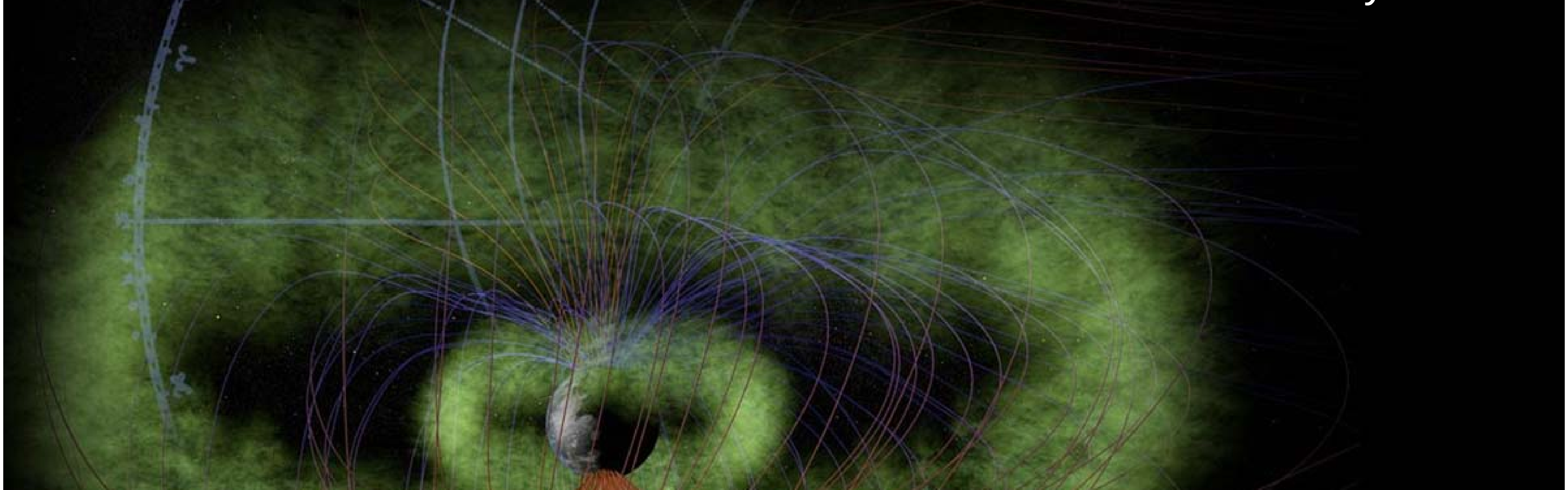
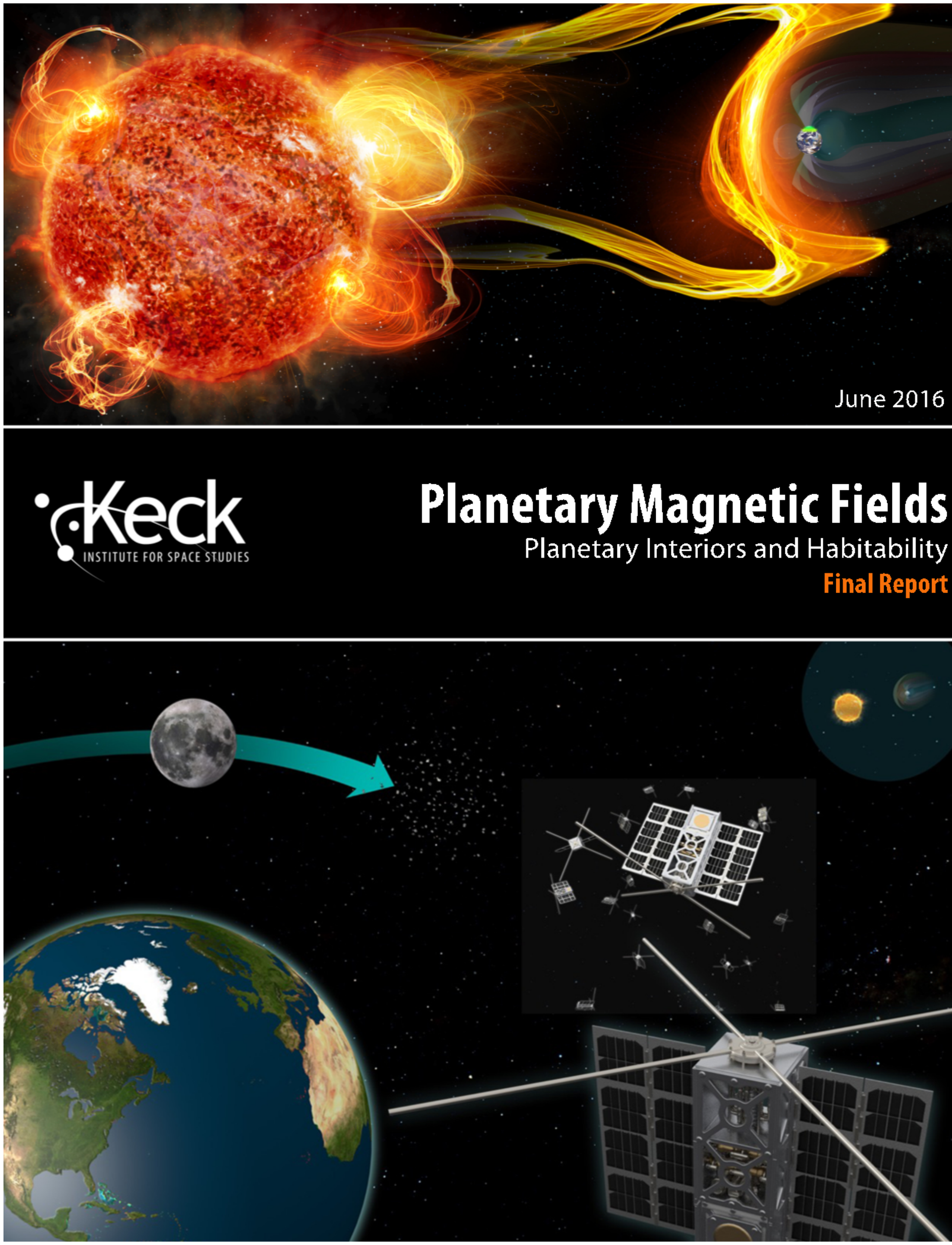
Jet Propulsion Laboratory
California Institute of Technology

Planetary Magnetic Fields: Planetary Interiors and Habitability

W. M. Keck Institute for Space Studies (KISS) Study

Joseph Lazio, Evgenya Shkolnik, Gregg Hallinan
on behalf of the KISS Study team





KISS Report

I. Magnetic Fields
   a.k.a. Why Do We Care?

II. Magnetic Fields are Important
   Wait, how might we study them?

III. Radio Emission

IV. Future

Keck Institute for Space Studies – Overview

- "Think-and-Do Tank" for new planetary, Earth and astrophysics science and engineering approaches that will impact future space missions
  - Develop new ideas that will lead to revolutionary advances in future space missions
  - Involve participants from Caltech, JPL, and the external community (academia, government, and industry)

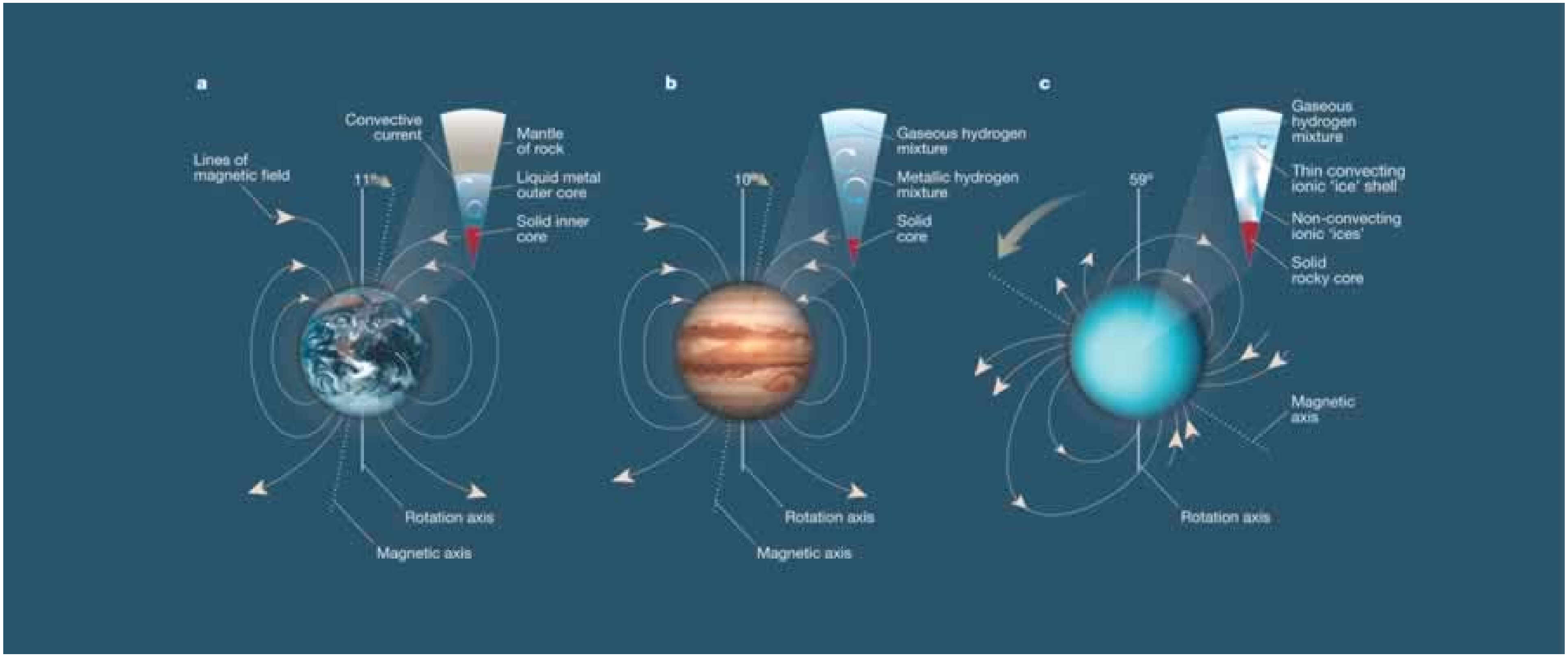
- Institute selects 5-7 topics to study each year
  - Proposal call is every October, with selections in the following January
  - Looks for those problems that are beyond the capabilities of single individual, research group, or even single institution
  - Brings together diverse team of 30 experts to brainstorm new ideas
  - Highly interactive environment, very few talks allowed during workshops

Act I: Magnetic Fields

a.k.a. Why Do We Care?

