Searching for extra solar planet-moon interactions with LWA

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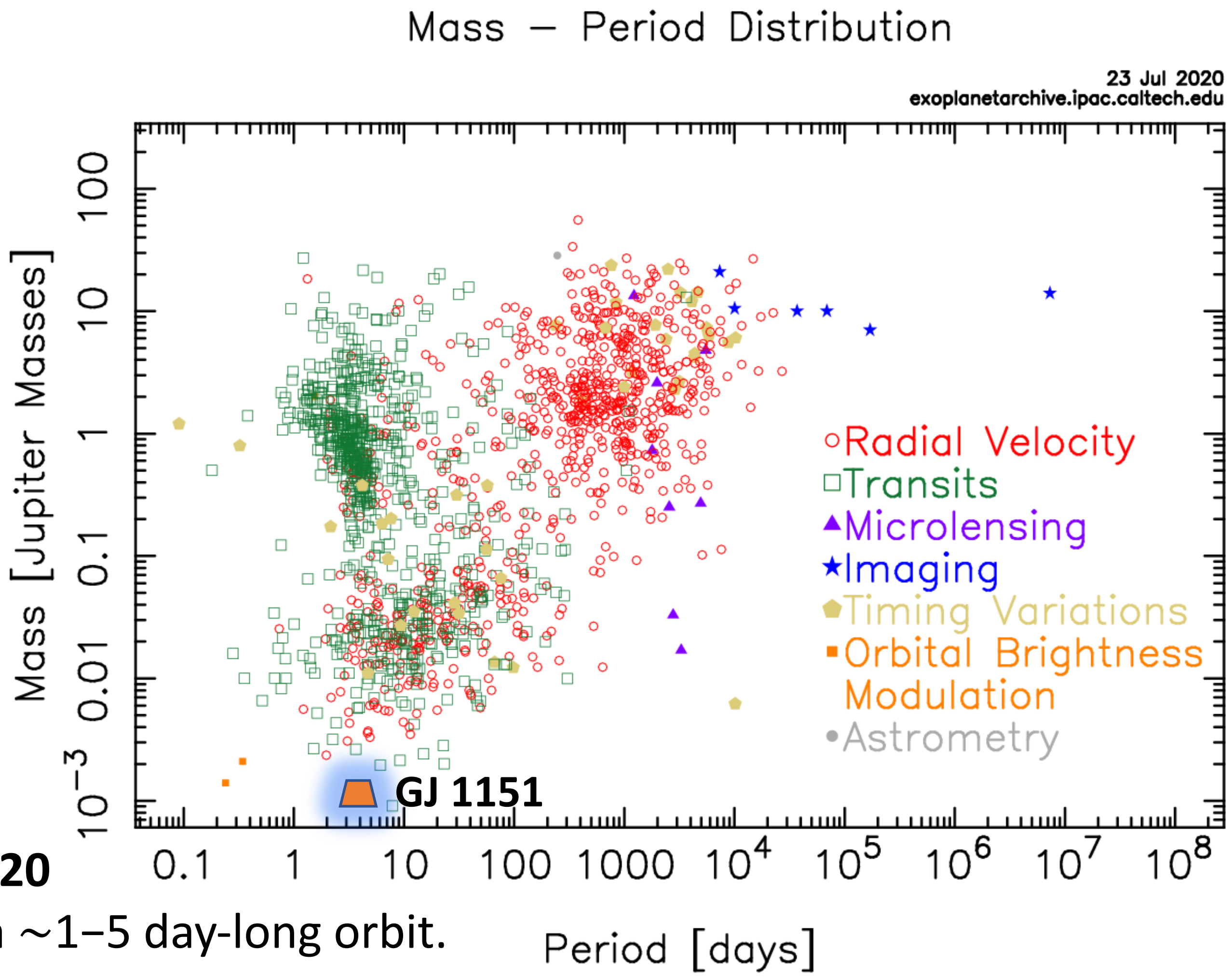
Status of Exoplanet and Exomoon Detections

- 4,000+ confirmed exoplanets.
- Possible magnetically driven exoplanet emissions recently detected.
- The first extra-solar moon (exomoons) has not been confirmed.



Vedantham et al. 2020

Earth-size planet in a ~1–5 day-long orbit.

