

# The search for radio emission from extrasolar planets with LOFAR

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# Exoplanetary radio emission

1. Planetary radio emission
2. **Ex**oplanetary radio emission?
3. **Models** for planetary radio emission?
4. Model **result**: expected emission frequency
5. Model **result**: expected radio flux

# Exoplanetary radio emission

1. Planetary radio emission
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4. Model result: expected emission frequency
5. Model result: expected radio flux

# Radioplanets: Solar system

## First radio observations:

- Jupiter: DAM 1955 (ground observation)
- Earth: AKR 1965 (Elektron-2)
- Saturn: SKR 1980 (Voyager 1)
- Uranus: UKR 1986 (Voyager 2)
- Neptune: NKR 1989 (Voyager 2)

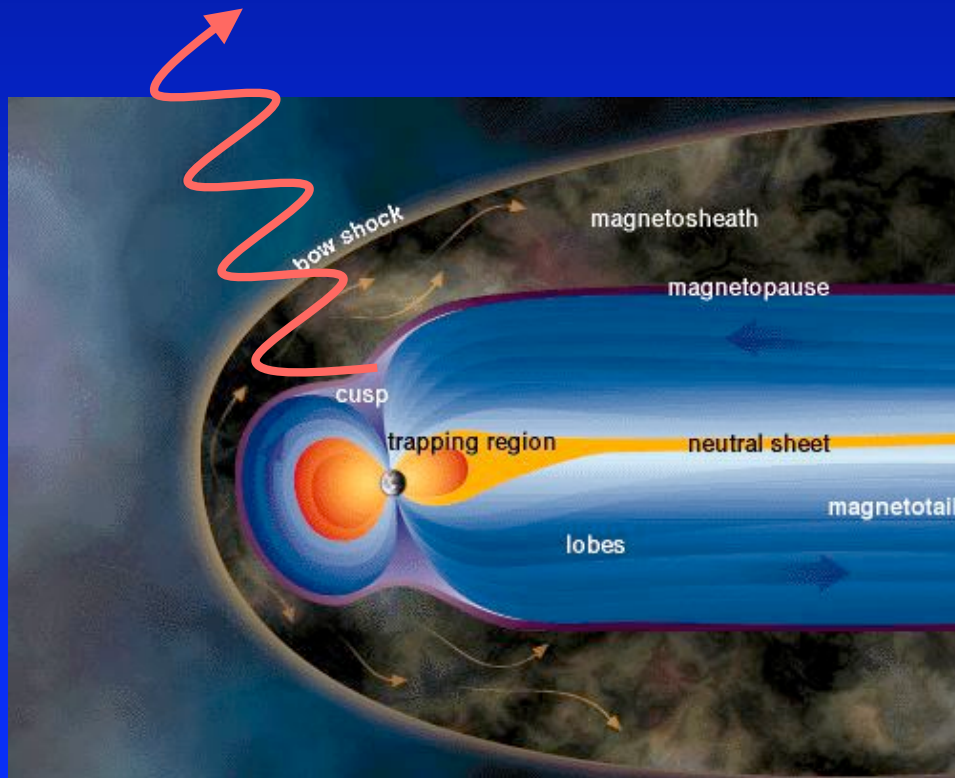
⇒ all strongly magnetized planets  
are nonthermal radio emitters!

# Magnetospheres

**Magnetopause:** separates regions dominated by interplanetary and planetary magnetic field

**Magnetosphere:** region inside the magnetopause

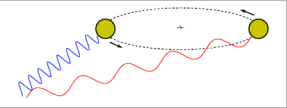
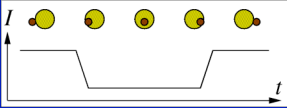
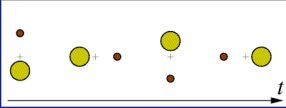
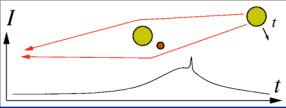
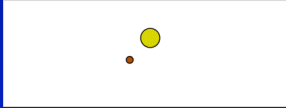
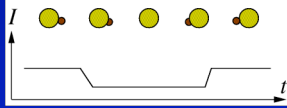
Earth's  
Magnetosphere