Planetary Interiors and Magnetic Fields

Solar System Guidance



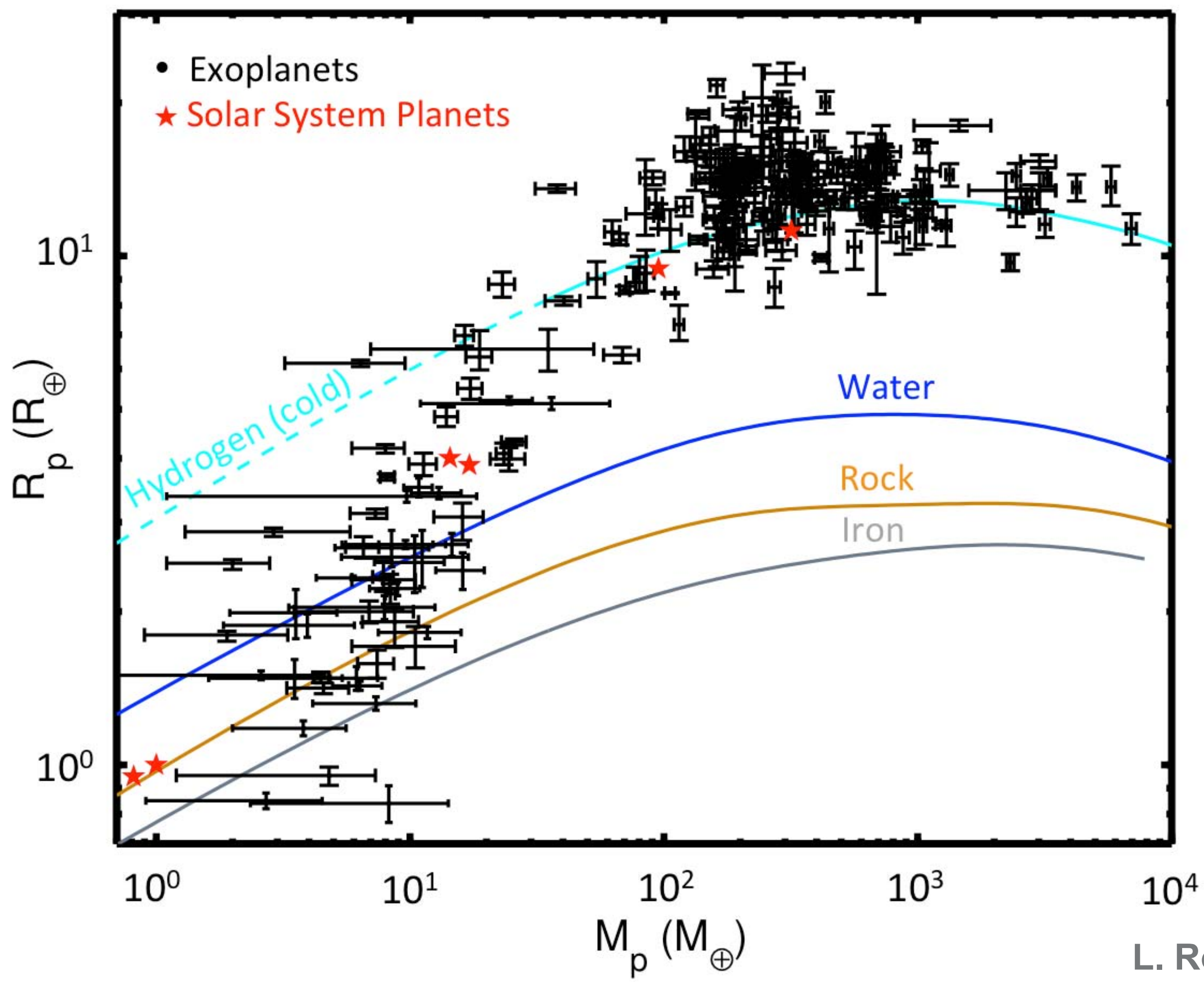
Aurnou 2004

Planetary Interiors

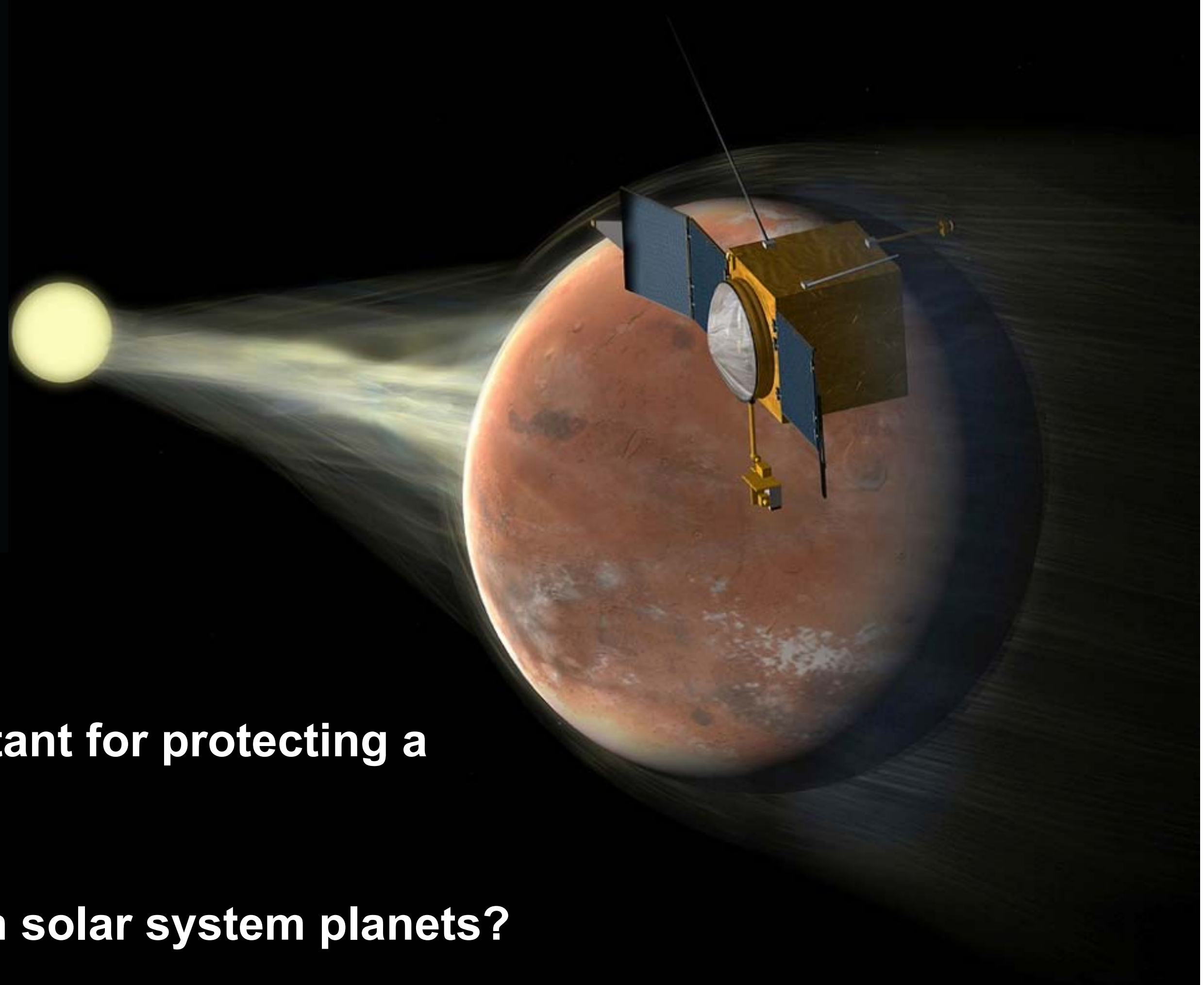
Mass-Radius Relation ➔ Mass-Radio-Magnetic Field Relation?

Mass from radial velocity

Radius from transit



L. Rogers



Magnetic fields are important for protecting a planet's atmosphere.