Status of Exoplanet and Exomoon Detections

Extrasolar moon (Exomoon)– natural satellite that orbits an exoplanet.

- No confirmed detections
- Candidate Kepler 1625b-I (Teachey & Kipping, 2018)

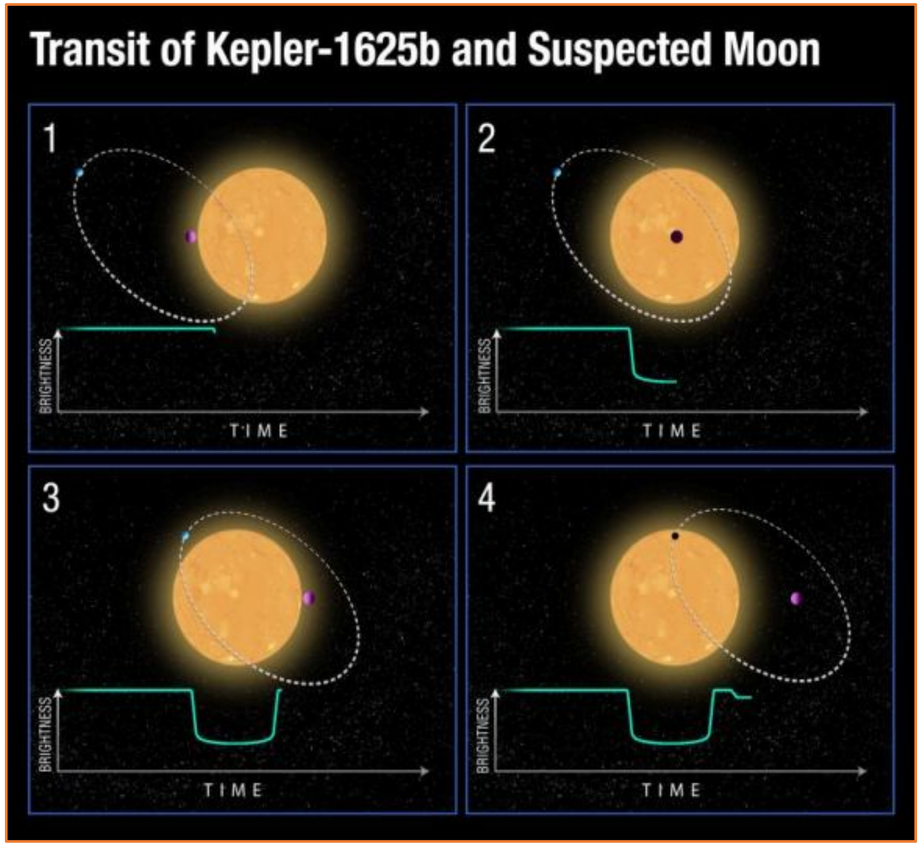
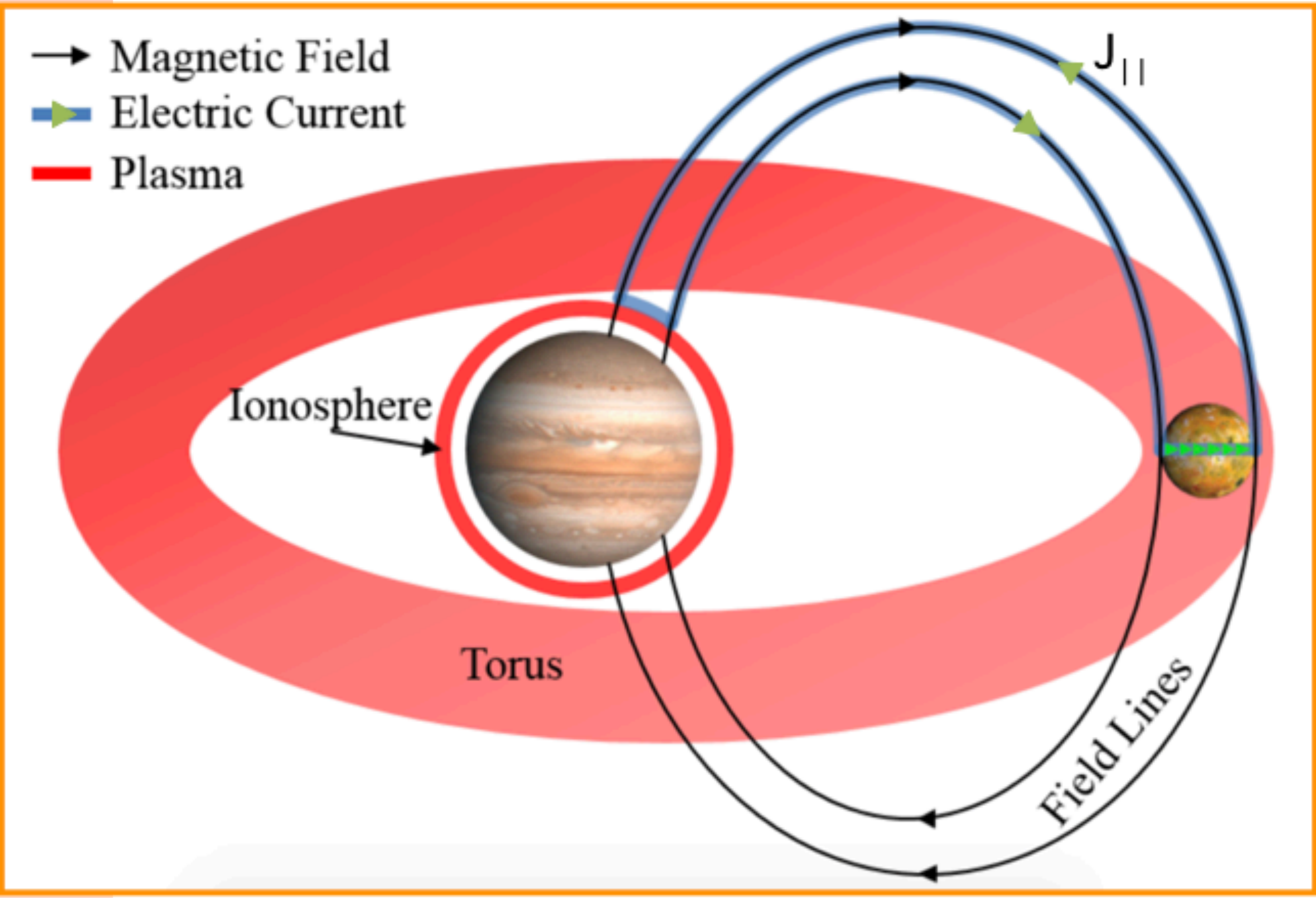
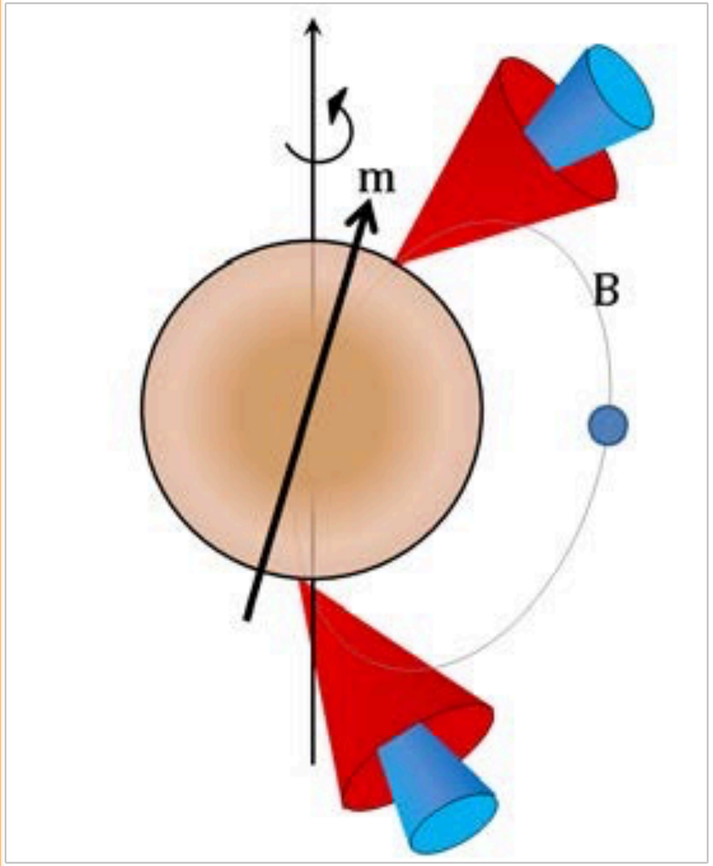