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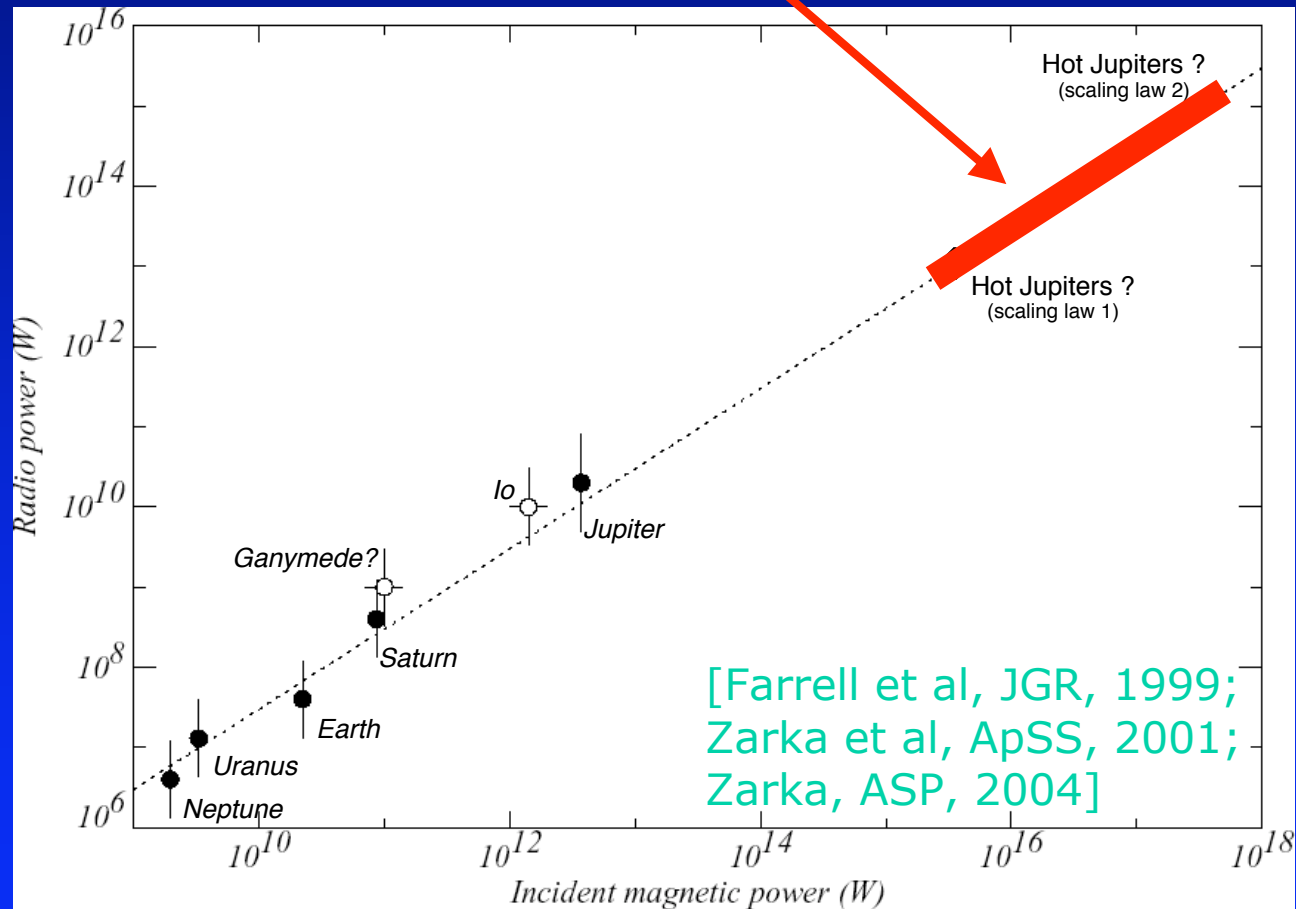
# Exoplanets: Observations

Doppler shift	Transit	Astrometry	Micro-lensing	Direct obs.	Second. Transit
					
1995 (51 Peg b)	2000 (HD209458b)	2002 ? (Gl 876 b)	2003 (O235/M53)	2004 (2M1207)	2004 (HD209458b)
>180	16	1 ?	4	4	2

Radio emission as additional source of information?

# Exoplanetary radio emission

Expect much stronger emission from  
extrasolar planets!



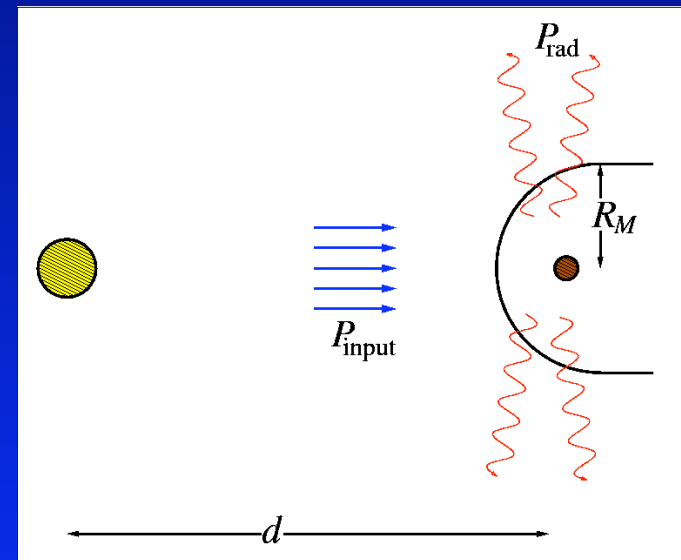


# Planetary radio emissions

Emitted radio power:  $P_{\text{rad}} \propto P_{\text{input}}$

[Zarka et al, ApSS. 2001]

