Detecting Volcanic Exo-Ios That May Fuel Auroras on Nearby Super-Jupiters

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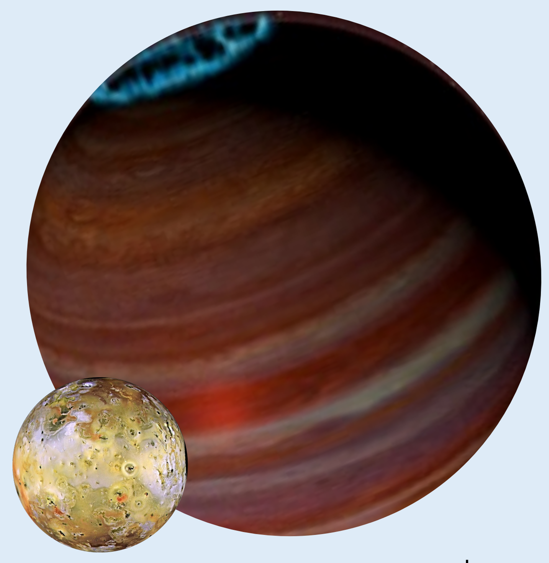

Are exo-Ios the source of plasma that fuel aurorae on free floating substellar objects?

Properties of test object SIMP0136	Ref. #
Mass = $12.7 \pm 1.0\ M_{Jup}$	1
Inclination = $80°^{+10}_{-12}$	2
Age = 200 ± 50 Myr	1
Spectral Type: T2.5	3

Repeating bursts of radio emission thought to trace massively scaled-up analogs of Jupiter's aurorae have been detected around nearly a dozen isolated substellar worlds, yet the source of the electrons fueling the aurorae remains unknown. Jupiter's aurorae are supplied with plasma from volcanic outflows on the planet's innermost moon, Io, and it is theorized that volcanism from tidally heated exosatellites could provide the plasma that fuel the aurora on the isolated substellar worlds.

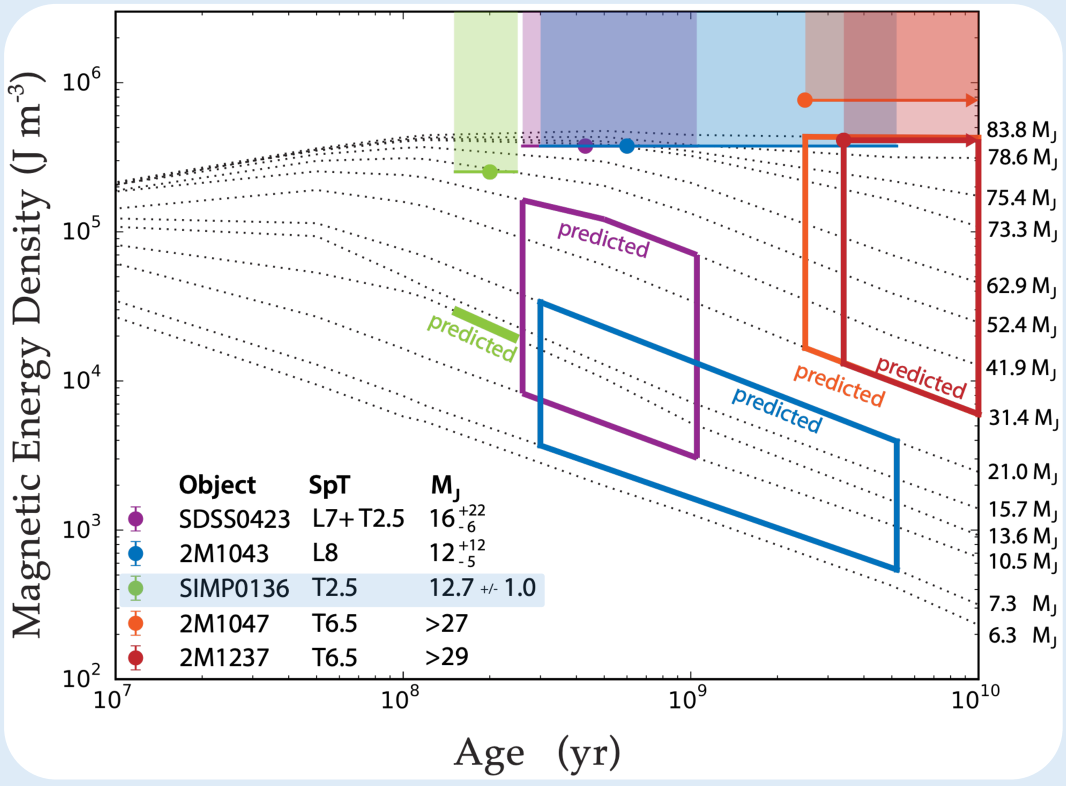

Figure 1: The unexpectedly high magnetic energy densities observed in some substellar worlds point to gaps in our understanding of the plasma environments that drive their aurorae. Figure from Kao+2018.