Image: NASA, ESA, D. Kipping (Columbia Univ.), and A. Feild (STScI)

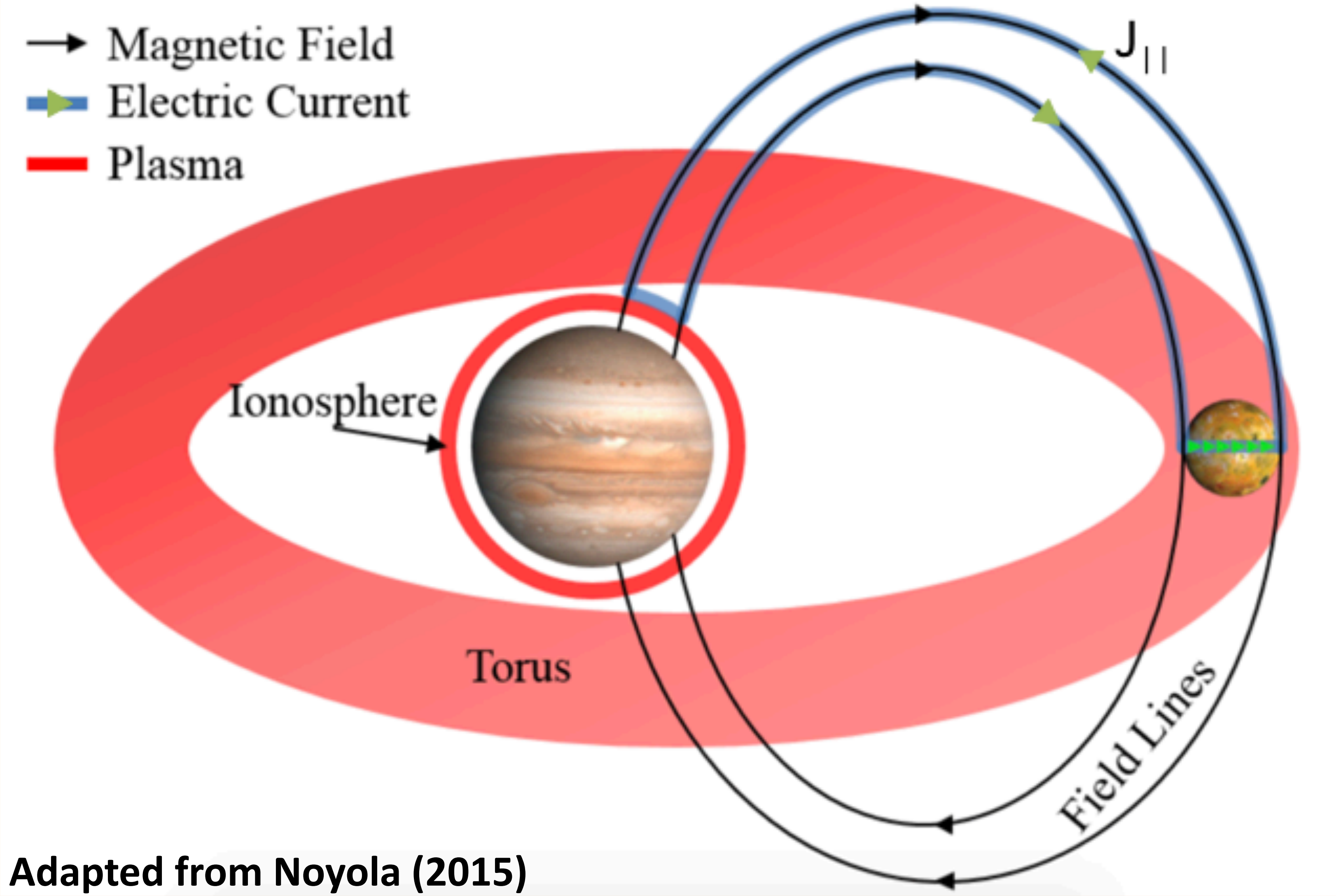
Jupiter-Io Interactions: ECMI Mechanism





Adapted from Noyola (2015)

Jupiter-Io Interaction: ECMI Mechanism



Adapted from Noyola (2015)

- Does not depend on host star properties
- Works with *cold Jovians*
- Works with *Icy moons*
- Independent of orbital plane's relation with our line of sight.
- Direct confirmation of exomoon and host planet.