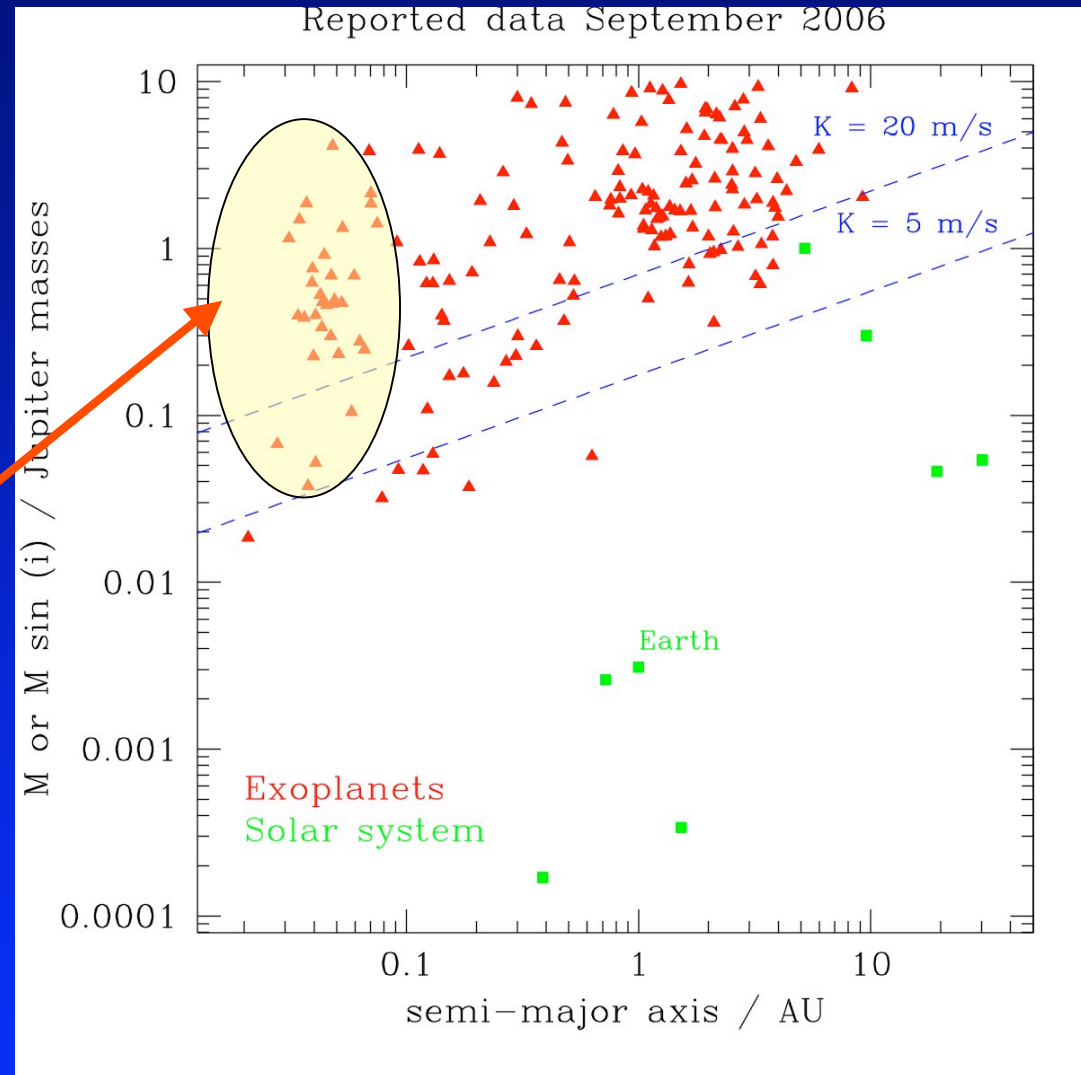
Power input:  $P_{\text{input}}$  (solar wind)



large power input for close-in planets

# Exoplanets: Orbital radii

Total:  
224 planets  
(20.04.2007)  
[<http://www.obspm.fr/encycl/encycl.html>]  
"Hot Jupiters":  
54 planets  
with  $d < 0.1$  AU



[<http://jilawww.colorado.edu/~pja/planets/extrasolar.html>]

# Radioplanets: Exoplanets

## Observation attempts:

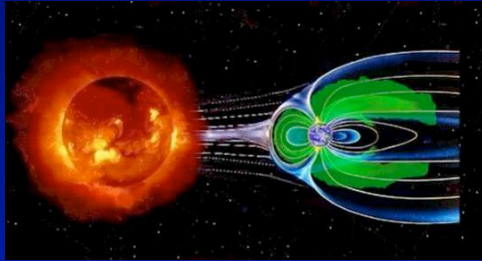
- Clark Lake: Yantis et al., BAAS, 1977
- VLA: Winglee et al., ApJ, 1986
- UTR-2: Zarka et al, PRE IV, 1997
- VLA: Bastian et al, ApJ, 2000
- VLA: Farrell et al., ASP, 2003
- VLA: Lazio et al., ApJ, 2004
- UTR-2: Ryabov et al., PSS, 2004
- Effelsberg: Guenther, 2004
- Mizusawa: Shiratori et al., 51 Peg, 2005
- GMRT: Majid et al., 51 Peg, 2005

- no detection yet
- models give reasons: sensitivity, frequency  
⇒ LOFAR better adapted

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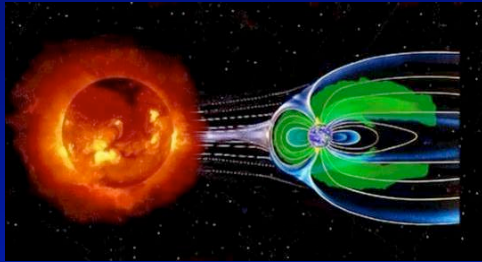
# Planetary radio emission



Flow \ Obstacle	weakly/not magnetized (solar wind)	strongly magnetized (Jovian magnetosphere)
weakly/not magnetized (Venus, Io)		
strongly magnetized (Earth, Jupiter)		

[Zarka, PSS, 2007]

