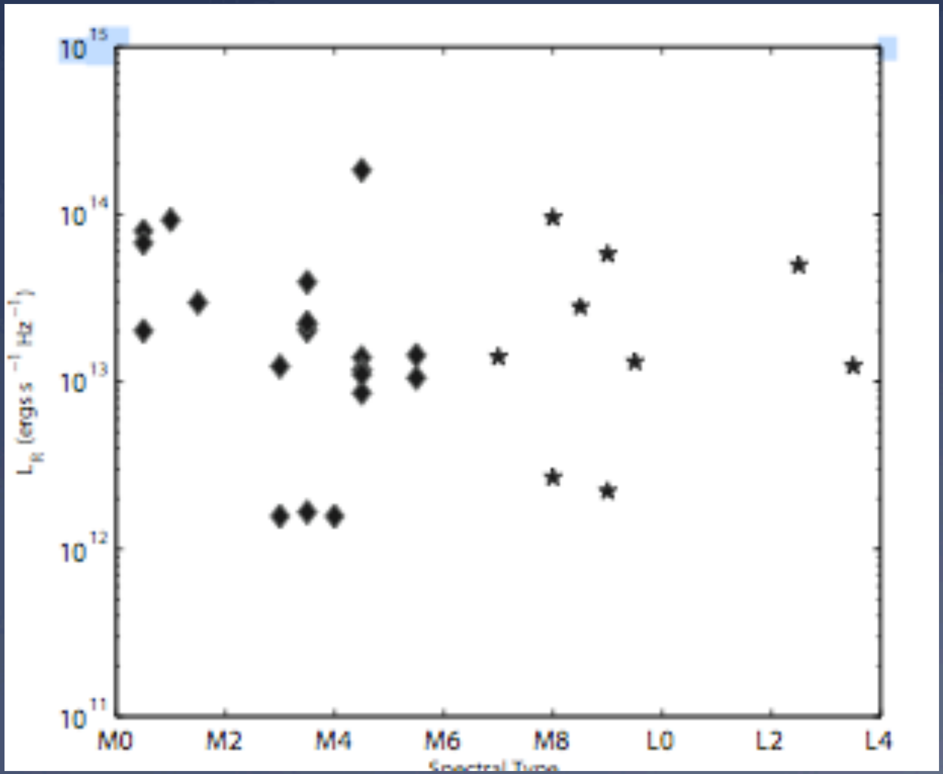
Table 1. Scientific Requirements for Extrasolar Planetary Magnetospheric Observations

Parameter	Value	Comment
Frequency (Wavelength)	<~ 100 MHz (>~ 3 m)	Determined by planetary magnetic field; Brown dwarf observations suggest higher frequencies possible.
Sensitivity	< 25 mJy	Extrapolations from solar system relations; Constrained by existing observations.

Table 2. Limits on Extrasolar Planetary Magnetosphere Emission[2]

Frequency	Limit	Telescope	Reference
150 MHz	0.3–2 mJy	GMRT	Hallinan et al. 2009; Winterhalter et al. 2009
74 MHz	135–300 mJy	VLA	Lazio & Farrell 2008
25 MHz	100–1600 mJy[3]	UTR-2	Zarka 2007