Detection Challenges

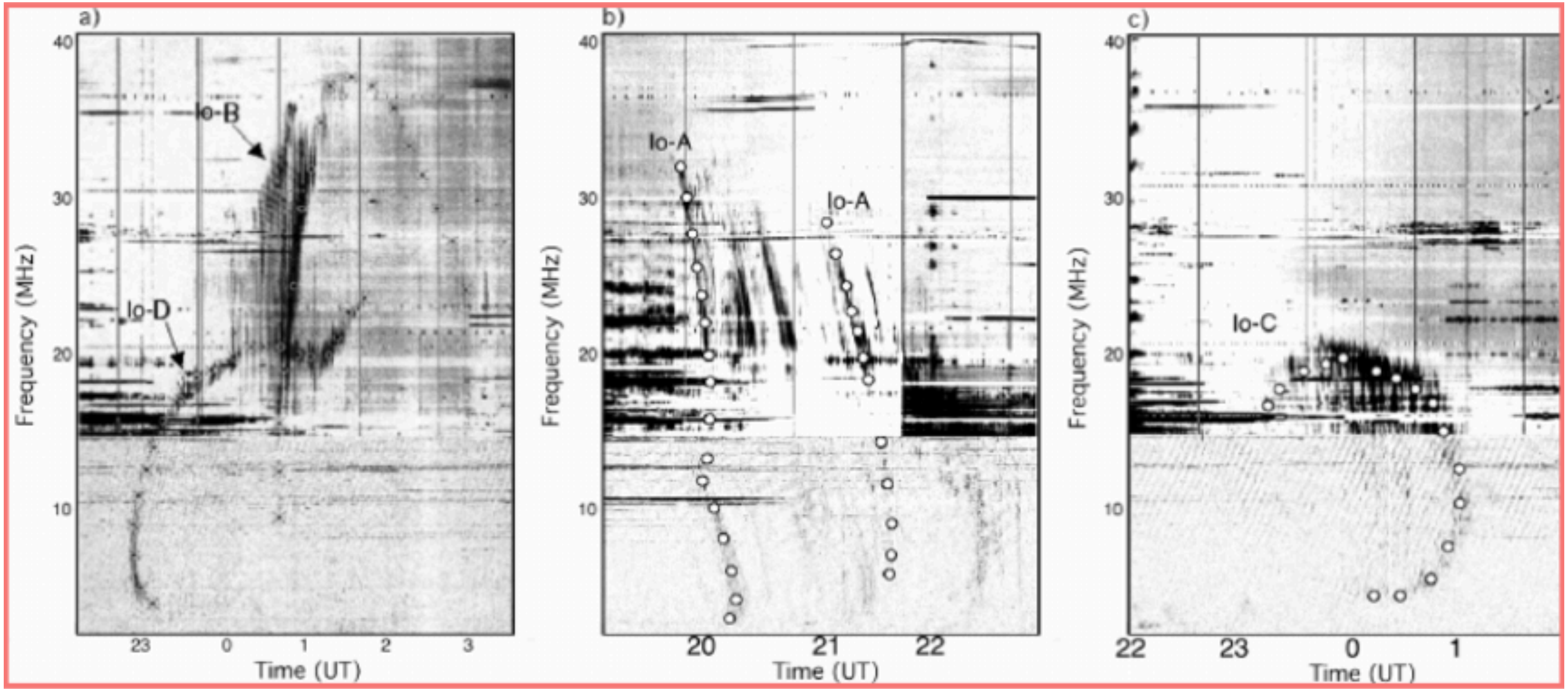
- Exomoon needs conductor for induction
- Distinguishing between solar winds, exoplanet induced emissions or exomoons emissions
- System distance constraint. Low intensity for far away systems.
- Very low frequencies but high resolution needed

