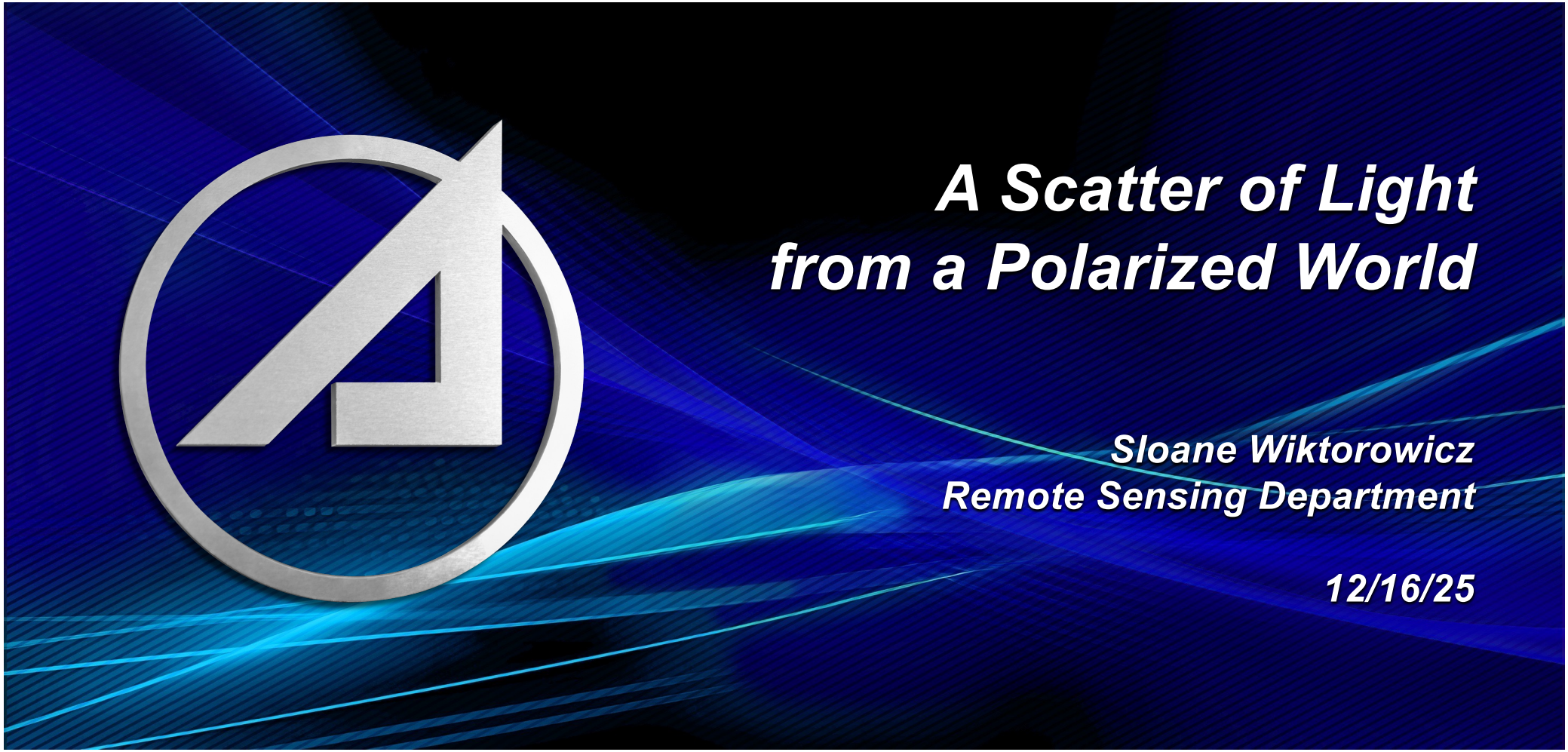
THE AEROSPACE CORPORATION



A Scatter of Light from a Polarized World

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