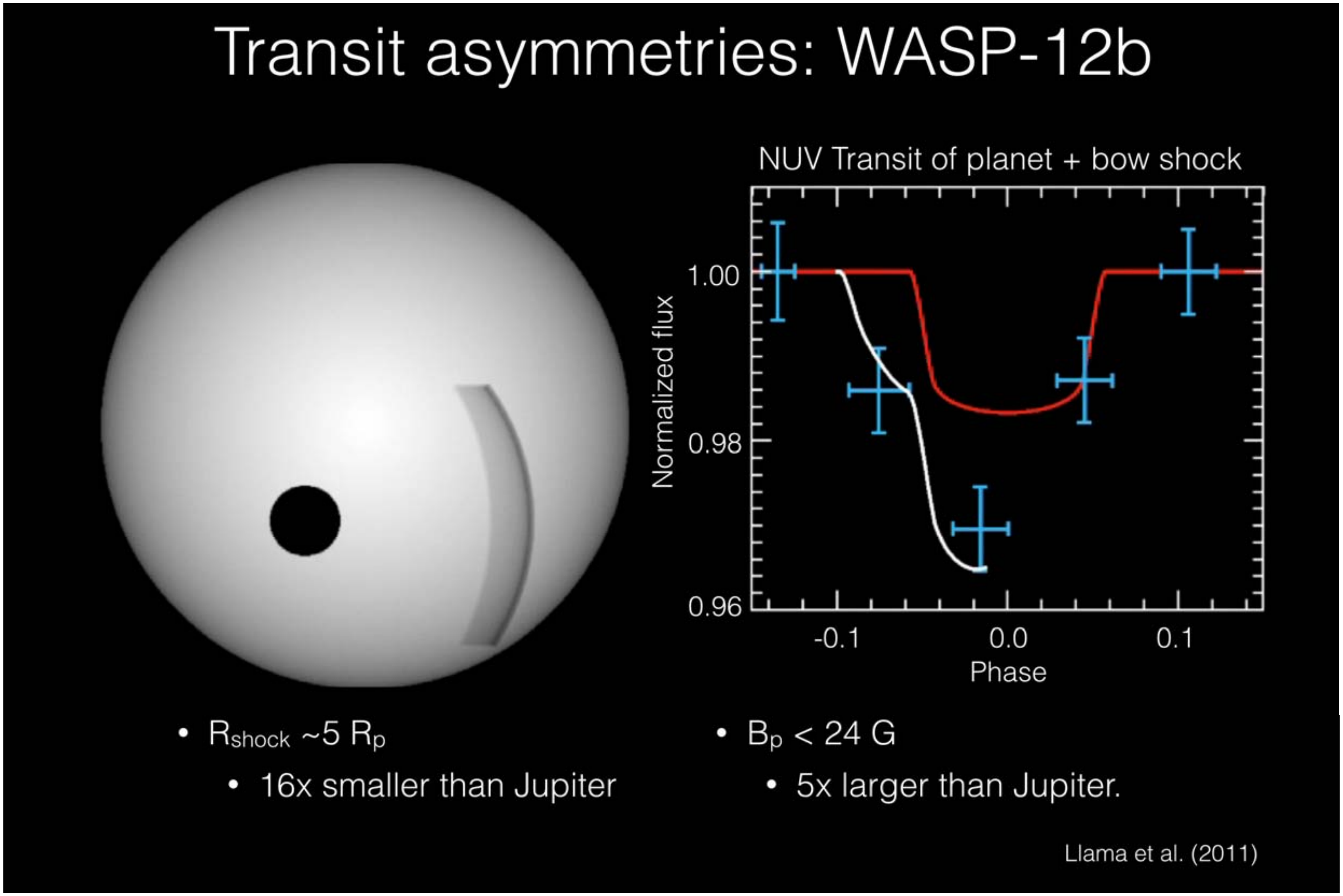
Yes?
… but atmospheric loss in solar system planets?

Act II: Magnetic Fields are Important

Wait, how might we study them?

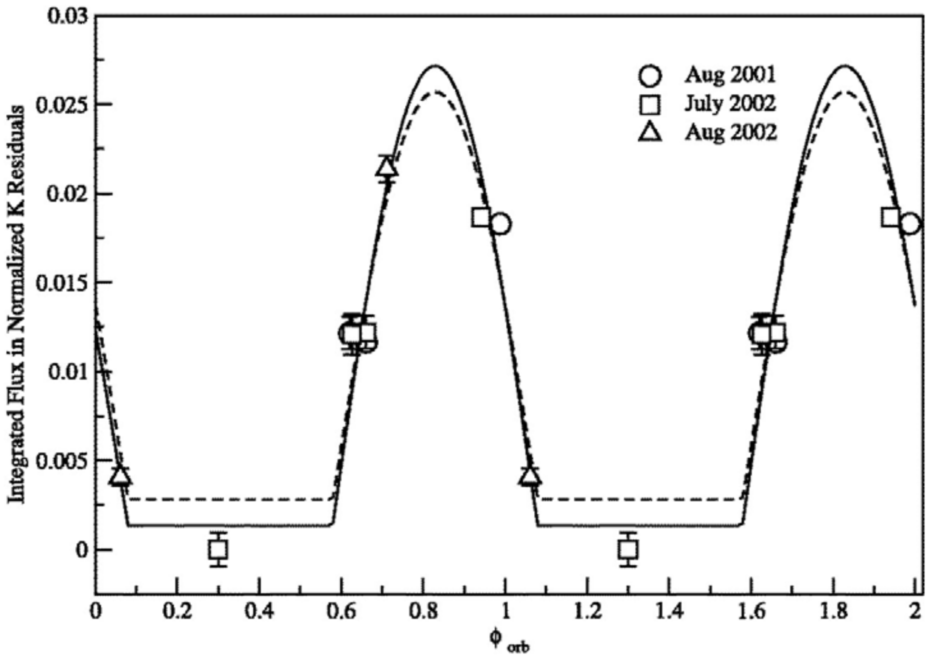
Magnetospheric Bow Shocks

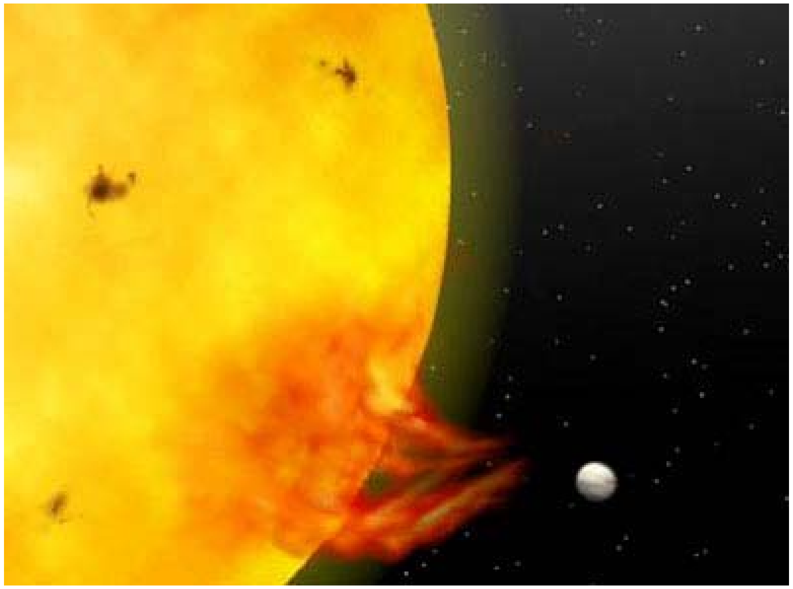
Talks by J. Llama, K. France, ….



Star-Planet Interactions

Tuesday talk by E. Shkolnik (KISS Co-Lead)!



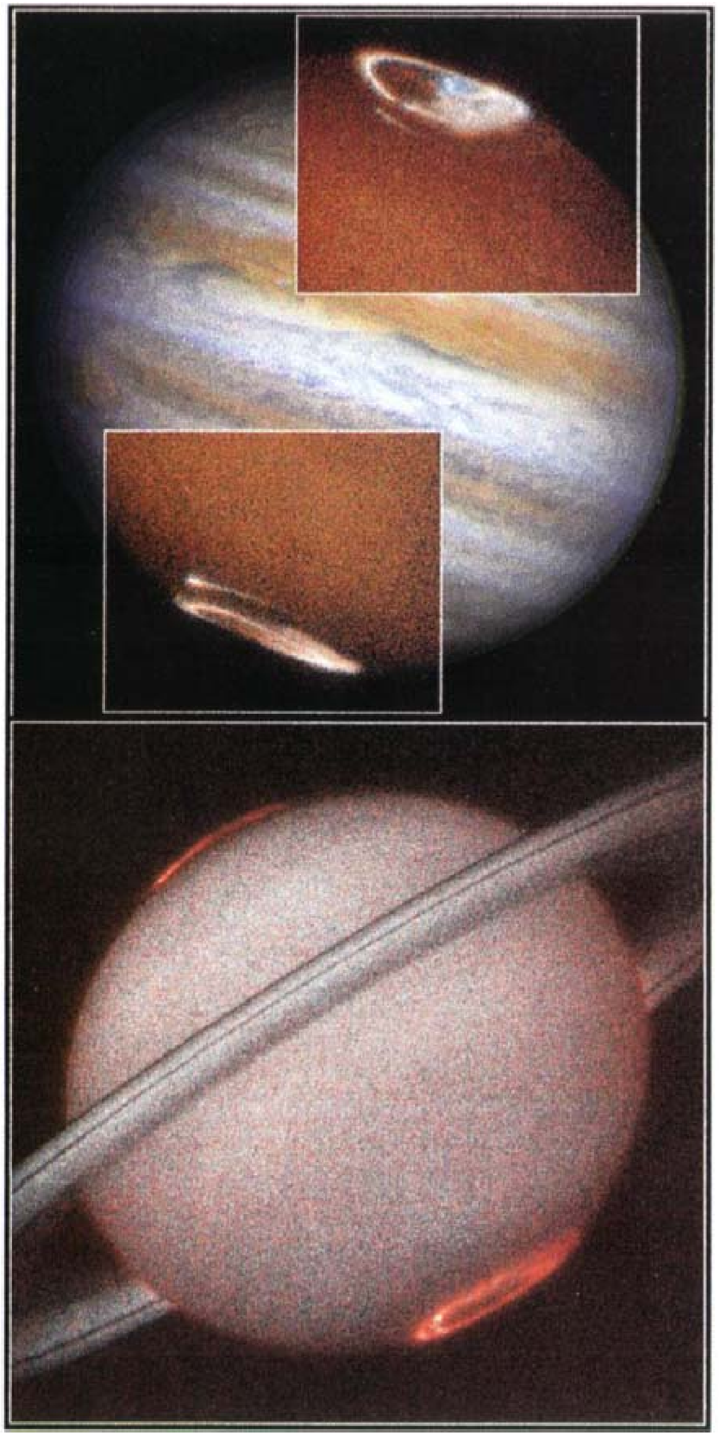


Ca II H and K lines (393.3, 396.8 nm)