Radio emission from low-mass stars

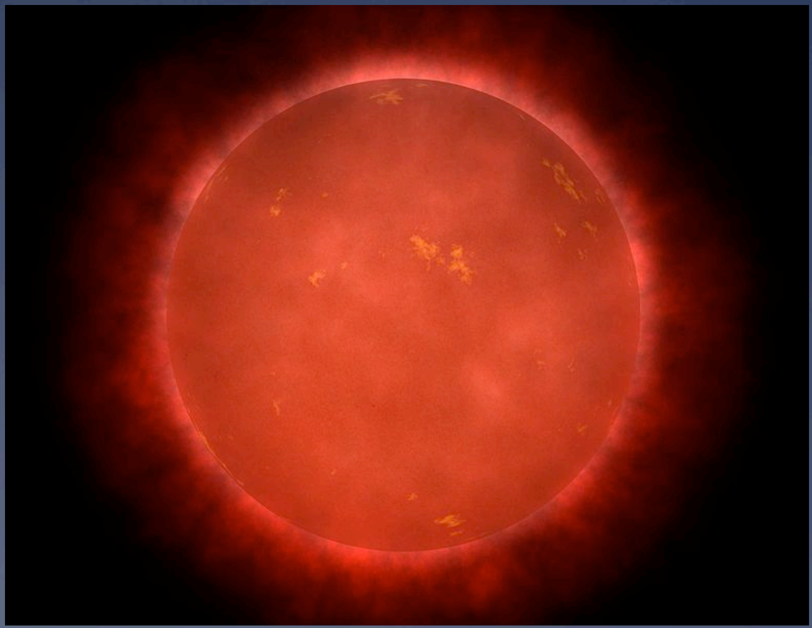


Hallinan et al. (2008)

- Persistent, bursty radio emission from M9 brown dwarf LP944-20 (Rutledge et al. 2000)
  - Violated Güdel-Benz relationship (L_X~$10^{15.5}L_R$) by 10^4
- DENIS 1048-3956 emitted bright, narrow bandwidth 100% circularly polarized flare with T>10^{13} K (Berger et al. 2005) → exceeded equipartition limit for incoherent nonthermal emission
- Periodic radio emission from 2MASS J00361617+1821104 (Berger et al. 2005)

TVLM 513-46546 dossier

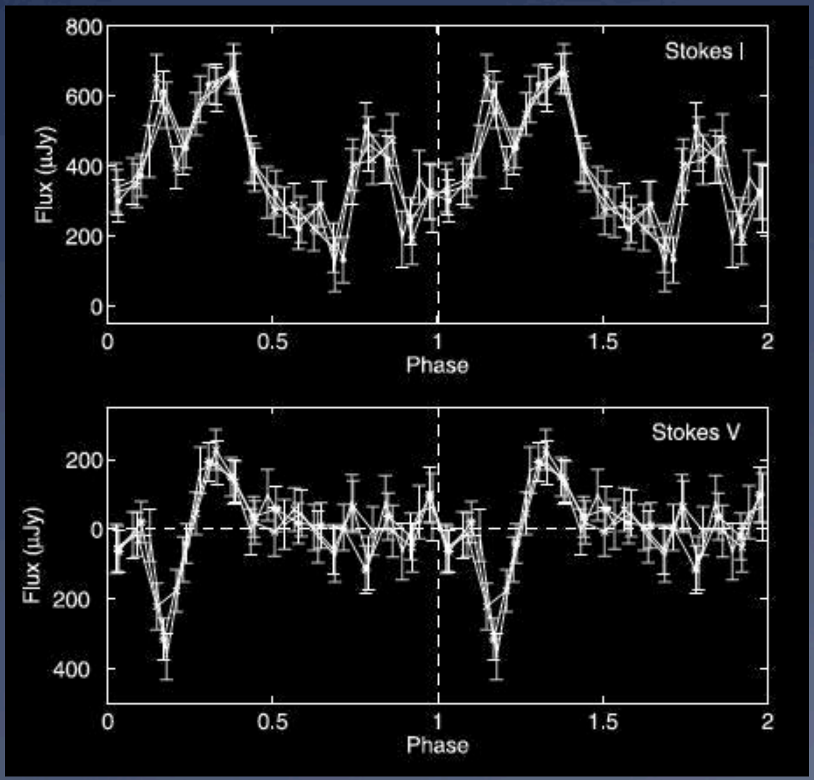
* Young disk M9 star
* Distance: 10.5 pc (Tinney et al. 1993)
* Mass: > 0.06 solar masses (Reid et al. 2002)
* Surface temp ~2200 K
* Rapid rotation: v*sin(i)~ 60 km/s (Basri 2001)