# Planetary radio emission

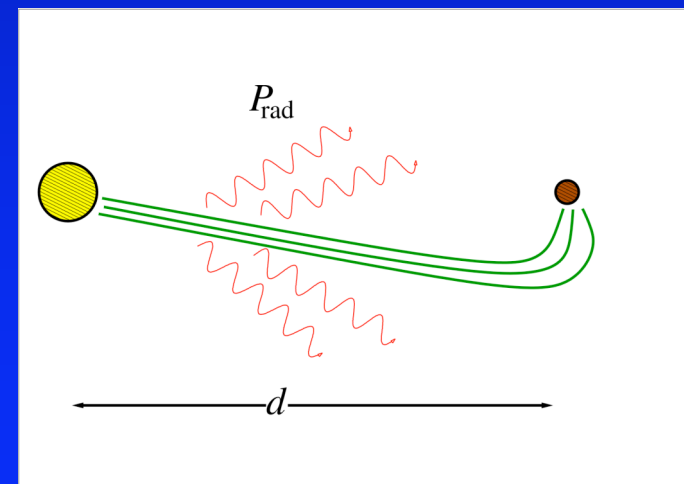
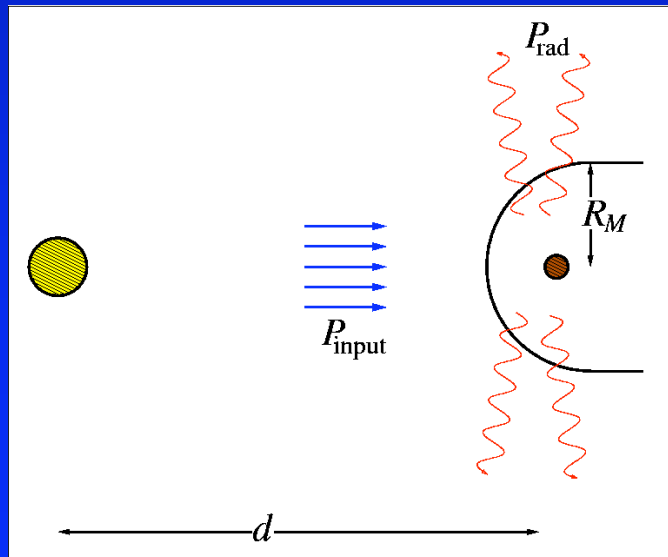


	<b>Flow</b>	weakly/not magnetized (solar wind)	strongly magnetized (Jovian magnetosphere)
<b>Obstacle</b>			
	weakly/not magnetized (Venus, Io)	no intense cyclotron emission	unipolar interaction (Jupiter-Io)
	strongly magnetized (Earth, Jupiter)	magnetospheric interaction (solar wind - Jupiter)	dipolar interaction (Jupiter-Ganymede)

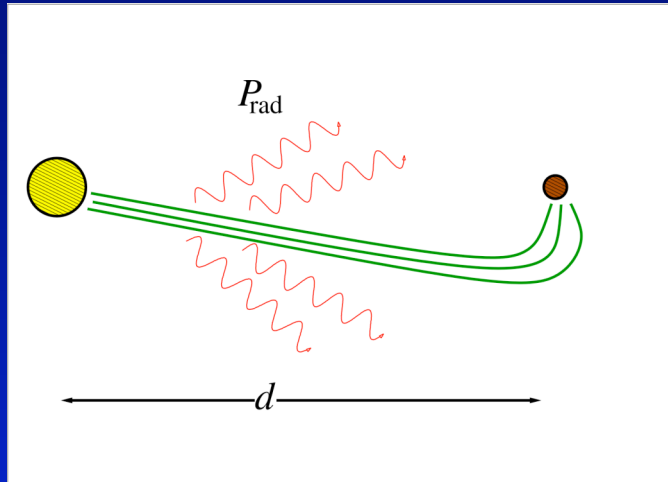
[Zarka, PSS, 2007]

# Planetary radio emission

Flow \ Obstacle	weakly/not magnetized	strongly magnetized
weakly/not magnetized	no intense emission	unipolar interaction
strongly magnetized	magneto-spheric interaction	dipolar interaction