We can detect exo-Io transits in light curves of these variable free-floating worlds

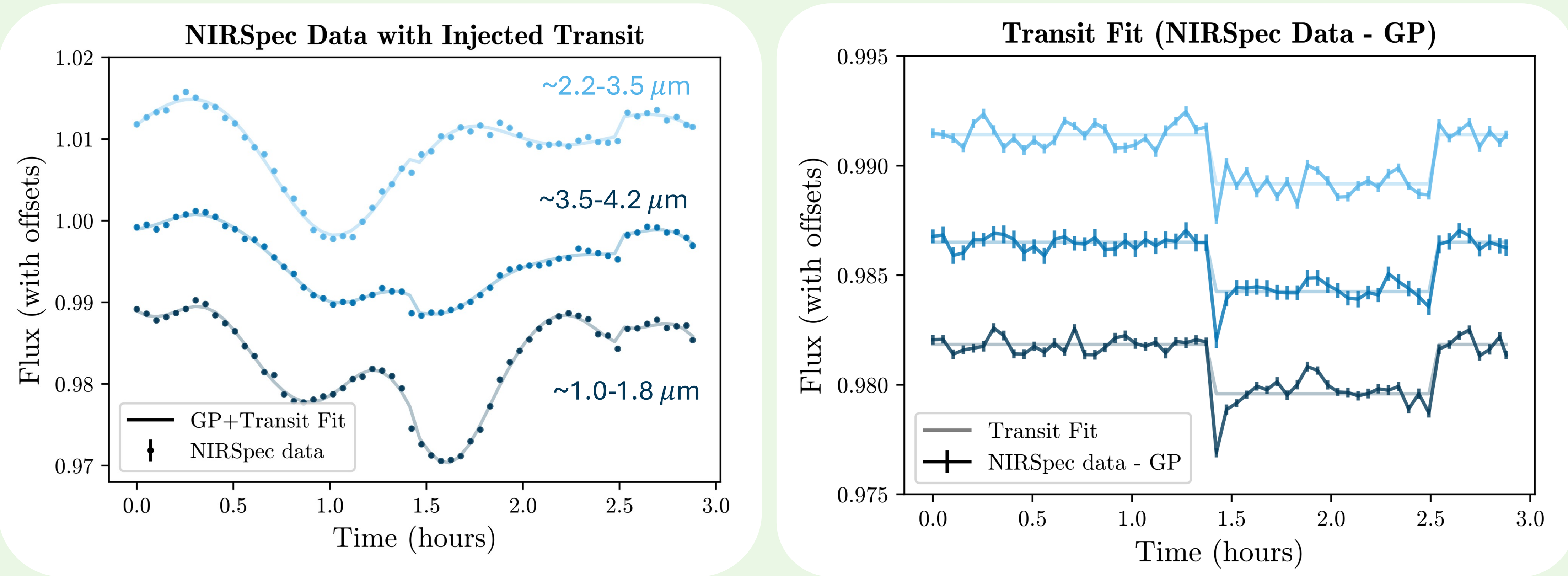

Figure 2: Multi-wavelength light curves from JWST NIRSpec observations of SIMP0136. A 3000ppm (0.75 $R_\oplus$) transit was injected (left panel) and recovered (right panel).

By constructing multiple light curves spanning many wavelength regions, we can identify achromatic transits. Our transit search algorithm models the variability using a Gaussian process while simultaneously allowing a single transit event in all light curves.

Based on injection-recovery testing with SIMP0136 JWST data, this transit search method can detect 66% of Io-mass analogs and 93% of Ganymede-mass analogs.