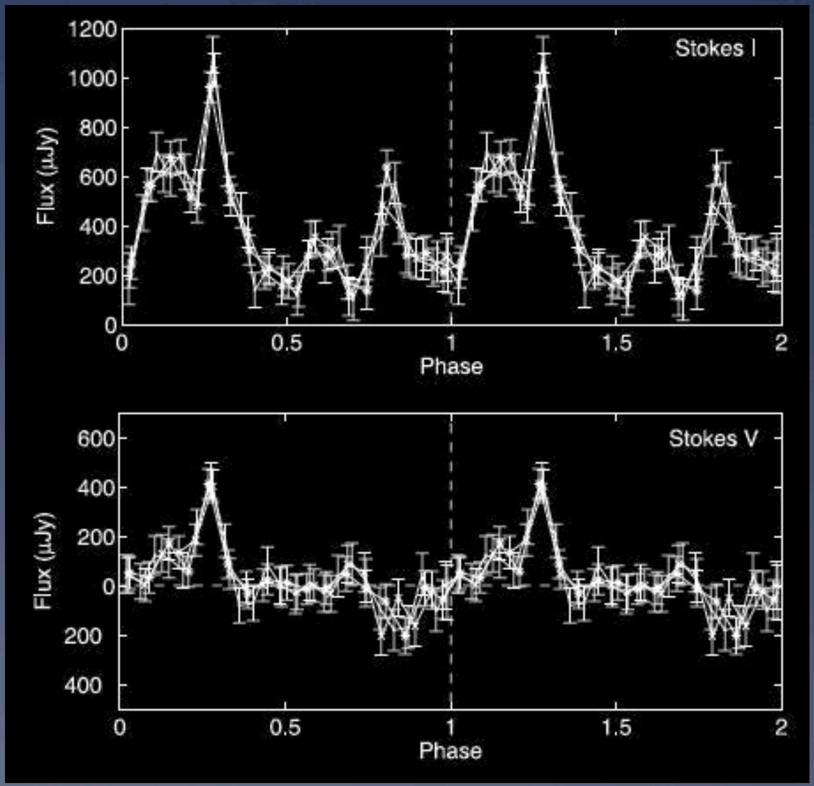
NASA/ Fermier

VLA observations of TVLM-513

4.88 GHz Epoch-folded Light Curve



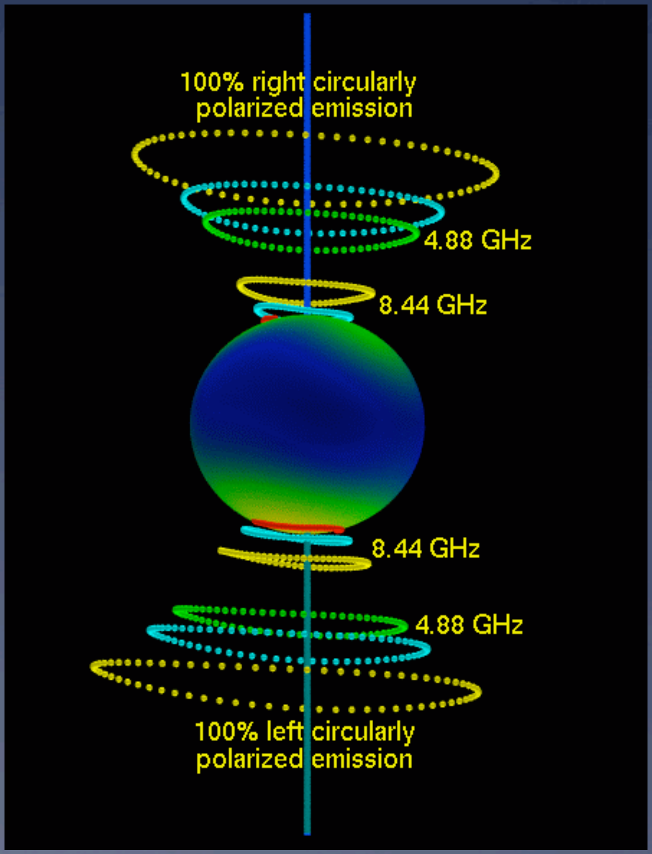
8.44 GHz Epoch-folded Light Curve



Hallinan et al. 2006

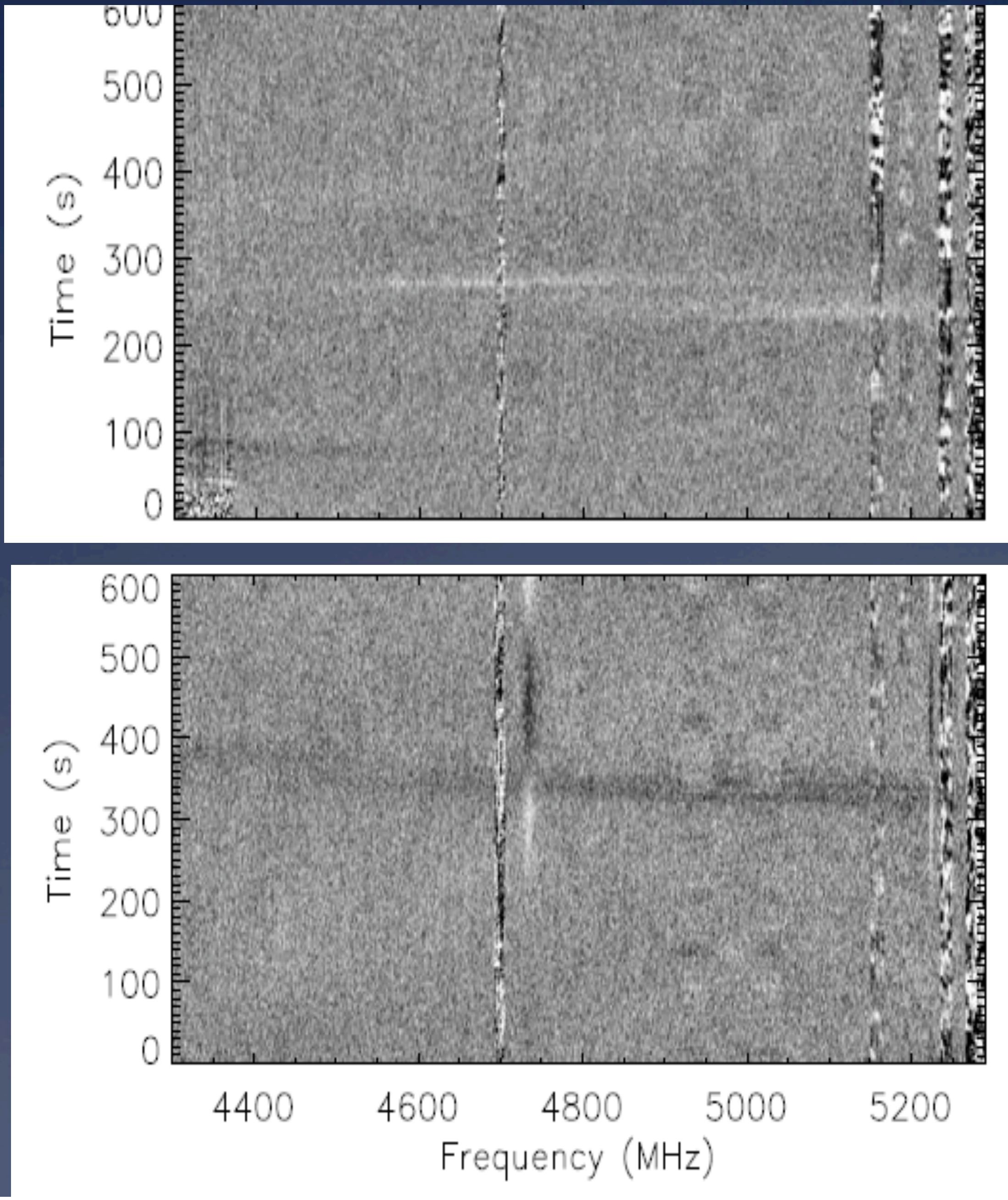
TVLM-513 results

* Persistent radio emission in both 4.88 GHz and 8.44 GHz bandwidths with a period of ~2 hr
* Radio emission periodicity correlates with rotational period of star
* Most likely source of radio emission: electron cyclotron maser emission from polar regions
* Dipole field strength of at least 3 kG



Hallinan et al. 2006

Arecibo observations of TVLM513



- 5 GHz receiver
- 1 GHz bandwidth
- 1 s sampling
- 80 kHz resolution
- 0.2 mJy rms
- 4 Stokes observed
- Highly circularly polarized bursts detected at 2-3 mJy level

The ongoing Arecibo project

* 40 hours of observing time for 38 sources at 5 GHz
* Sources include 14 brown dwarfs and 24 planets
* Sources selected based on declination, distance, mass, and spectral type
* New backend: 20 kHz, 0.1 s resolution