HD 179949b: 0.84 M_J planet in 3.1 d orbit (Shkolnik et al. 2003, 2008)

Auroral Emissions

Wednesday talk by Kevin France
(KISS Alumnus)

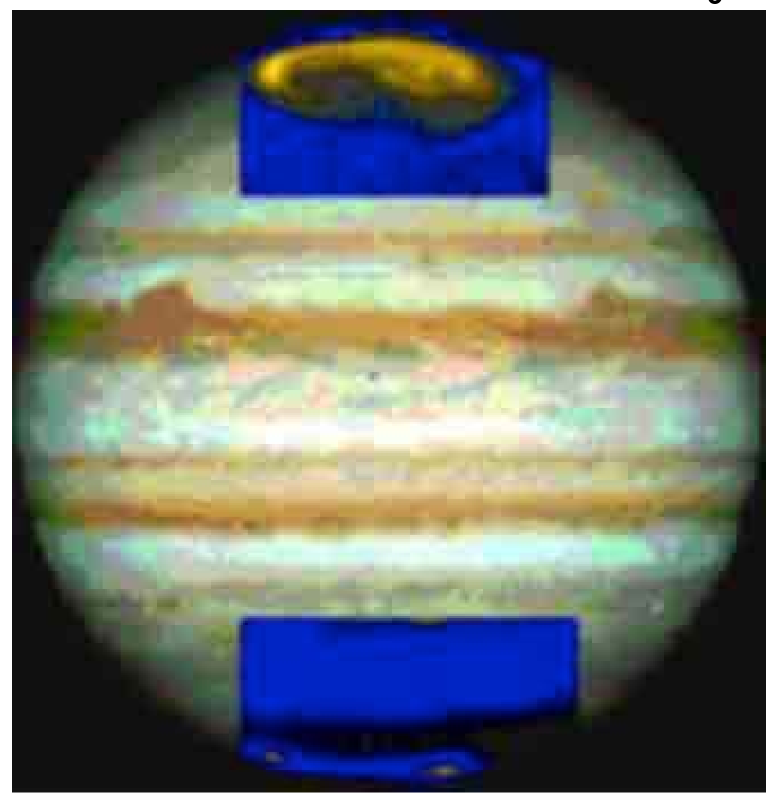


UV

electron impact H_2 fluorescence

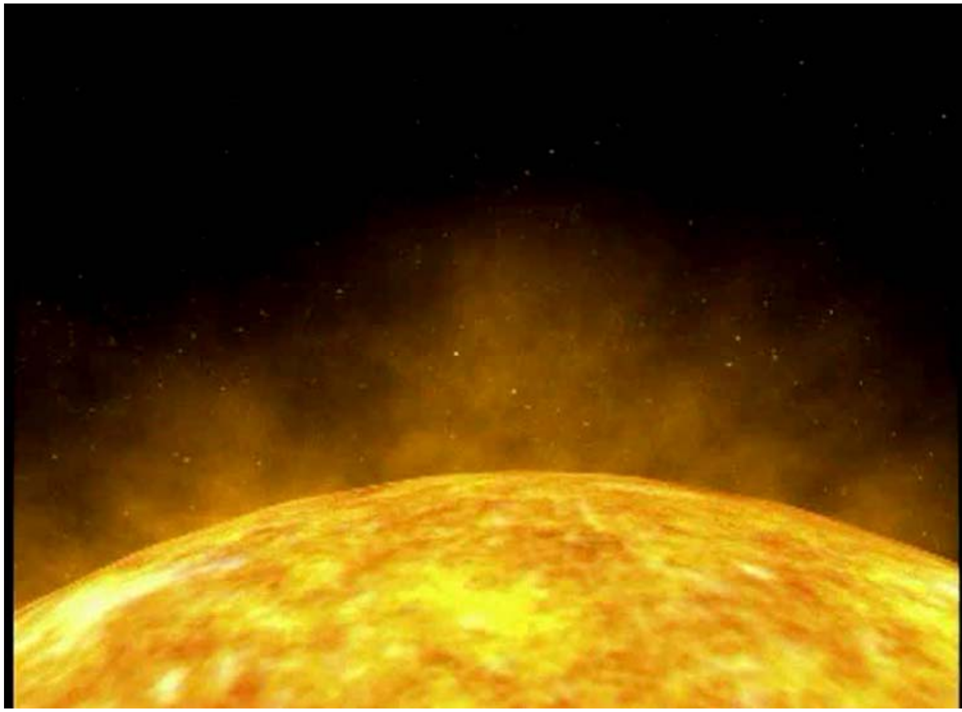
IR

H_3^+



Electron Cyclotron Maser Radio Emission

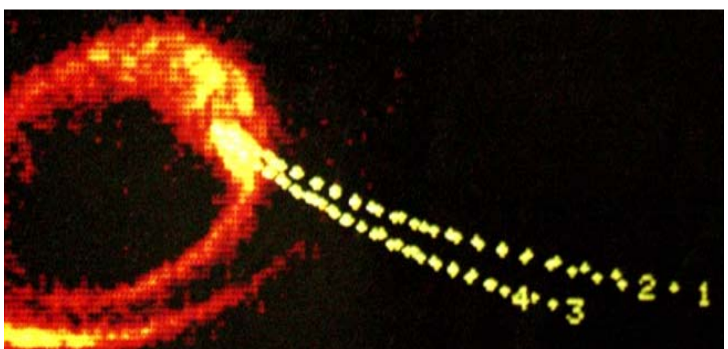
Talks by R. Mutel, P. Brandt, ….



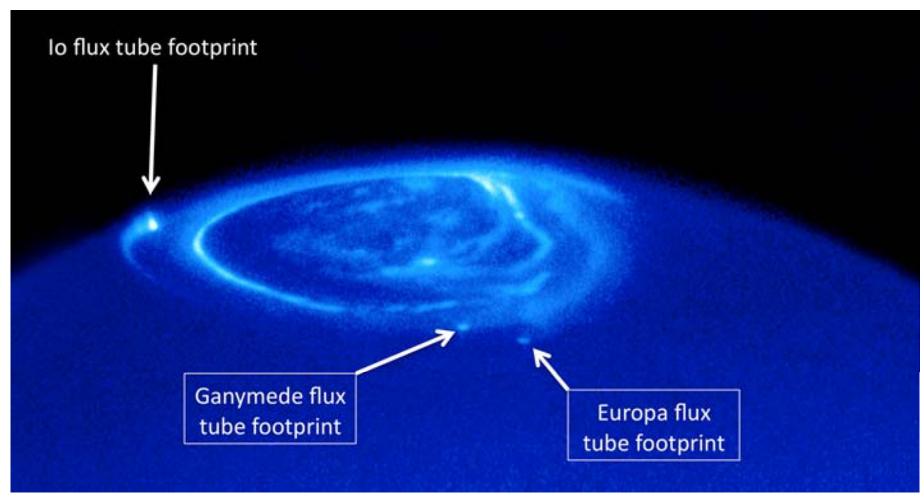
Stellar wind provides energy source to magnetosphere

~ 1% of input energy to auroral region emitted in UV

~ 1% of auroral input energy into electron cyclotron maser radio emission



Earth (DE-2)



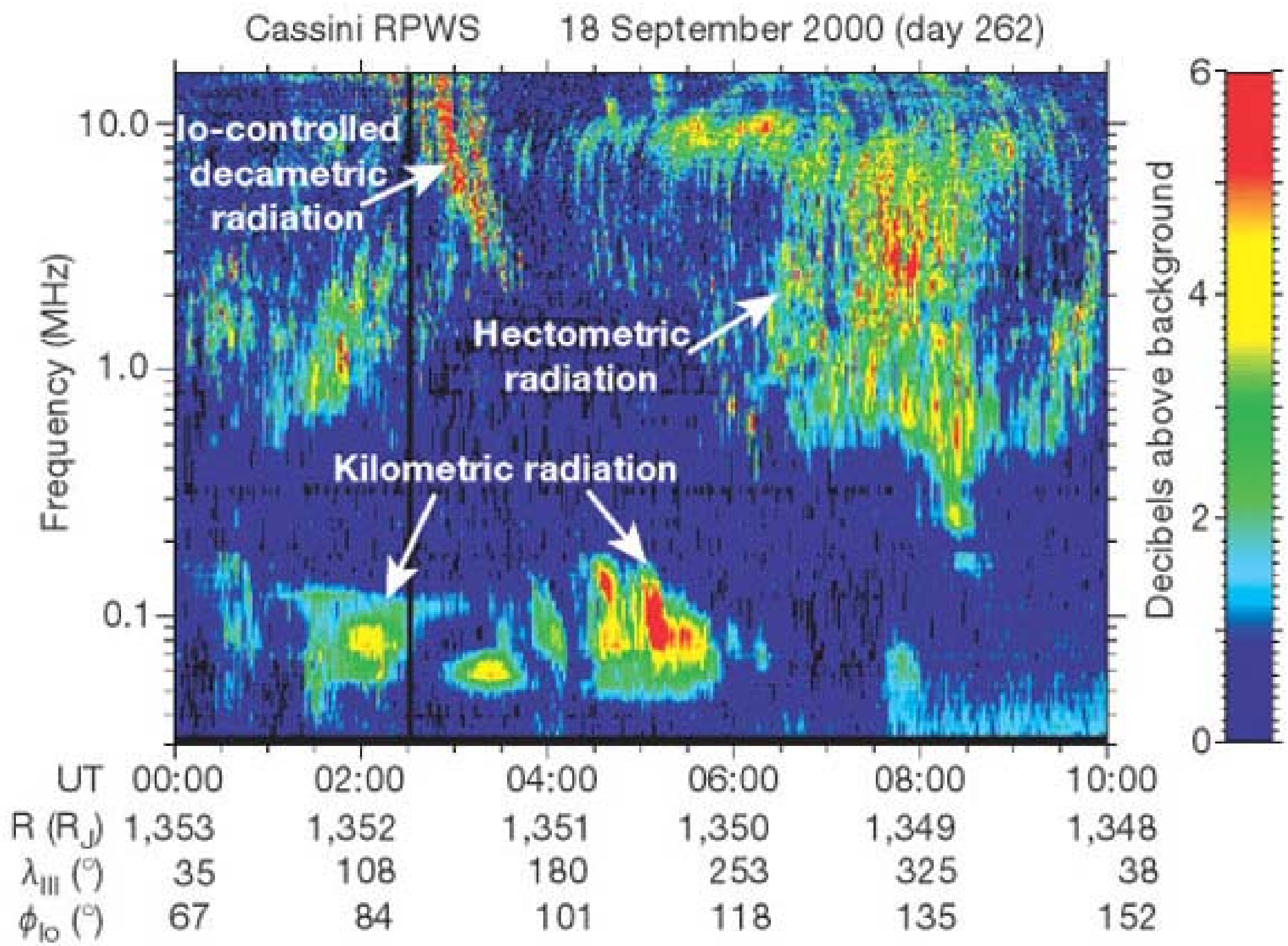
Detecting Extrasolar Planetary Magnetic Fields