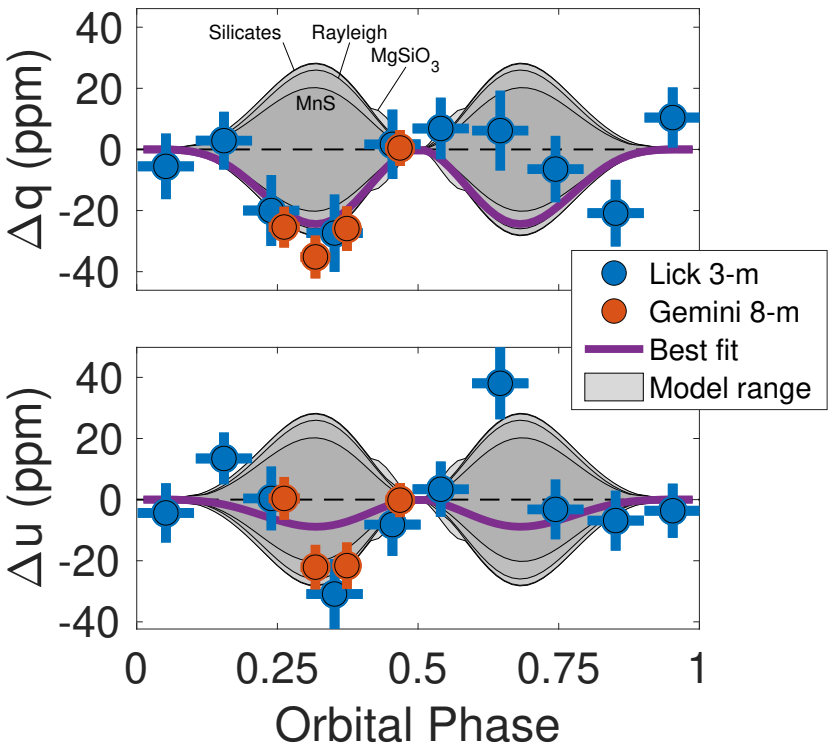
12/16/25

Polarimetry with No Time for Background

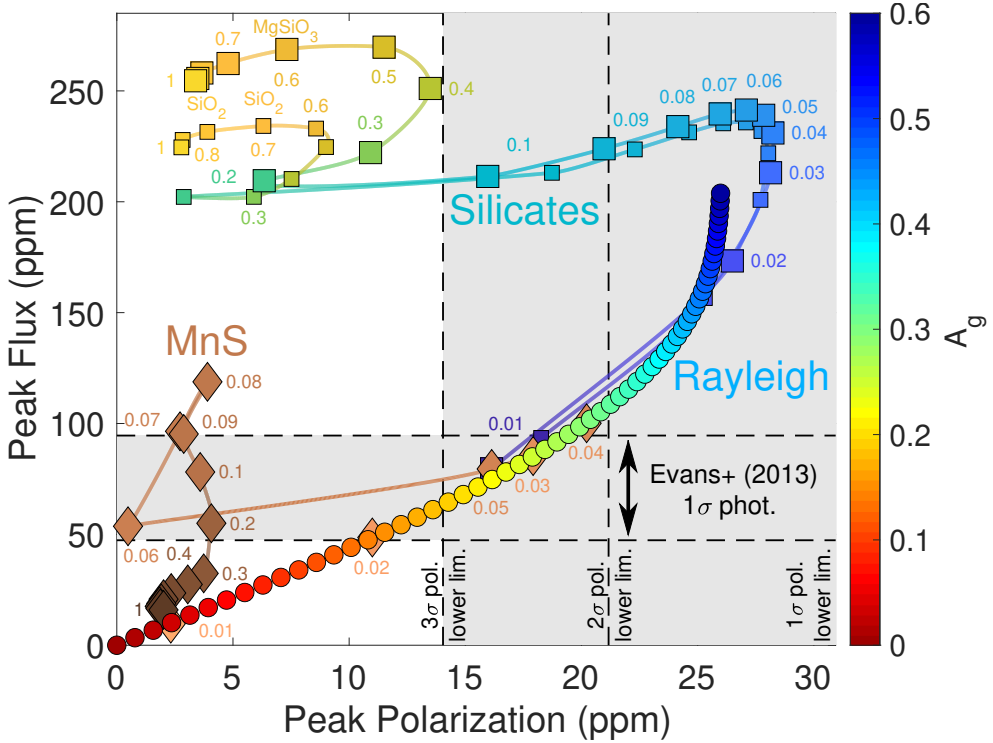
And lo! A detection! 20 years later.