# Emission by unipolar interaction

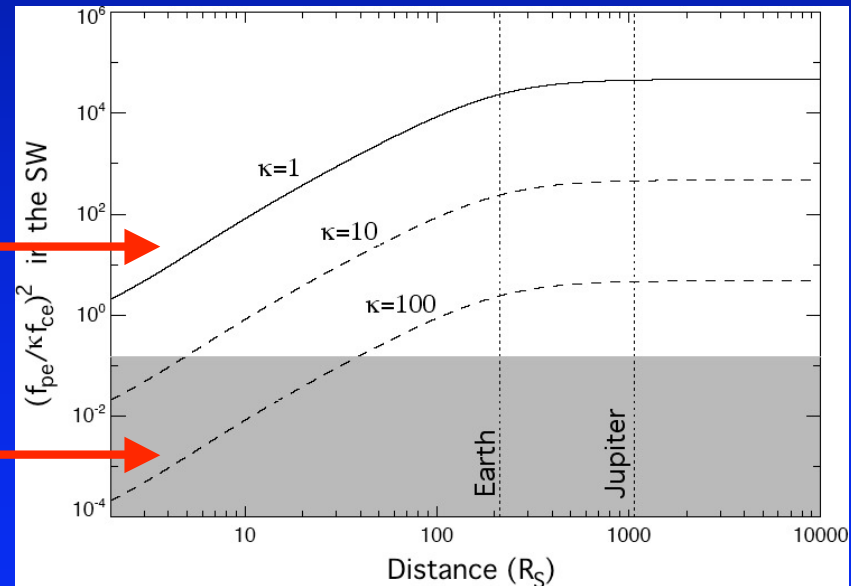


$$\frac{f_{\text{plasma}}}{f_c} \lesssim 0.4$$

$$f_c \propto \frac{eB}{m_e}$$

sun-like

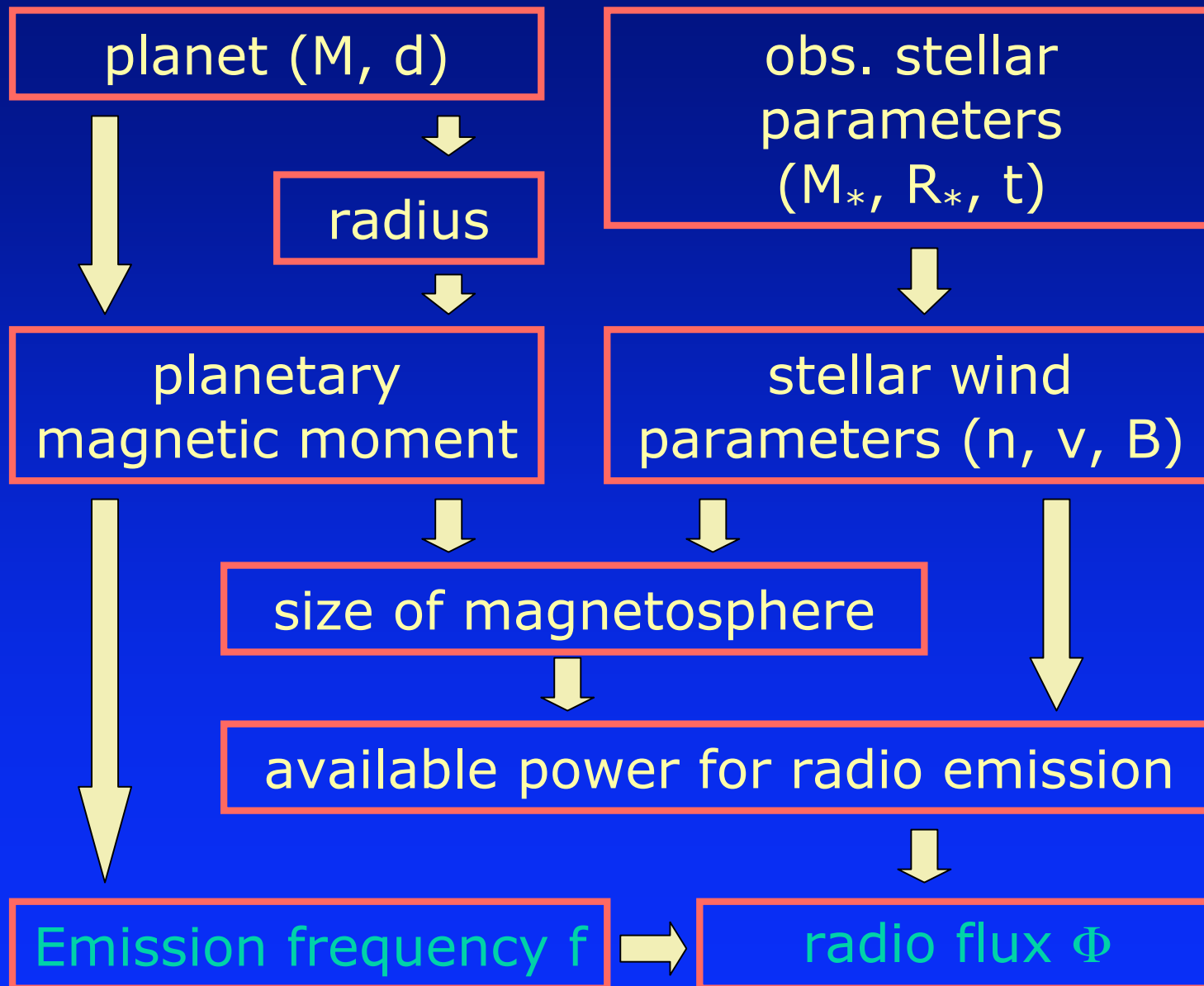
100x sun



⇒ only possible for strongly magnetized stars



# Radio flux estimation



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# Expected emission frequency