Method	Considerations
Magnetospheric Bow Shocks	Only for transiting planets Doesn’t provide B field magnitude
Star-Planet Interactions	Doesn’t provide B field magnitude
Auroral UV Emissions	Not clear that B field even required
Auroral IR (H_3^+) Emissions	Not clear that B field even required
Auroral Electron Cyclotron Masers	Provides B field magnitude, (topology?), but Faint(!)

Act III: Radio Emission

Planetary Radio Emission

Jupiter



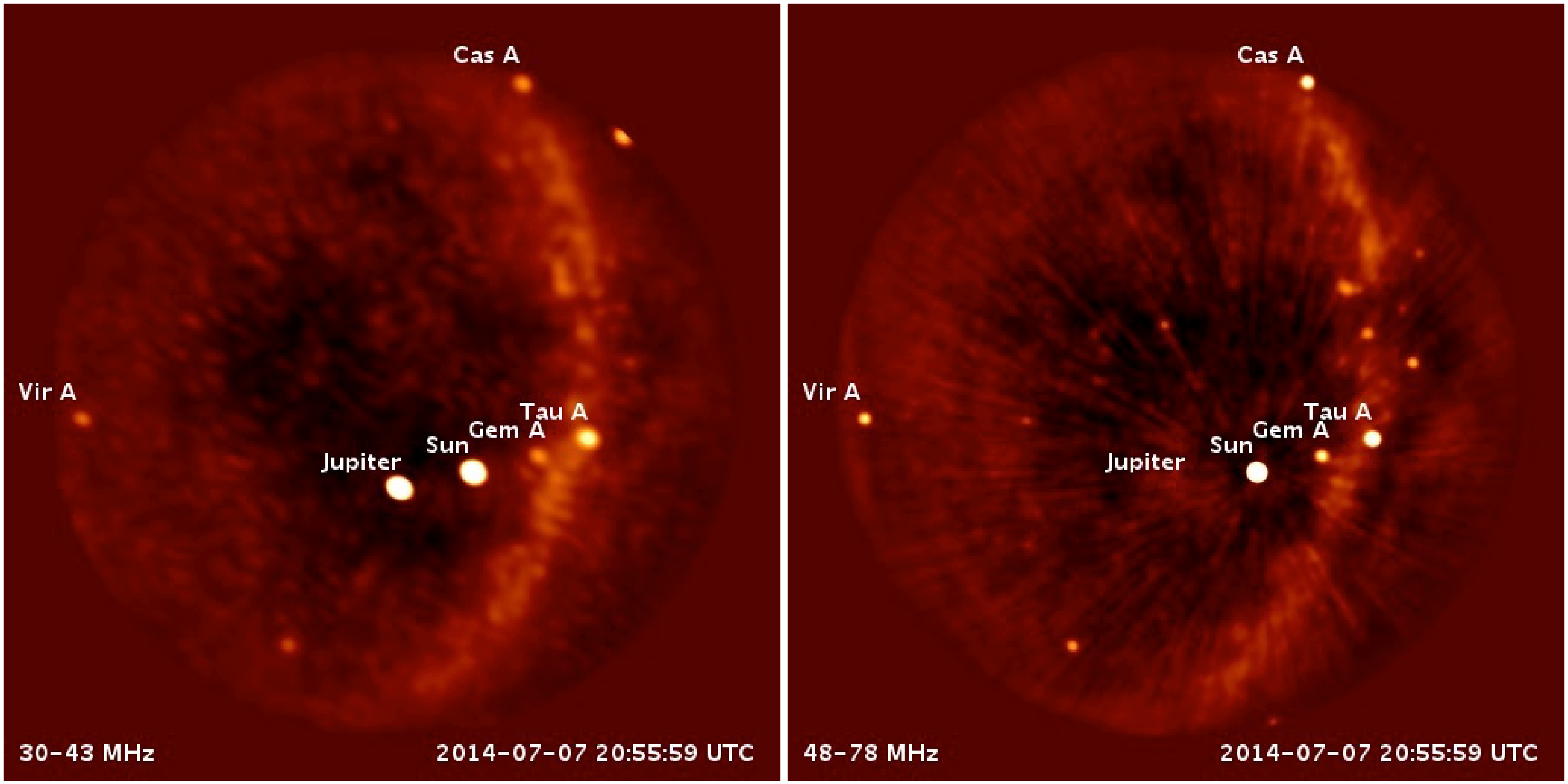
- **All gas giants and Earth have strong planetary magnetic fields and auroral / polar cyclotron emission.**

Jupiter: Strongest at 10^{12} W

Talk by Pontas Brandt

Planetary Radio Emission

Jupiter – and What We Want To See for an Extrasolar Planet!



Credit: M. Anderson

"Nothing New Under the Sun"

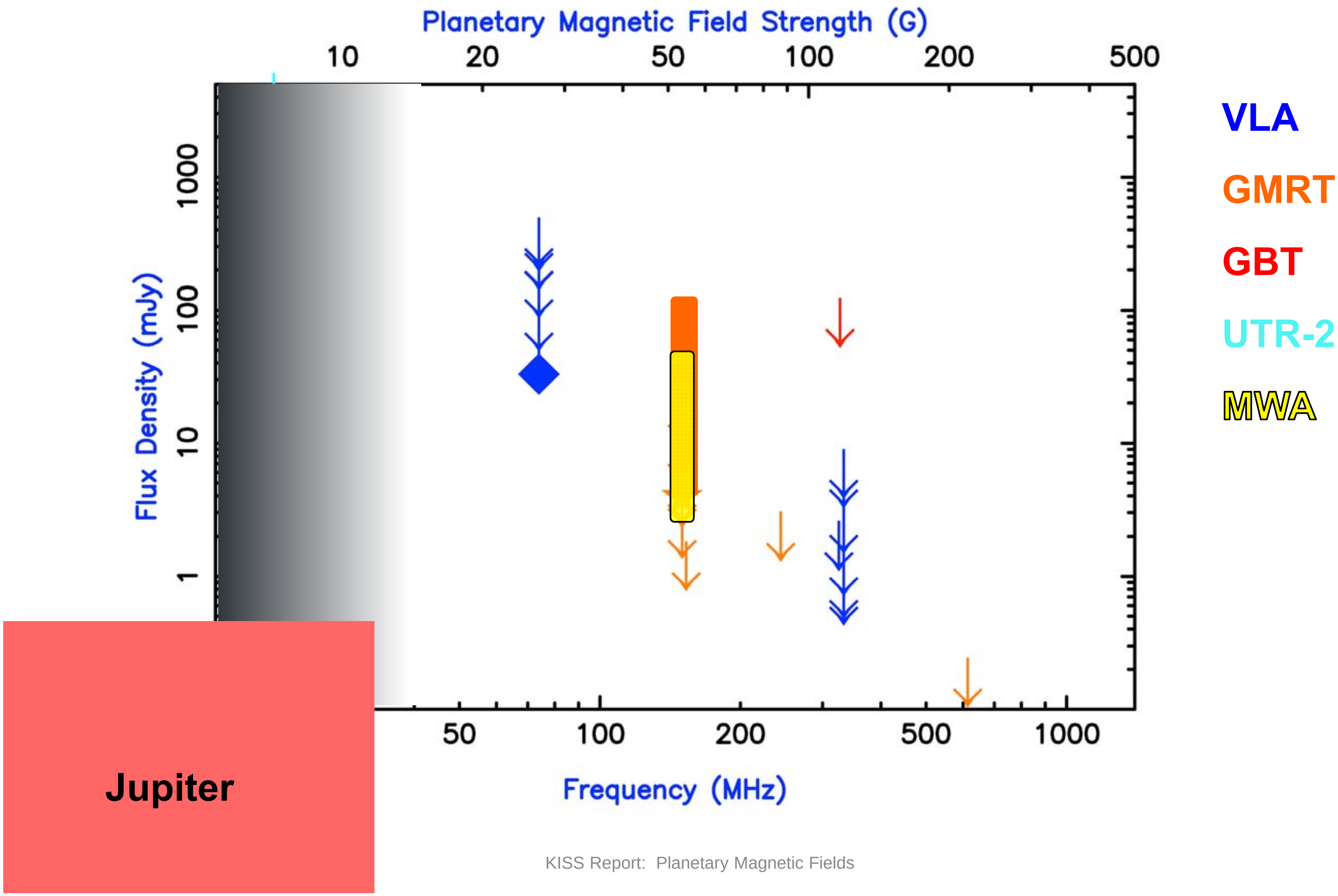
035-5 A Search for Extra-Solar Jovian Planets by Radio Techniques. W.F. YANTIS, U. Wash. and Goldendale Observatory, W.T. SULLIVAN, III, U. Wash. & W.C. ERICKSON, U. Maryland. - We propose to search for the presence of planets associated with nearby stars through detection of Jovian like decametric radio bursts. Planetary bursts would be distinguished from possible stellar bursts by the presence of a high-frequency cut-off and possibly a modulation associated with the rotation of the planet. A search for such planetary radio bursts at 26.3 MHz is presently being conducted at The Clark Lake Radio Observatory. The sample includes 22 stars within 5 parsecs. The sensitivity limit is 10^{-26} watts m^{-2} Hz^{-1}, about 1,000 times the signal expected from a strong Jovian burst. However, it is expected that the strength of any bursts will depend strongly on the planetary magnetic field and also possibly on the presence of a stellar wind. Initial observations exhibit several non-instrumental features which are under current study. Further results will be reported and monitoring observations are continuing.

