

# Direct Detection of Exoplanets with Polarimetry

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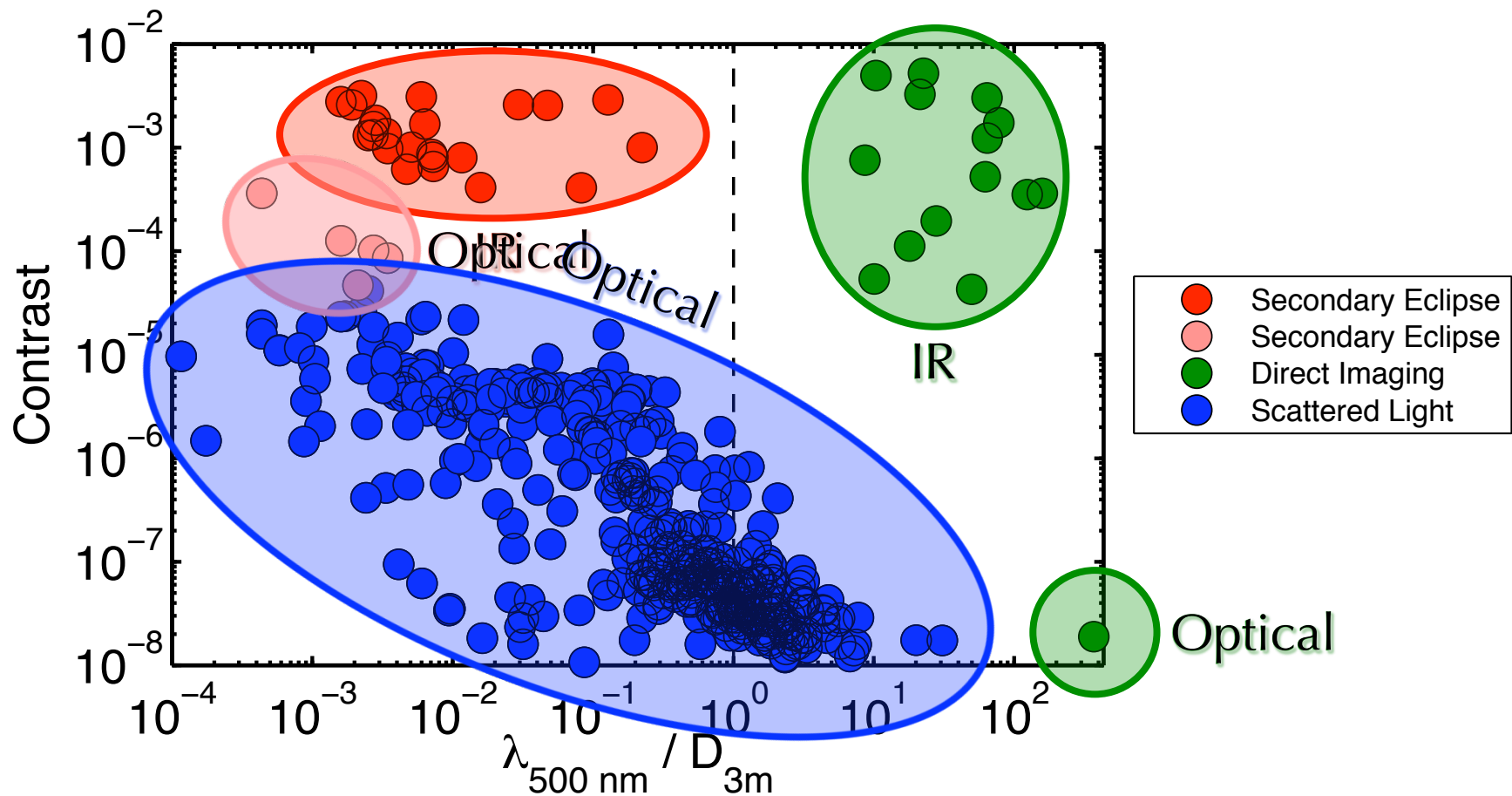
Postdoc, UCB ( $\Rightarrow$  Sagan Fellow, UCSC)