$$f_c \propto \frac{eB_p}{m_e}$$

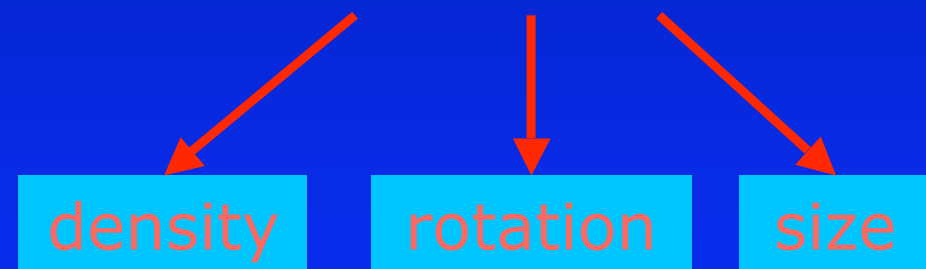
⇒ depends on magnetic field

$$B_p \propto \frac{\mathcal{M}}{R_p^3}$$

⇒ depends on magnetic moment

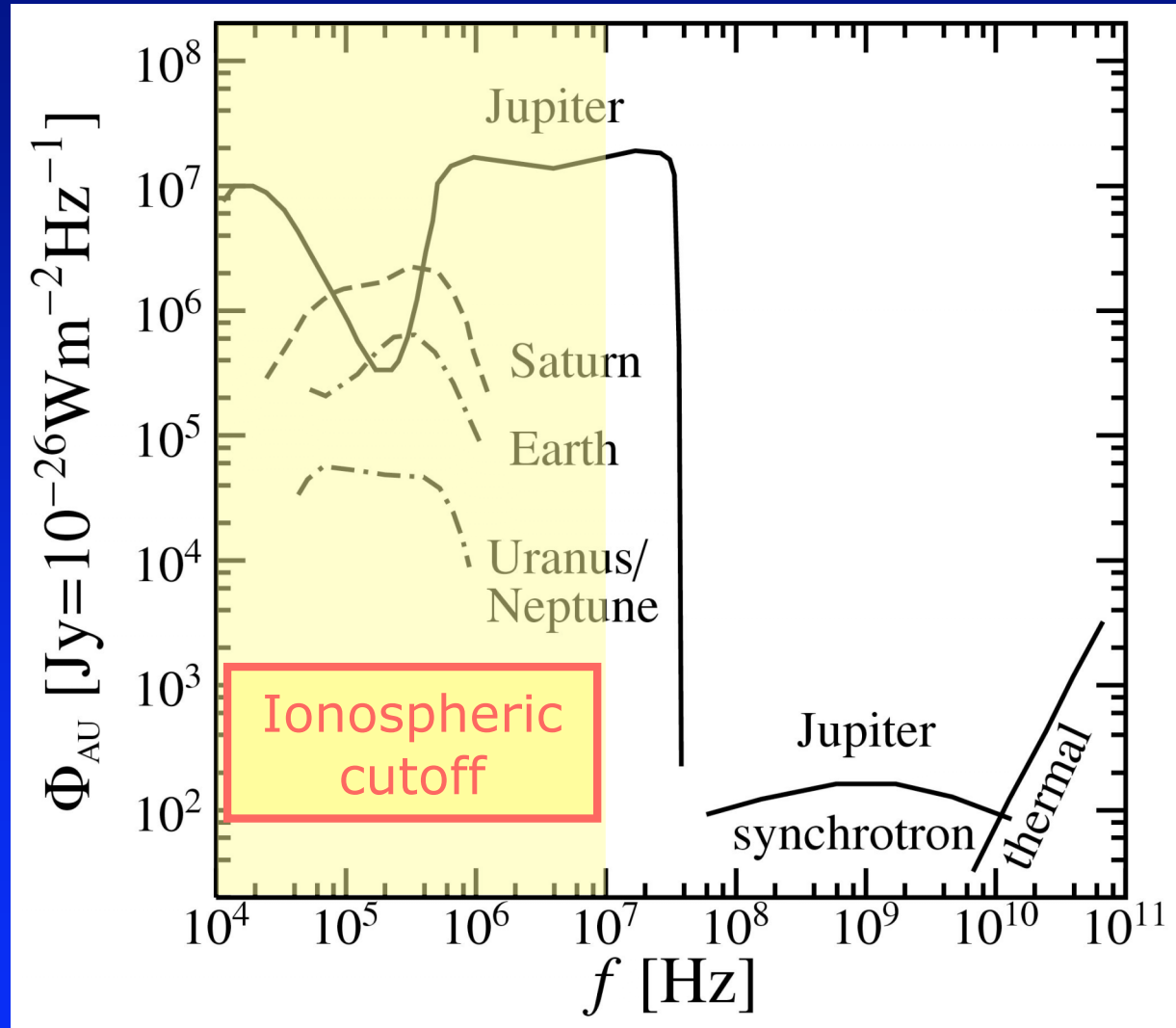
theoretical models e.g.