"A Search for Extra-Solar Jovian Planets by Radio Techniques" (Yantis, Sullivan, & Erickson 1977)

- **Soon after recognition that Saturn also intense radio source**
- **Earth, Jupiter, Saturn**

"A Search for Cyclotron Maser Radiation from Substellar and Planet-like Companions of Nearby Stars (Winglee, Dulk, & Bastian 1986)

Radio Searches – State of the Field



Blind Search of the Solar Neighborhood

Sample	Flux Density (3σ, mJy)	Luminosity (erg/s)	Stellar Wind Amplification Factors					K.E. * Jupiter	M.E. * Jupiter
			v	n	B	nv^3	vB^2		
NStars	17	9×10^{23}	1.7	9.8	2.4	48	9.5	4.8×10^{20}	9.5×10^{19}
SPOCS -age	33	1.1×10^{24}	1.4	4.9	1.8	15	4.8	1.5×10^{20}	4.8×10^{19}
SPOCS -eage	28	5.1×10^{23}	1.6	8.6	2.2	38	8.3	3.8×10^{20}	8.3×10^{19}
GCS-age	18	7.3×10^{23}	1.6	6.7	2.0	25	6.5	2.5×10^{20}	6.5×10^{19}
GCS-eage	14	5.8×10^{23}	2.2	30	3.6	319	28	3.2×10^{21}	2.8×10^{20}

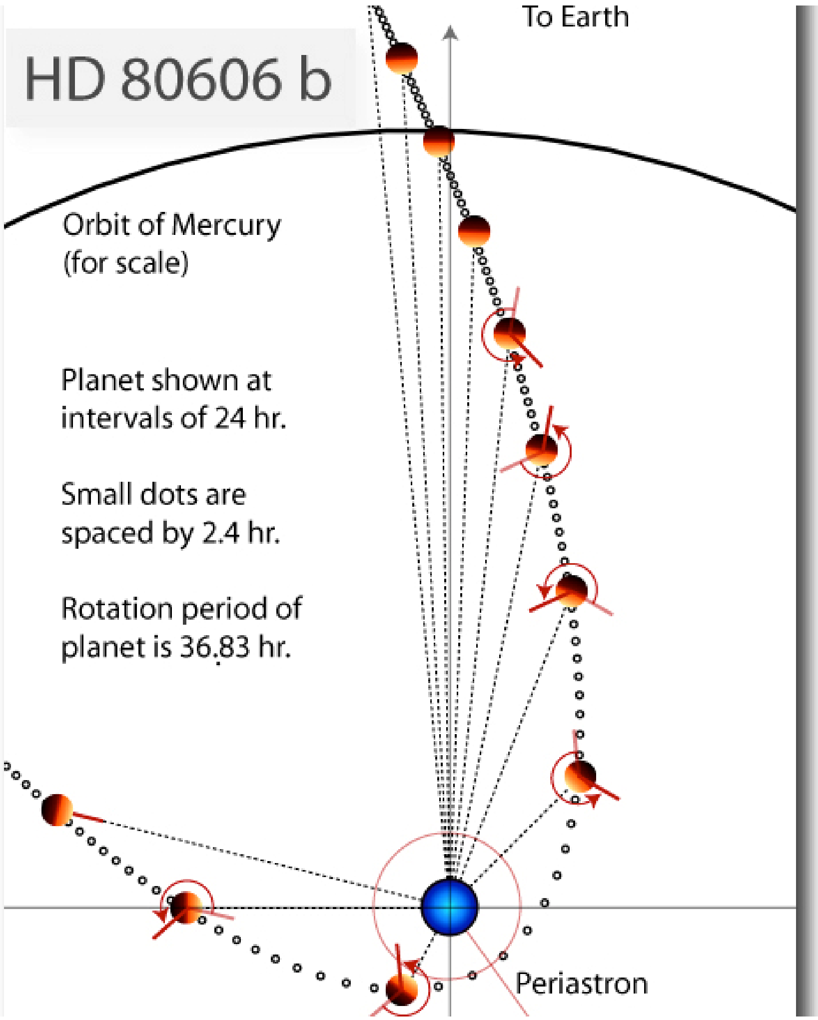
From nearby star catalogs, select

- **F, G, K stars**
- **Age < 3 Gyr**
- **D <~ 40 pc**

Required for detection

Jupiter's scaled luminosity

HD 80606b

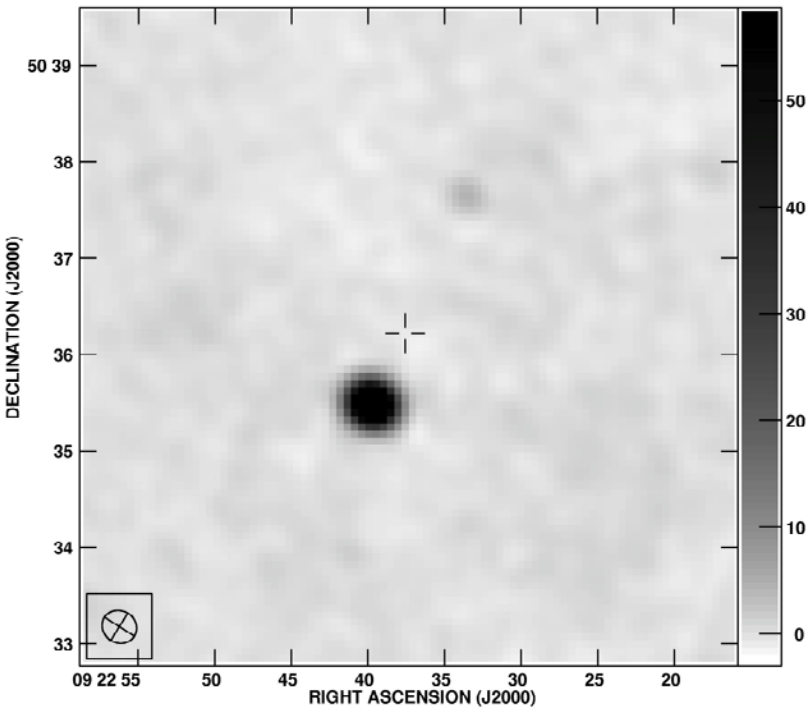


- G5 star
- 4 M_J planet, 111-day orbit
- e = 0.93 (!)
- 2007 November 20 periastron passage
- 330 MHz (λ90 cm), 1400 MHz (λ20 cm)