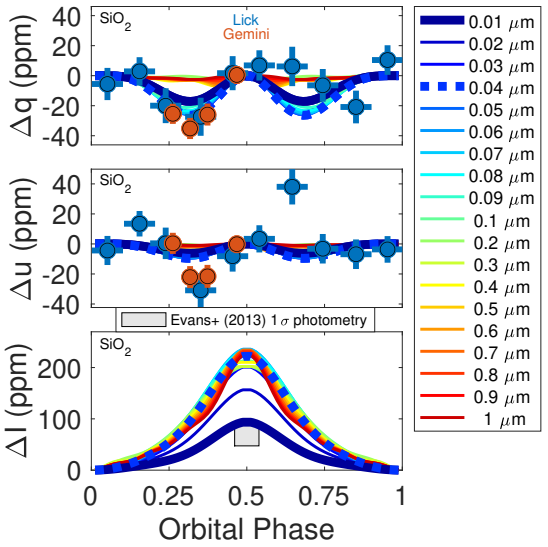
- 10 years of HST data: HD 189733b has Rayleigh-like clouds or the star has unocculted spots I guess? (The French+ 2008a,b; McCullough+ 2014)
  - It's not haze. Haze is photochemical, and organics are not present on this 1200 K planet with just SiO_2 clouds (Inglis+ 2024).
- JWST 8.7 μm absorption in one secondary eclipse: $3.2^{+13}_{-2.5}$ nm SiO_2 clouds, no other composition comes close (Inglis+ 2024)
- Gemini North POLISH2 B band polarimetry in ~1 night: 38^{+47}_{-23} nm SiO_2 or $MgSiO_3$ clouds (90% confidence), no other composition comes close
- Polarization is sensitive to the size, shape, and refractive index of scattering particles

Polarimetric detection requires Kepler-like accuracy from the ground: alt-az telescopes or bust

Polarization Breaks Degeneracies



- Photometry and polarimetry are independent and wavelength-dependent
  - The figure at left is just for B band
- Polarization is way too strong to be consistent with weak HST secondary eclipse depth (Evans+ 2013)



HD 189733b Is Polarized like Titan

Both have ~40 nm scattering particles/monomers but that's where the similarities end