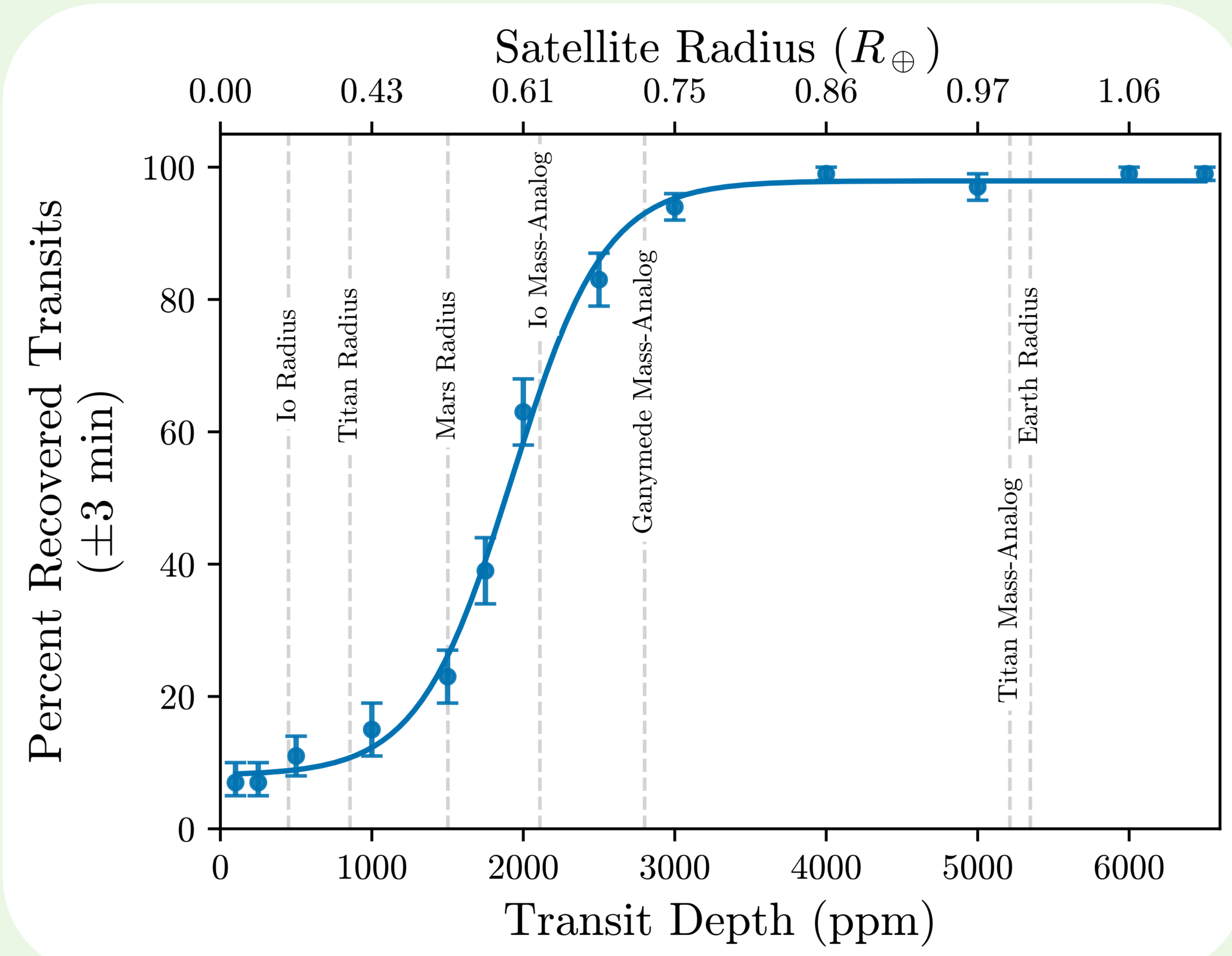

Figure 3: Injection recovery results for SIMP0136 NIRSpec data. Our transit search method is sensitive down to 0.60 $R_\oplus$ sized exosatellites.

The total transit probability of these worlds is favorable for a transit search of exo-Ios

The total probability of a transit is given by:

$$P_{total} = P_{geometric} \times P_{observational} \times P_{detection}$$

For a 36-hour JWST survey of a host with i ≥ 68°,* the probability of detecting a transiting Ganymede mass-analog ($0.72\ R_\oplus$, $0.32 M_\oplus$) on a 1-day orbit is 29%.

Assuming each target hosts an exo-Io, we should expect to detect an exo-Io with four 36-hour observations. With 12 null observations, we can rule out exo-Io ubiquity at the 2σ level.