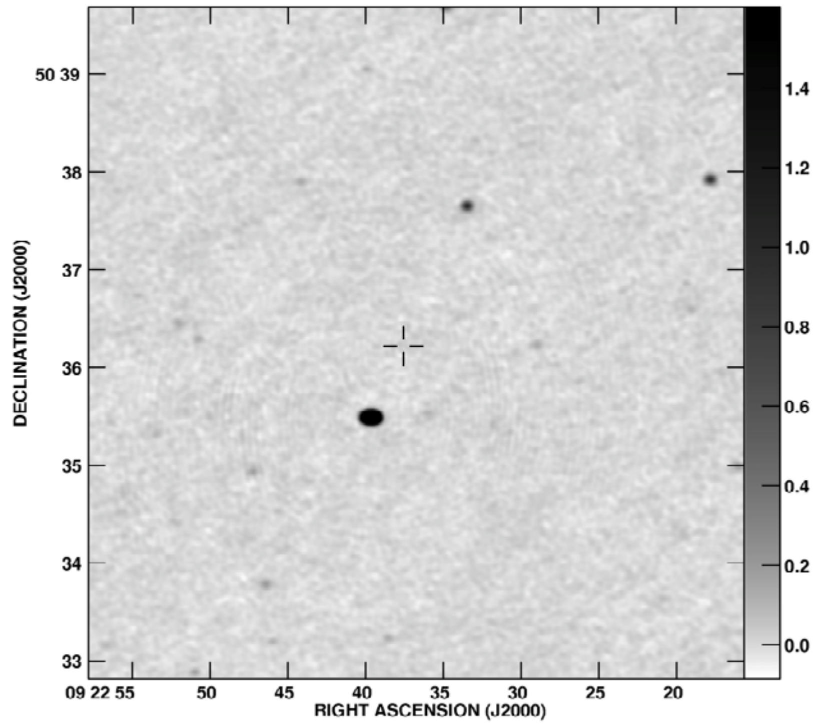
HD 80606b

VLA

330 MHz – 1.7 mJy (3σ)



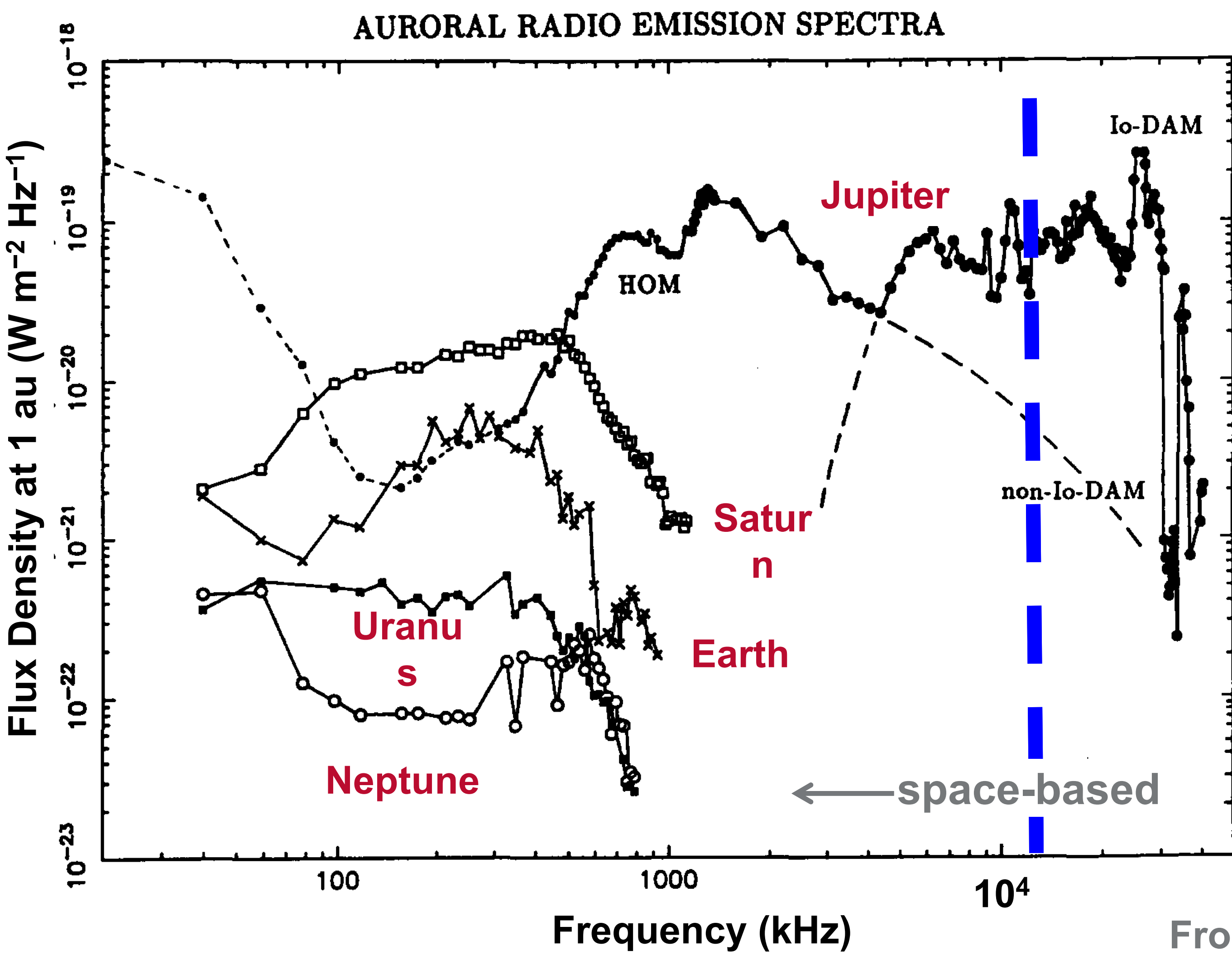
1400 MHz – 48 μJy (3σ)



LOFAR results (Cycles 0 and 4) coming soon …!