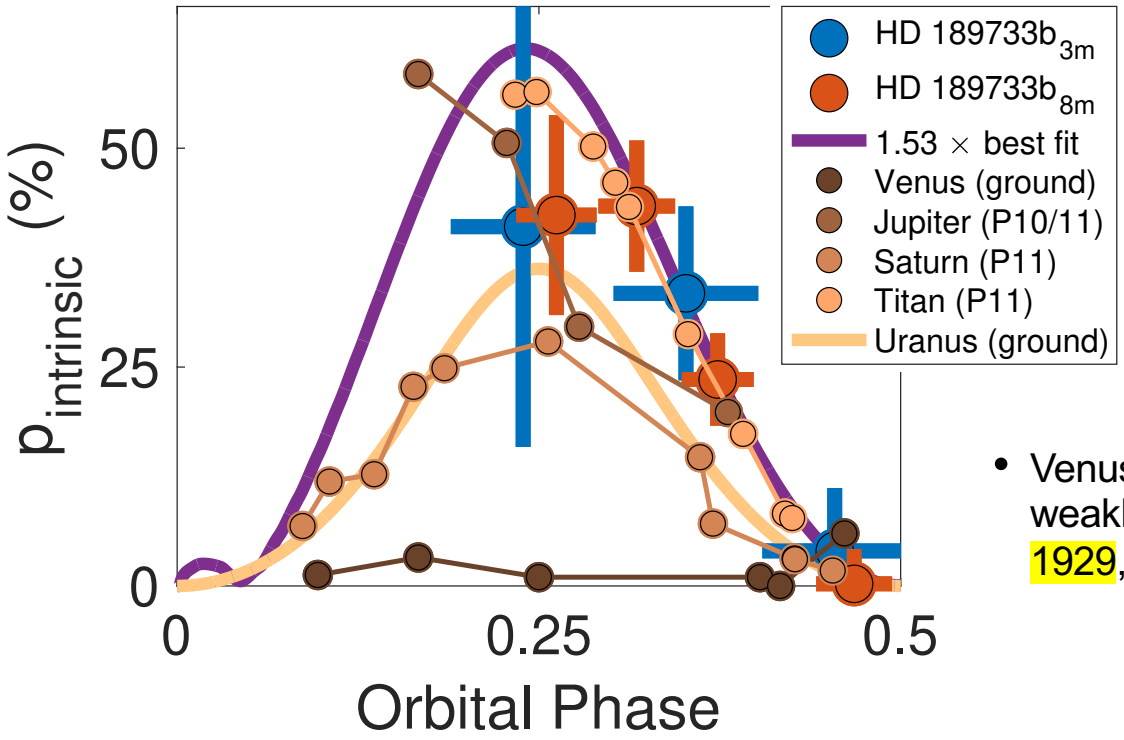


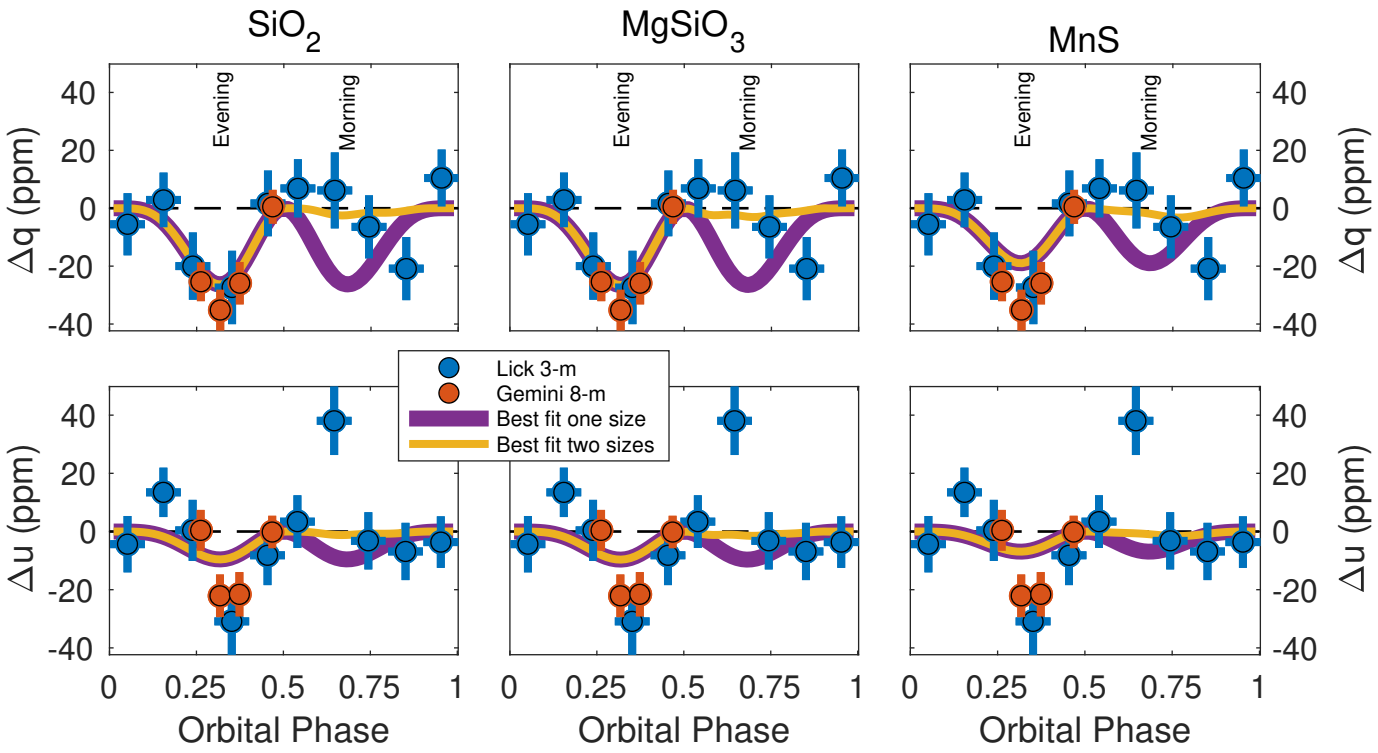
Table 6
Peak Blue Optical Intrinsic Linear Polarization