- Plasma, Ice or Atmosphere.
- Particular Dynamic Spectra & Temporal differences in emissions
- Future telescopes might improve depth & resolution.
- $f_c = \frac{\mu_o}{8\pi^2}\frac{e}{m_e}\frac{m_P}{R_P^3}\left(4 - 3\frac{R_p}{r_s}\right)^{\frac{1}{2}}$

Exomoon Radio Signals

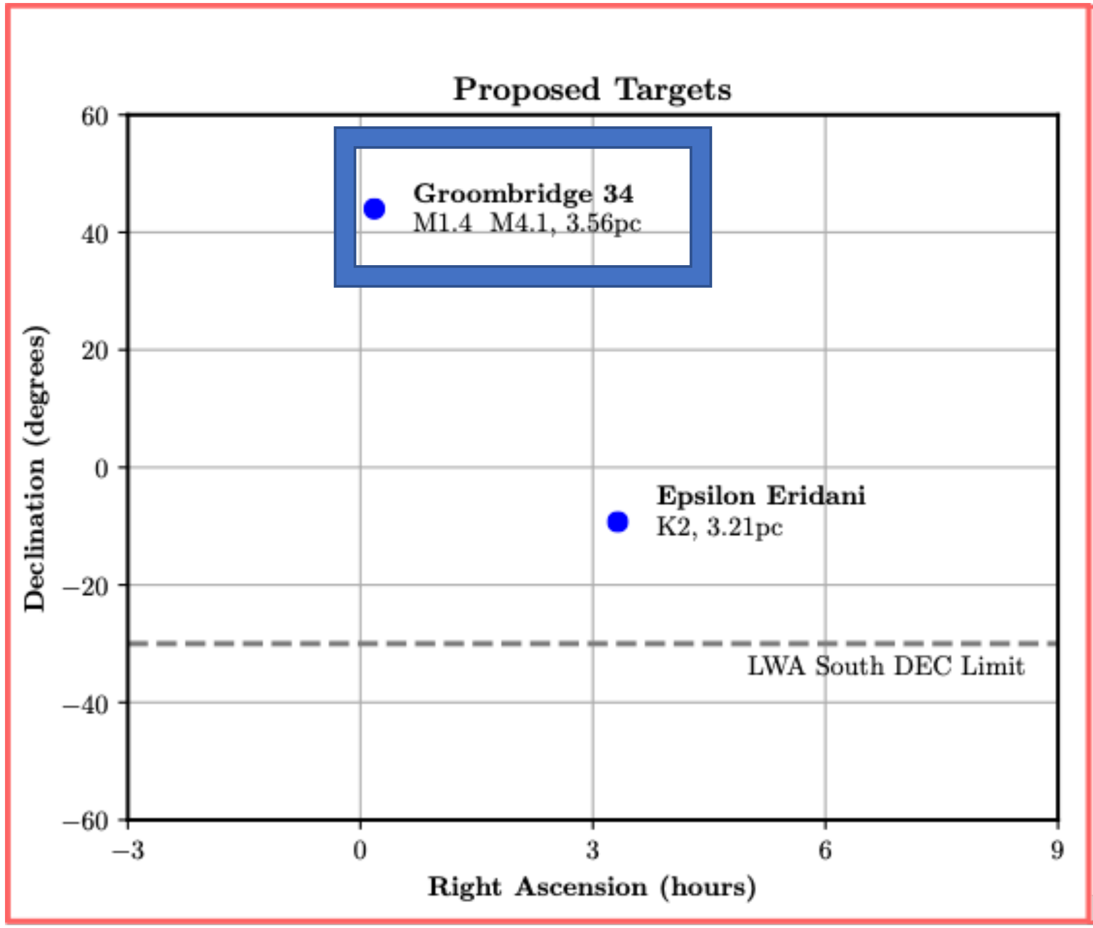
FREQUENCY [MHz]	$$f_{c,max} = 12.8\sqrt{4 - 3\frac{R_P}{r_s}}$$
INTENSITY [Jy]	$$P_s = \frac{\pi \beta_s R_s^2 B_s V_p}{\mu_0} \sqrt{\frac{\rho_s}{\rho_s + \mu_0^{-1}\left(\frac{B_s}{V_p}\right)^2}}$$