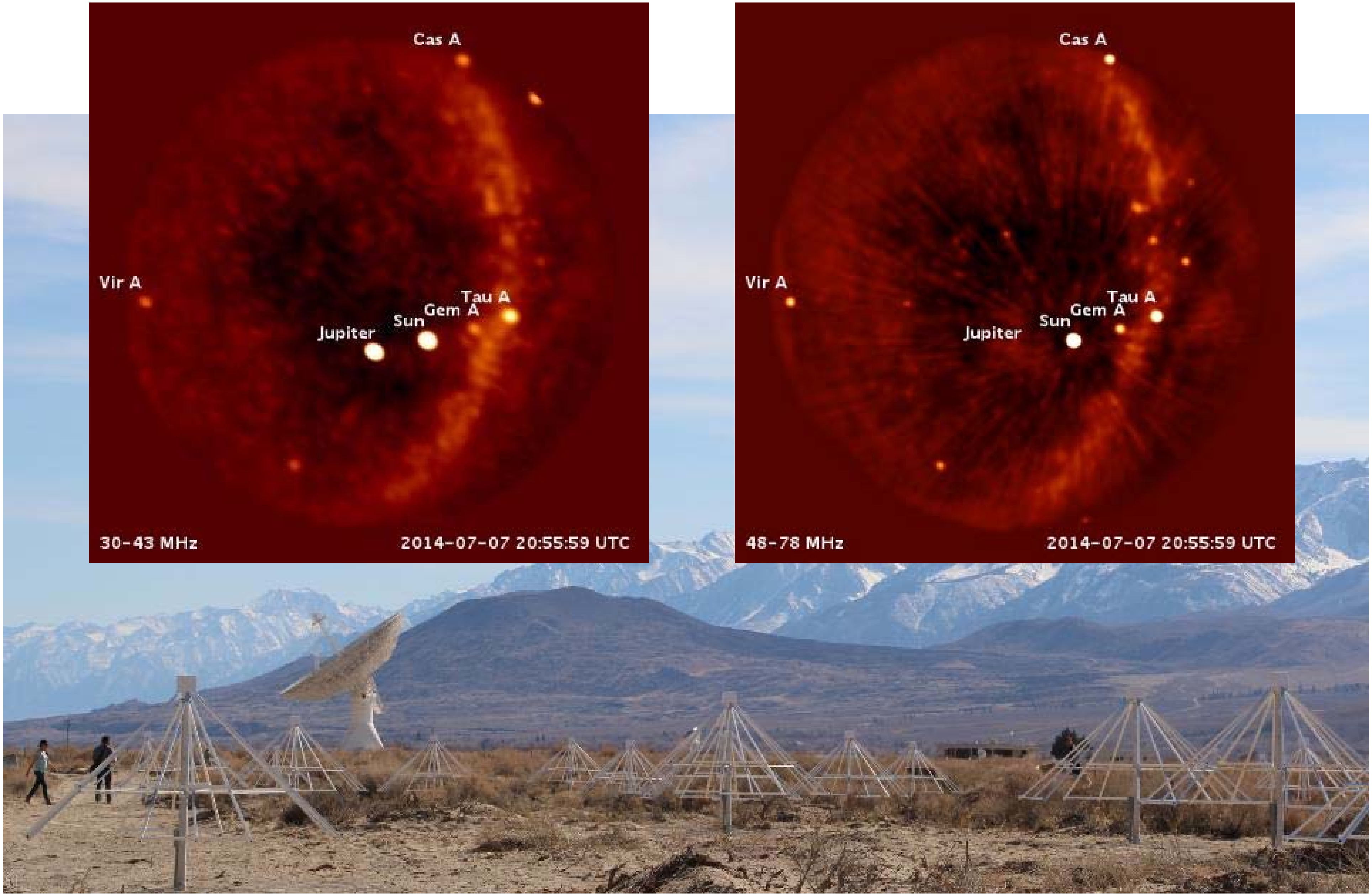
Act IV: Future

Magnetic Emissions from Solar System Planets

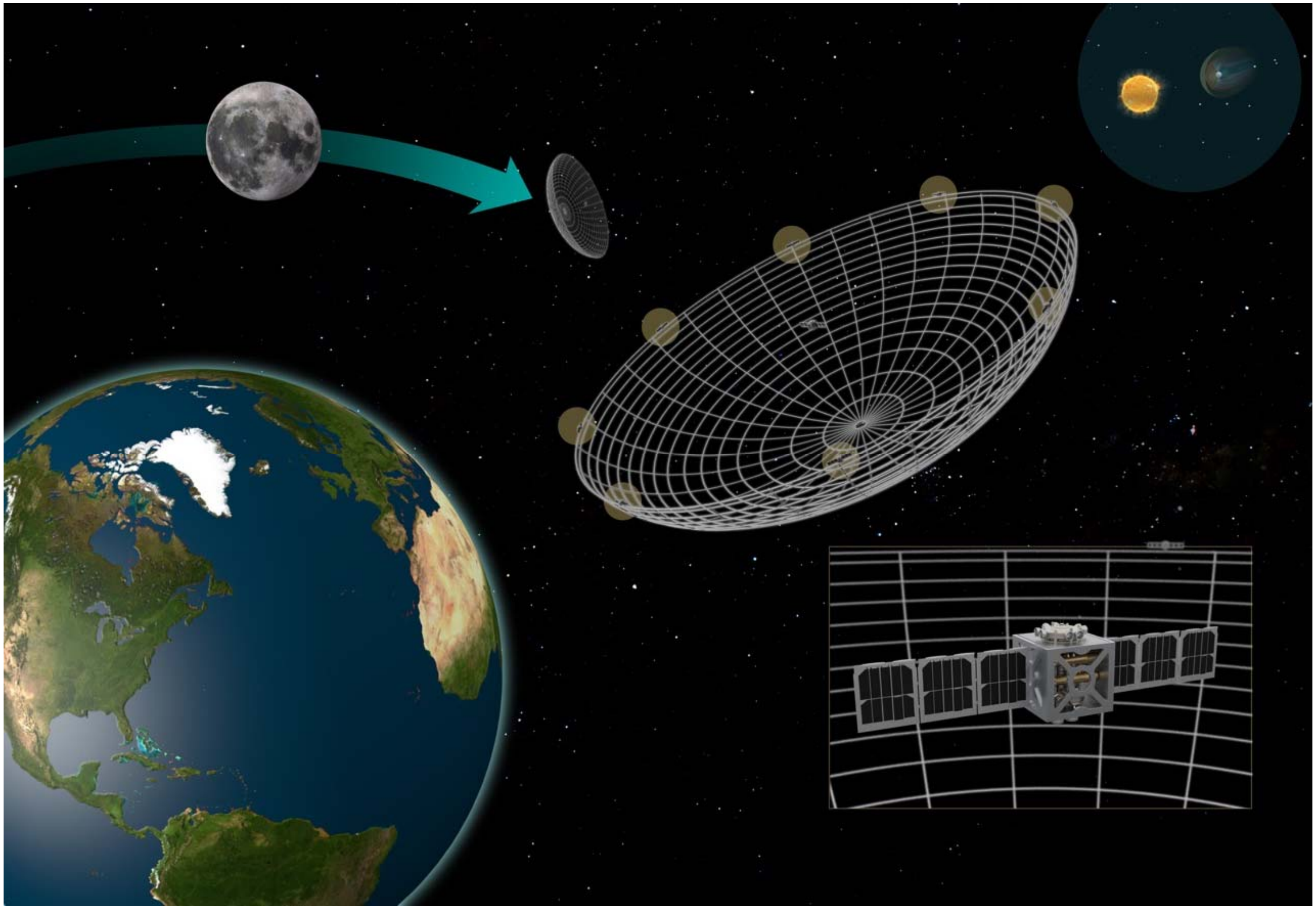


From Zarka (1992)

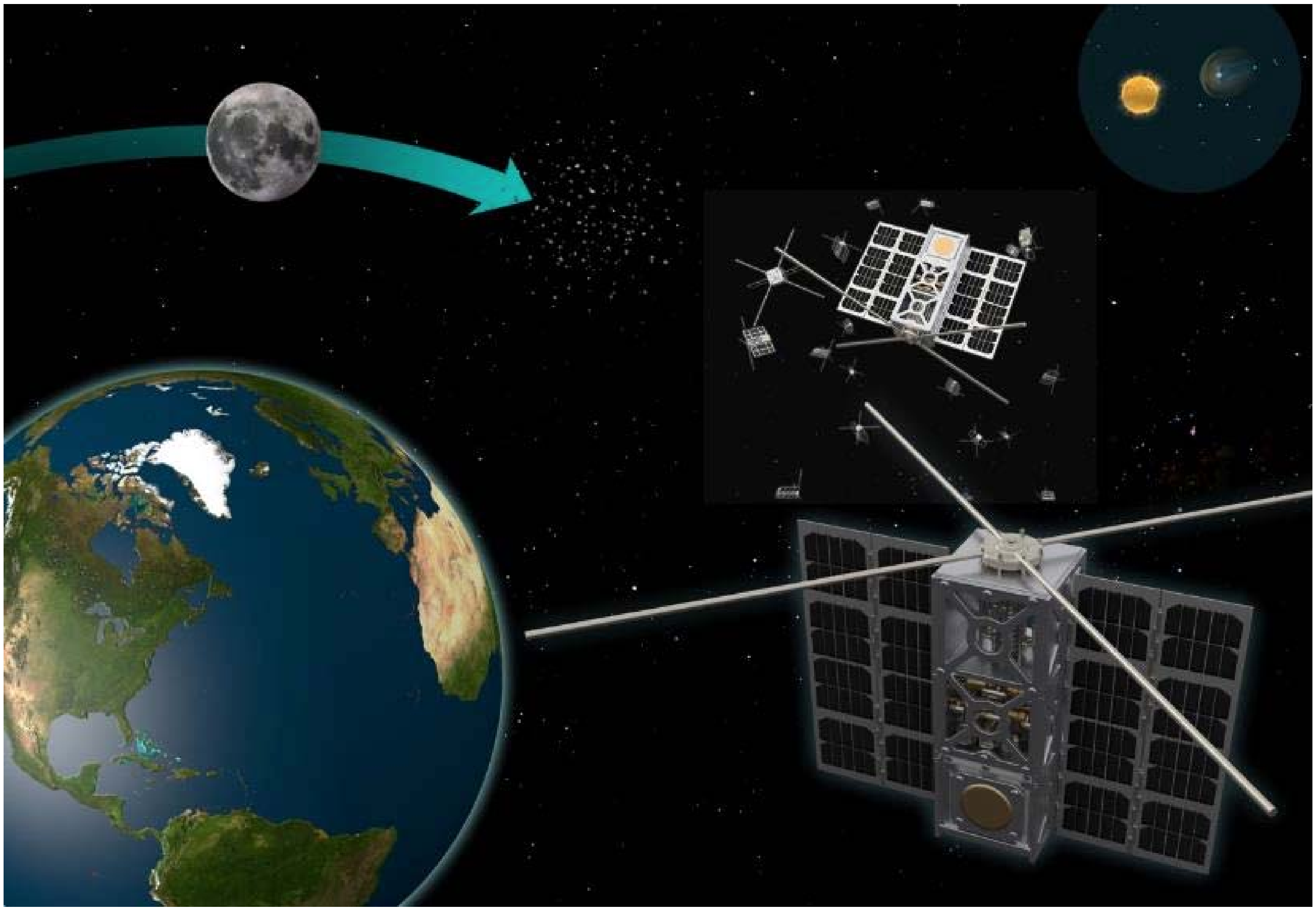
LWA-OVRO Today



Tomorrow: Big Aperture Radio Telescope?



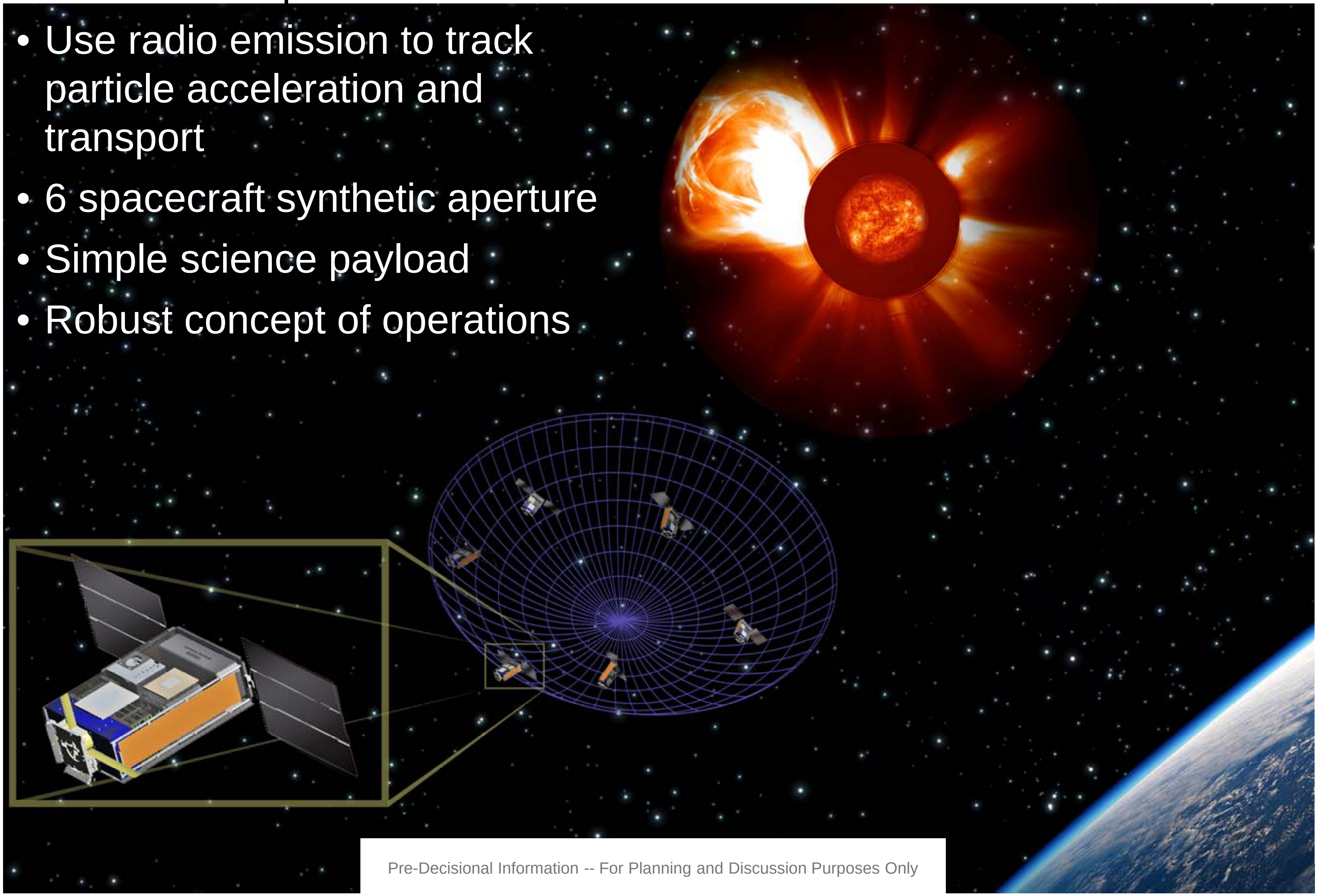
Tomorrow: Radio Array in Space?



Sun Radio Imaging Space Experiment

Mission Concept

- Use radio emission to track particle acceleration and transport
- 6 spacecraft synthetic aperture
- Simple science payload
- Robust concept of operations



Extrasolar Planetary Magnetic Fields

- **Magnetic fields provide probe of planetary interiors**
  - **Both solar system and extrasolar!**
- **Variety of possible approaches, with varying (dis-)advantages**
  - **Bow shocks, star-planet interactions, auroral UV, IR, radio emission, …**
- **Radio emissions show promise**
  - **Improving upper limits, new telescopes, path to future space telescopes**