Object	$p_{\text{intrinsic}}$	References
HD 189733b	61.4(1.5)%	This work
Jupiter	~58%	ST84
Titan	~56%	TS82
Uranus	36.22(89)%	MS77, W26
Saturn	~28%	TD84
Venus	~6%	L29, CG69, DC70

References. L29 (B. Lyot 1929), CG69 (D. L. Coffeen & T. Gehrels 1969), DC70 (A. Dollfus & D. L. Coffeen 1970), MS77 (J. J. Michalsky & R. A. Stokes 1977), TS82 (M. G. Tomasko & P. H. Smith 1982), ST84 (P. H. Smith & M. G. Tomasko 1984), TD84 (M. G. Tomasko & L. R. Doose 1984), W26 (S. J. Wiktorowicz et al. 2026)

- Venus' 1.05 ± 0.10 μm sulfuric acid clouds are weakly polarizing because they're big (data: Lyot 1929, model: Hansen & Hovenier 1974)

Cloud Condensation on the Nightside?

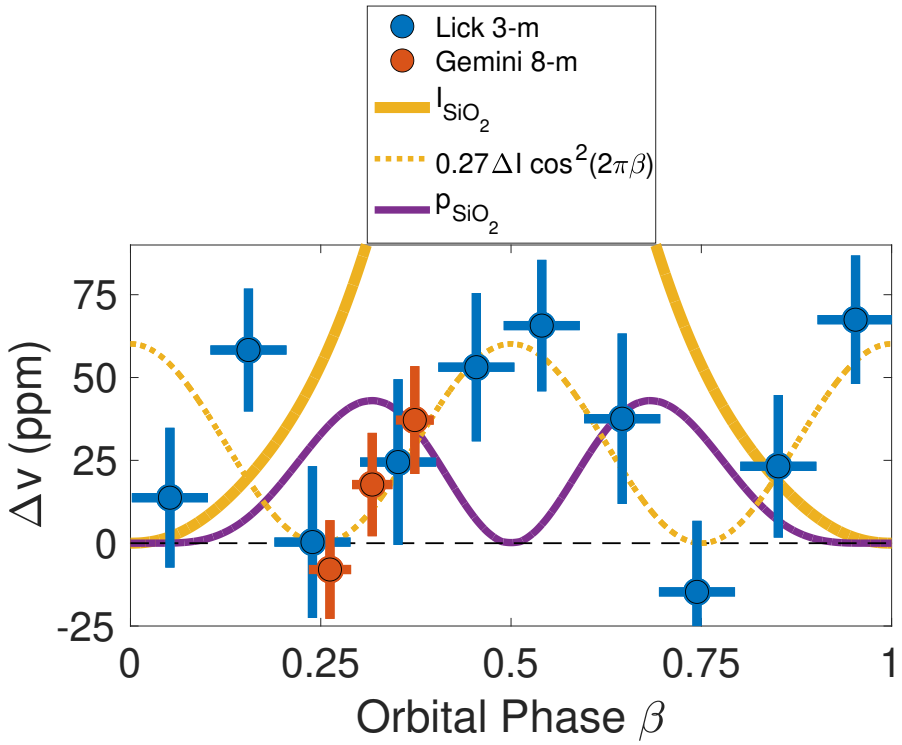


- Good data (Gemini) only probe evening terminator
- OK data (Lick) probe both
- Though Lick systematics are not great, they suggest muted polarization on the morning terminator
- > 100 nm SiO_2 on the night side, 40 nm SiO_2 on the day side?
- There are precedents: WASP-76b (Ehrenreich+ 2020) and LTT 9779b (Coulombe+2025)