$$\mathcal{M} \propto \rho^{1/2} \omega r_c^{7/2}$$



⇒ emission frequency:  $f < 200$  MHz

# Radioplanets: Solar system



Ionosphere  
requires  
 $f > 10$  MHz  
for observation



observations at  
 $10 < f < 200$  MHz

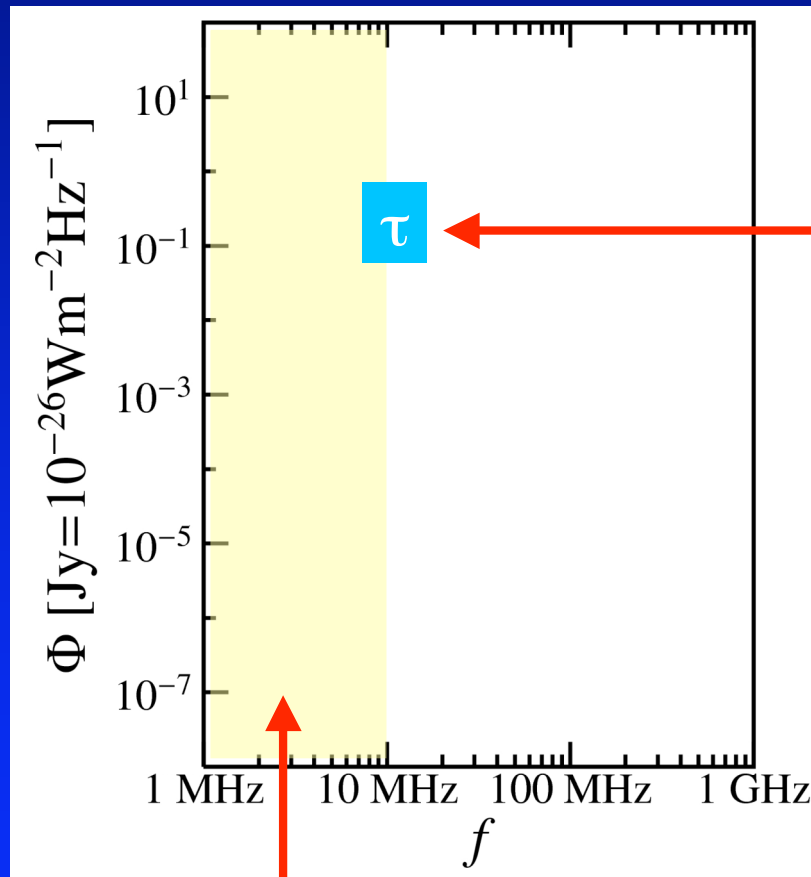
flux  
normalized  
to 1 AU

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# Radioplanets: Detection

Flux reaching Earth

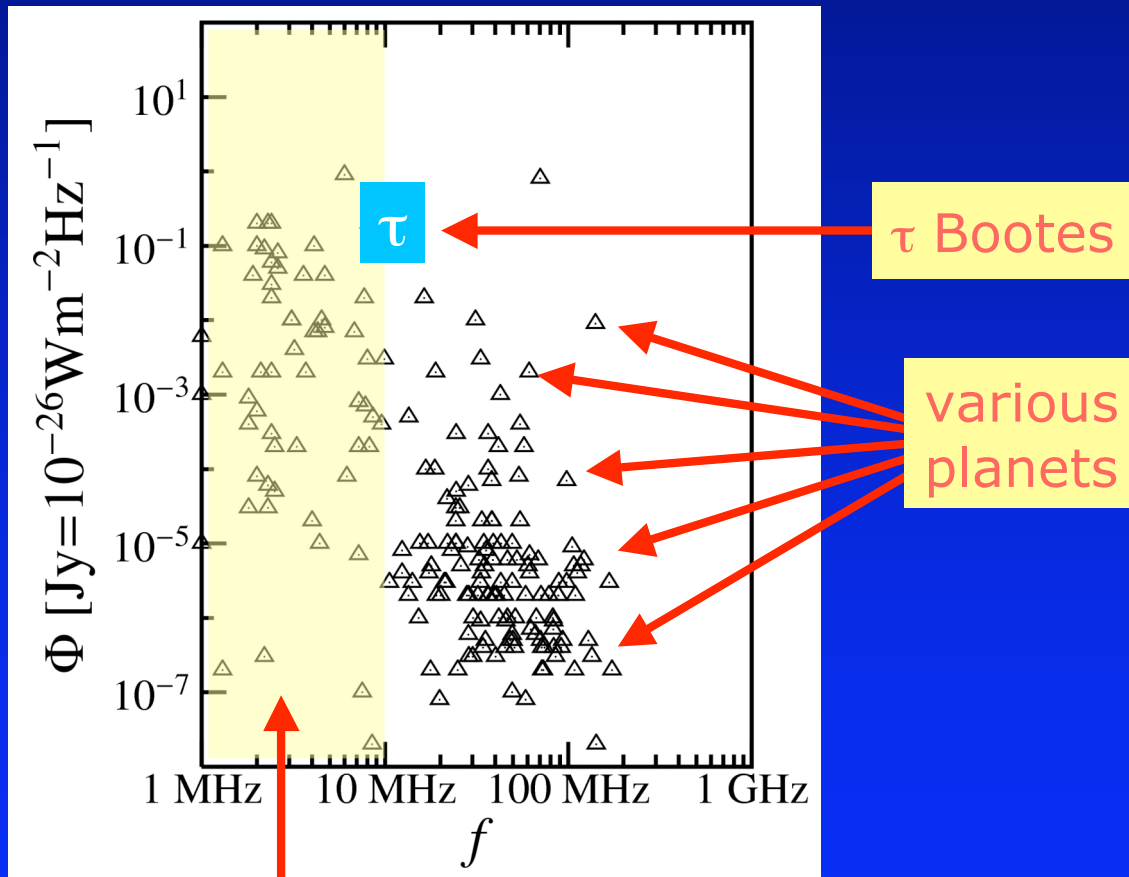


not observable (ionosphere)