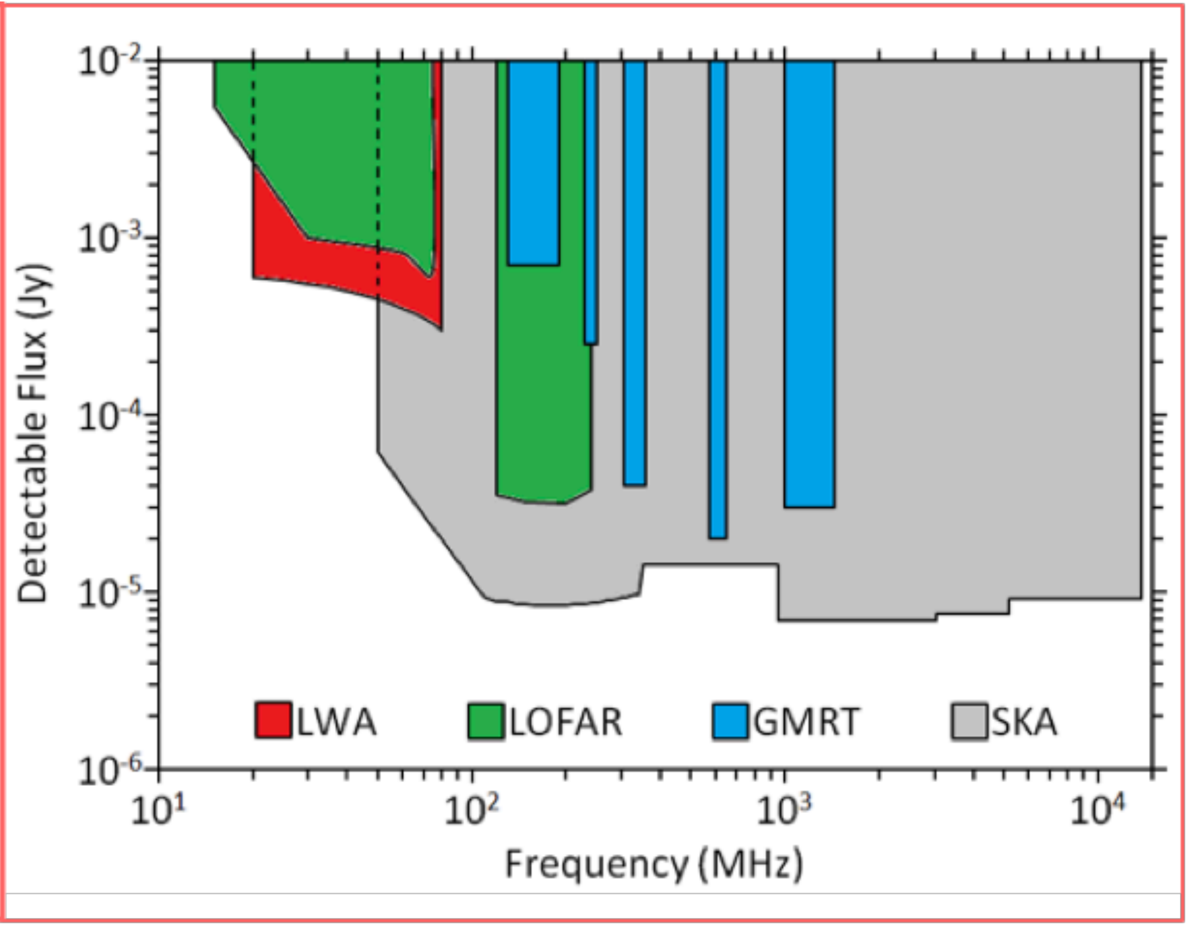
Exomoon Radio Signals



Adapted from Queinnec and Zarka (1998)