Easy to test with another night or two at Gemini

HD 189733 Star-Planet Interactions Seem to be Back

Crap

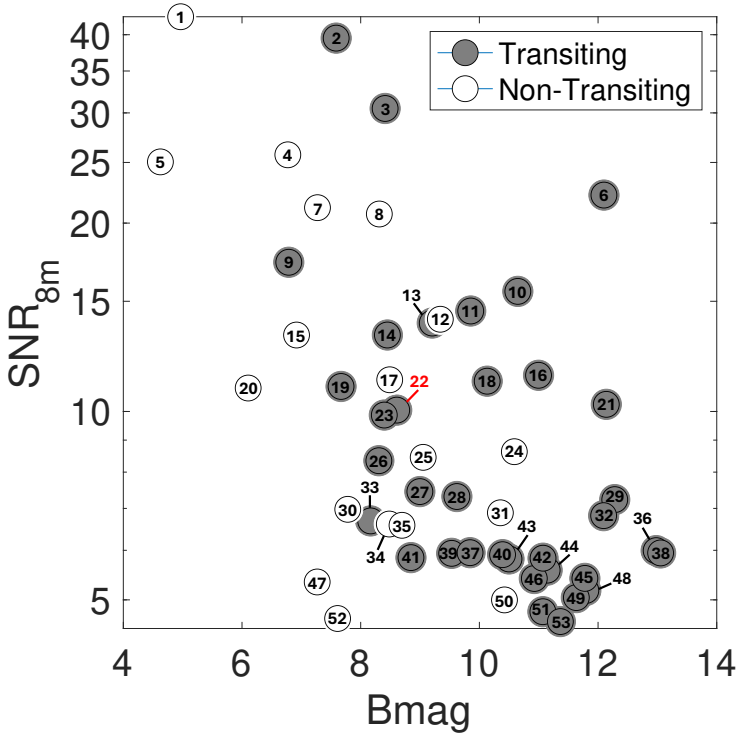


- POLISH2 measures linear and circular polarization simultaneously, but who cares? (Asteroid metals do)
- Circular polarization appears to modulate on the planet's orbital period and is observed at both Gemini (2018) and Lick (2011-2014)
- Unless the atmosphere's made of scarab beetles, it can't be intrinsic to the planet
- Why is circular polarization modulation so large?
- Why does it peak at transit and midtransit?
- HD 189733 = BY Dra variable like HD 129333, whose circular polarization variations are due to starspots and are 10x larger than HD 189733 (Elias & Dorren 1990)
- Circular polarization can't be an artifact of the instrument (Wiktorowicz+ 2023)

Starspots are circularly polarized (especially in B band), HD 189733 is spotted, and another BY Dra is even stronger

A Lot of Juicy Targets Out There

Shouldn't have led with HD 189733b



1 τ Boo b	27 KELT-7 b
2 KELT-9 b	28 HAT-P-70 b
3 WASP-33 b	29 KELT-16 b
4 HD 179949 b	30 GJ 3222 b
5 υ And b	31 HIP 86221 b
6 HIP 65 A b	32 TOI-1855 b
7 HD 143105 b	33 HD 209458 b
8 HD 212301 b	34 HD 149143 b
9 WASP-189 b	35 HD 46375 b
10 TOI-2109 b	36 WASP-103 b
11 WASP-18 b	37 TOI-1408 b
12 HD 86081 b	38 WASP-19 b
13 TOI-1518 b	39 KELT-17 b
14 MASCARA-1 b	40 WASP-74 b
15 HD 75289 b	41 HD 202772 A b
16 WASP-121 b	42 WASP-77 A b
17 HD 187123 b	43 KELT-4 A b
18 WASP-76 b	44 TOI-1181 b
19 KELT-20 b	45 KELT-14 b
20 51 Peg b	46 WASP-167 b
21 WASP-12 b	47 HD 185269 b
22 HD 189733 b	48 HAT-P-32 b
23 MASCARA-4 b	49 K2-31 b
24 WASP-94 B b	50 HD 63454 b
25 HD 83443 b	51 WASP-3 b
26 TOI-1431 b	52 HD 103774 b
	53 WASP-87 b