$\tau$  Bootes

# Radioplanets: Detection

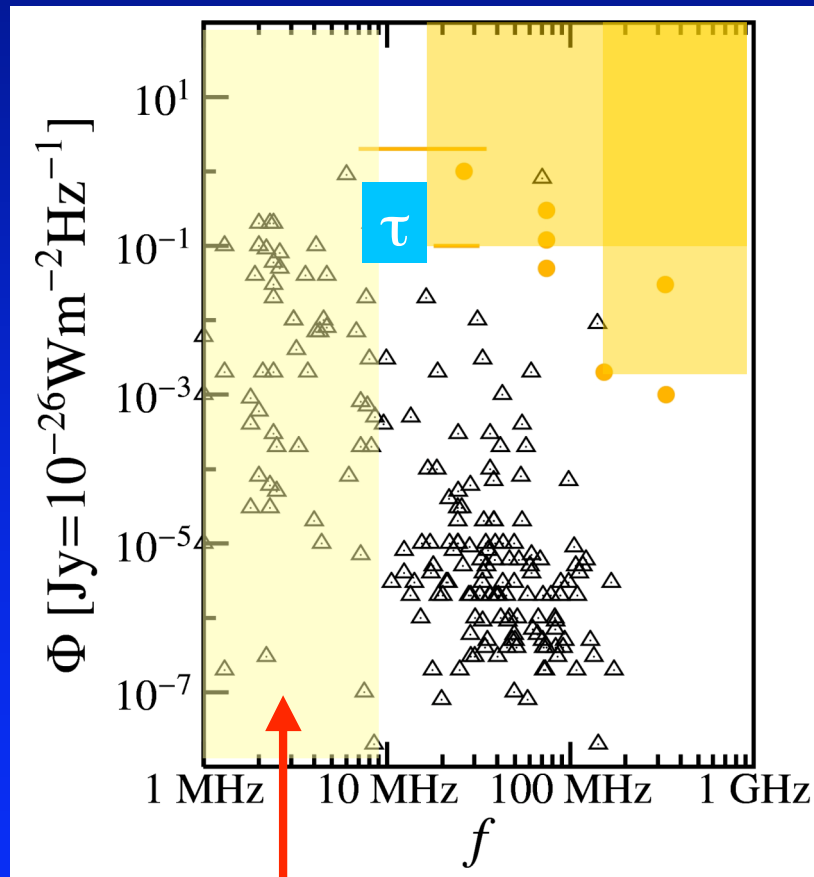
Flux reaching Earth



not observable (ionosphere)

# Radioplanets: Detection

Flux reaching Earth



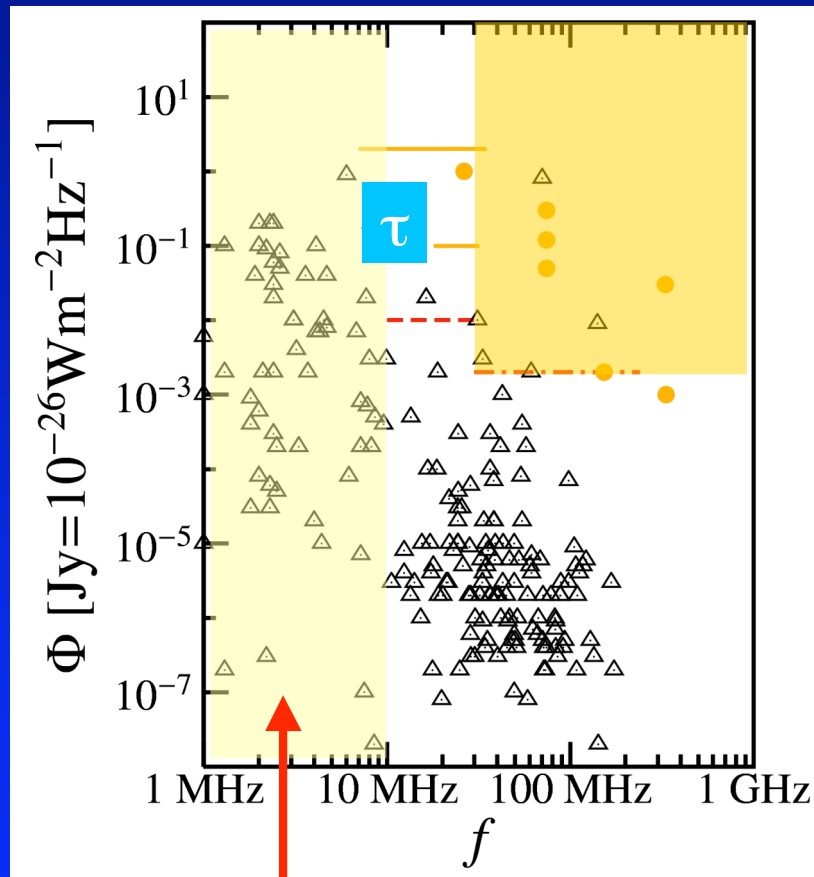
Non-detections (1977-2006):  
sensitivity not sufficient  
too high frequency

not observable (ionosphere)



# Radioplanets: Detection

Flux reaching Earth



not observable (ionosphere)

**Non-detections (1977-2006):**  
sensitivity not sufficient  
too high frequency

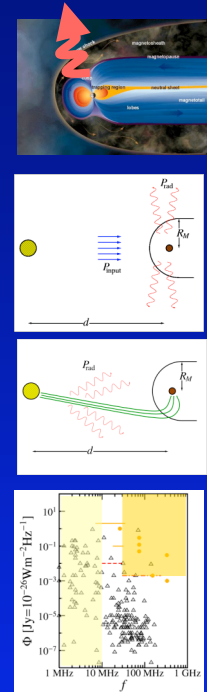
**UTR-2:** improved sensitivity  
at 10-35 MHz  
observations 2006-08

**LoFAR:** sensitivity: few mJy  
at 30-240 MHz  
ready 2007/08?

[Grießmeier et al, A&A,  
submitted, 2007]

# Summary

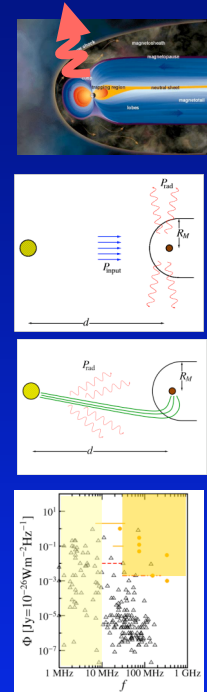
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Exoplanets should be  
observable with LOFAR

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We will try!