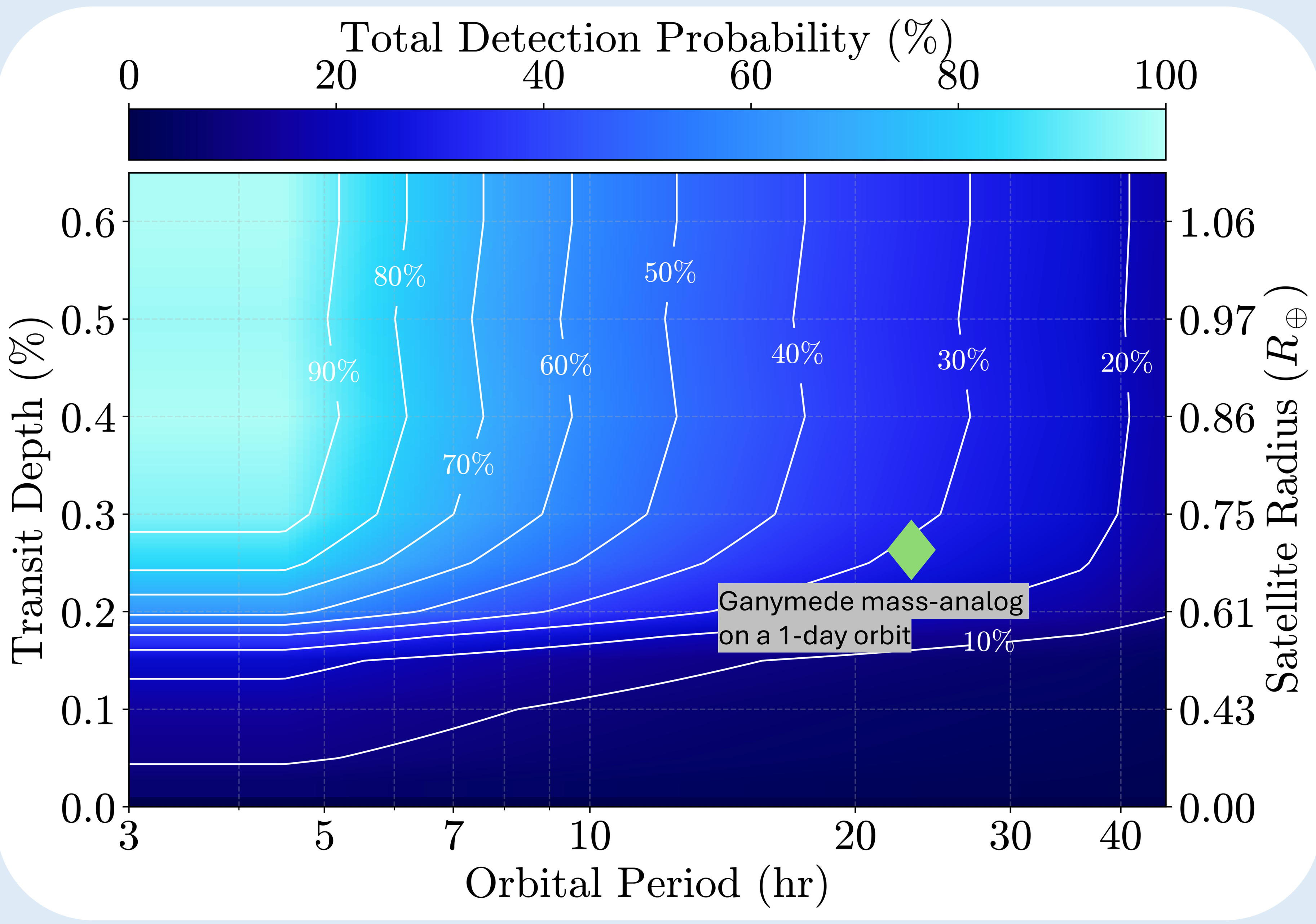

Figure 4: Total transit probability of an exosatellite using constraints from the SIMP0136 system.

JWST light curves spanning ~1.5 days for 4-12 aurorally active super-Jupiters could constrain whether exo-Ios serve as a significant plasma source for substellar aurorae

*Brown dwarfs and planetary mass objects with strong detected aurora are more likely to be detected at intermediate to equatorial viewing angles, as their radio emission is beamed and therefore disfavored in near pole-on geometries [5].

References. **(1)** Gagné, J., Faherty, J. D., Burgasser, A.J., et al. 2017, ApJL, 841, L1 **(2)** Vos, J. M., Allers, K. N., & Biller, B. A. 2017, ApJ, 842, 78 **(3)** Artigau, É., Doyon, R., Lafrenière, Dl, et al. 2006, ApJL, 651, L57 **(4)** Kao, M. M., Hallinan, G., Pineda, J. S., Stevenson, D., & Burgasser, A. 2018, ApJS, 237, 25 **(5)** Pineda, J. S., Hallinan, G., & Kao, M. M. 2017, ApJ, 846, 75
Also see McCarthy, A. M., Vos, J. M., Muirhead, P. S., et al. 2025, ApJL, 981, L22

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