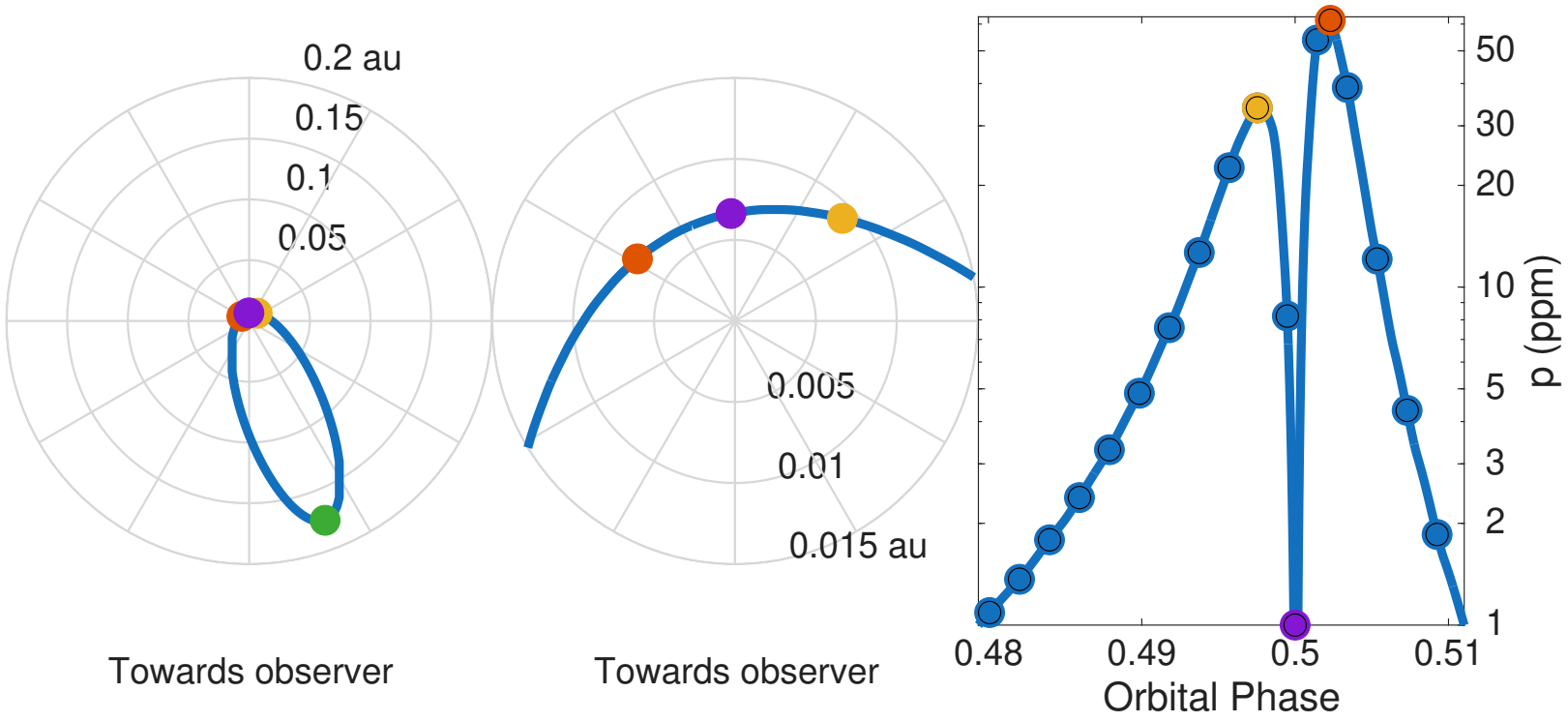
$$\mathrm{SNR} = 7.2\left(\frac{D}{8\,\mathrm{m}}\right)\left(\frac{R/1.138\,R_J}{a/0.031\,\mathrm{au}}\right)^2 \times \sqrt{\left(\frac{n}{0.5\,\mathrm{orbits}}\right)10^{0.4(8.578-B\,\mathrm{mag})}}$$

If on a circular orbit

We still know nearly nothing about the non-transiting planets from the 90s, polarimetry can change that

Such as GJ 3222b, My New Favorite Planet

M sin i = 11.4 $M_{\oplus}$, e = 0.929



Should have a polarization spike that lasts ~1.5 h every 10.7 d