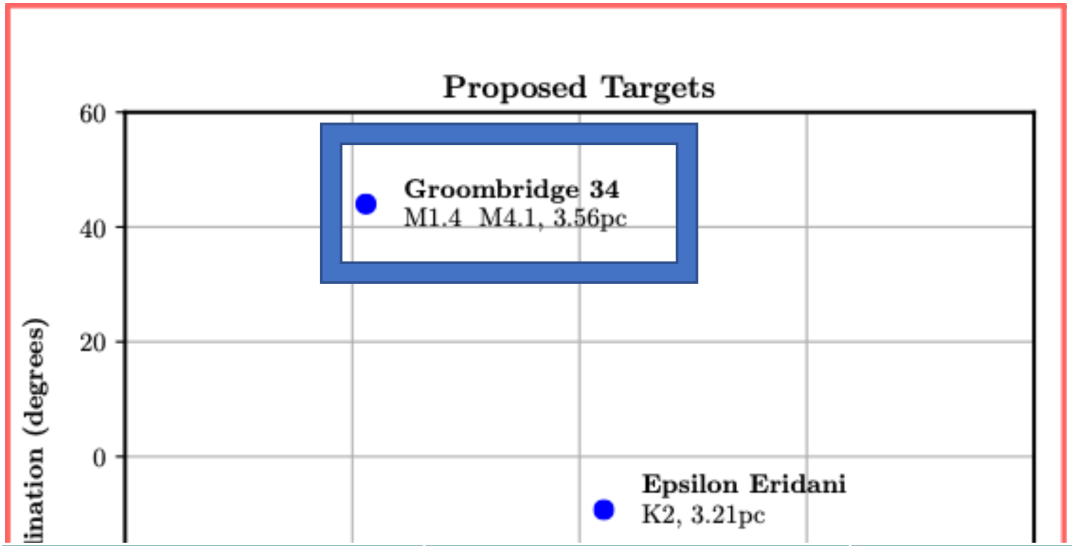
Target criteria





Spectral types (M) and a distance from Earth <4.6 pc for each star, were some of the the criteria applied to choose the best candidates.

Targets: Beaming Scenarios



S&L bursts may increase the intensity of the emitted signal. Such bursts are dependent on the phase of the moon's orbit.

$$S = (2.7\ mJy)\left(\frac{P_S}{P_{IO}}\right)\left(\frac{24\ MHz}{f_C}\right)\left(\frac{0.31pc}{d}\right)^2$$

Target	S [mJy]	Int. Time [hrs]	S [mJy]	Int. Time [hrs]
	X100 Beaming	X100 Beaming	X100 Beaming X20 P_{IO}	X100 Beaming X20 P_{IO}
Epsilon Eridani	2.31	460	46.2	1.2
Groombridge 34	1.88	706	37.6	1.8

Beam Formed Observations

Fast (~30 seconds) phase changes on baselines, due to the atmosphere, are one of the challenges of performing such low-frequency observations. Therefore, we continuously solve for the phase using a calibrator beam.

Name	Intent	Duration (minutes)
3C 41	Check Source	5
Groombridge 34	Target	55
3C 41	Check Source	5
Groombridge 34	Target	55

Name	Intent	Duration (minutes)
3C 48	Flux Calibrator	5
4C 44.02	Phase Calibrator	55
3C 48	Flux Calibrator	5
4C 44.02	Phase Calibrator	55

Simultaneous scans are carried out using two beams: A target/ON-source beam and a calibrator/OFF-source beam. The calibrator beam that trails the target by ~3.4 degrees. Total observation time per night is 3hrs per beam.

Summary

- First exomoon is yet to be confirmed.
- Searching for exomoons through radio waves based on IO-DAM emissions. No source detected for Epsilon Eridani (GMRT).
- Ongoing campaign for Groombridge 34.
- Expanding to lower frequencies with LWA, currently performing follow up observations with LWA Interferometer Mode (Sevilleta & LWA1 stations).

Future Work

- Reduction and processing to be performed using AIPS.
- A detection would demonstrate LWA's capability to integrate down to mJY levels, which has not yet been proven.
- A non-detection still constitutes one of the first applications of this method and would provide the necessary information to establish upper limits.
- Finding exomoons would provide insight to planetary formation, habitability & magnetic fields.

Acknowledgements

- NRAO Reber Fellowship
  - Bryan Butler
  - Amy Kimball
- LWA's Group
  - Greg Taylor
  - Jayce Dowell
- UTA's Exoplanet Group
- UTA's LSAMP BD Program

QUESTIONS?