May 6, 2011

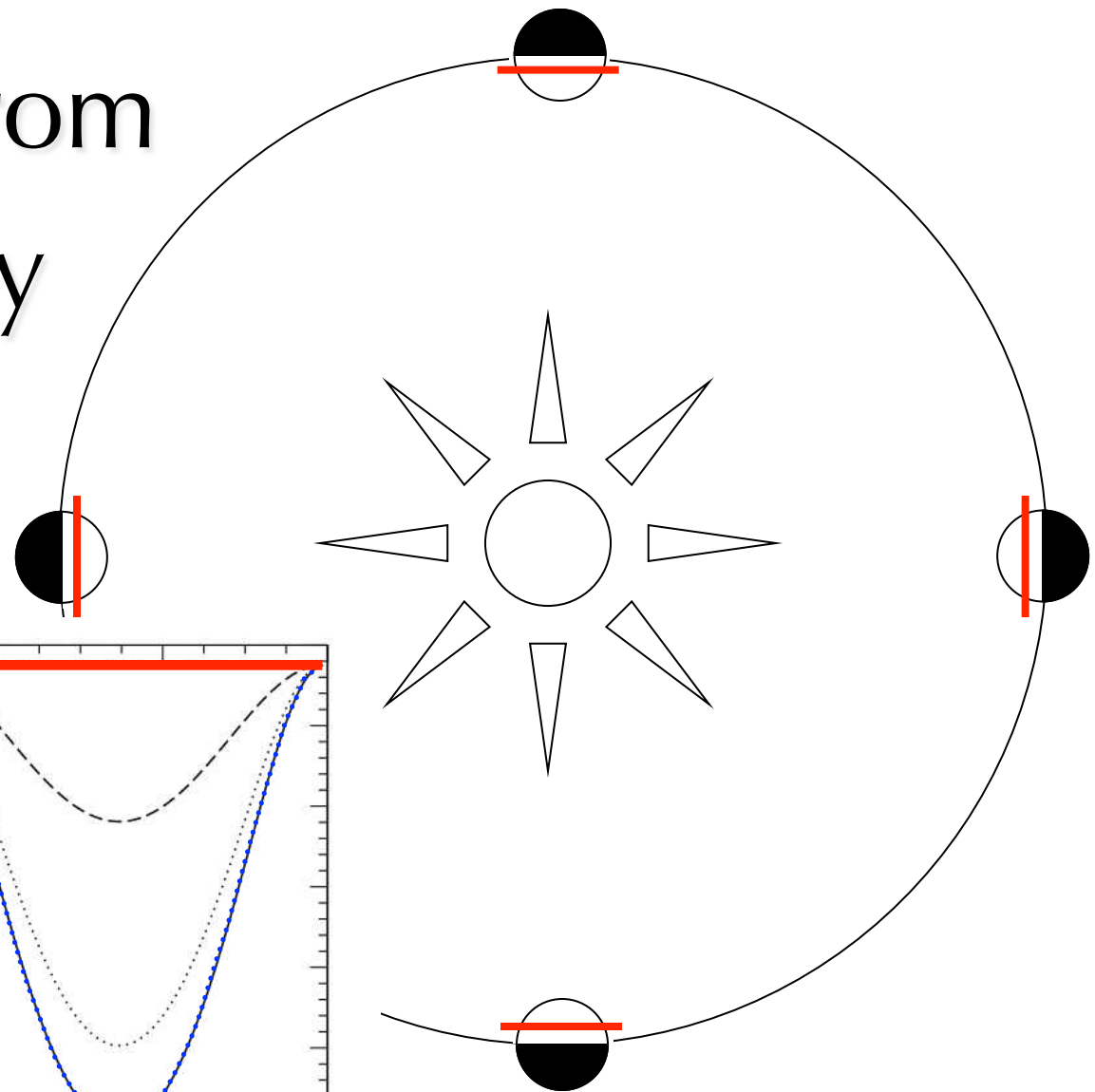
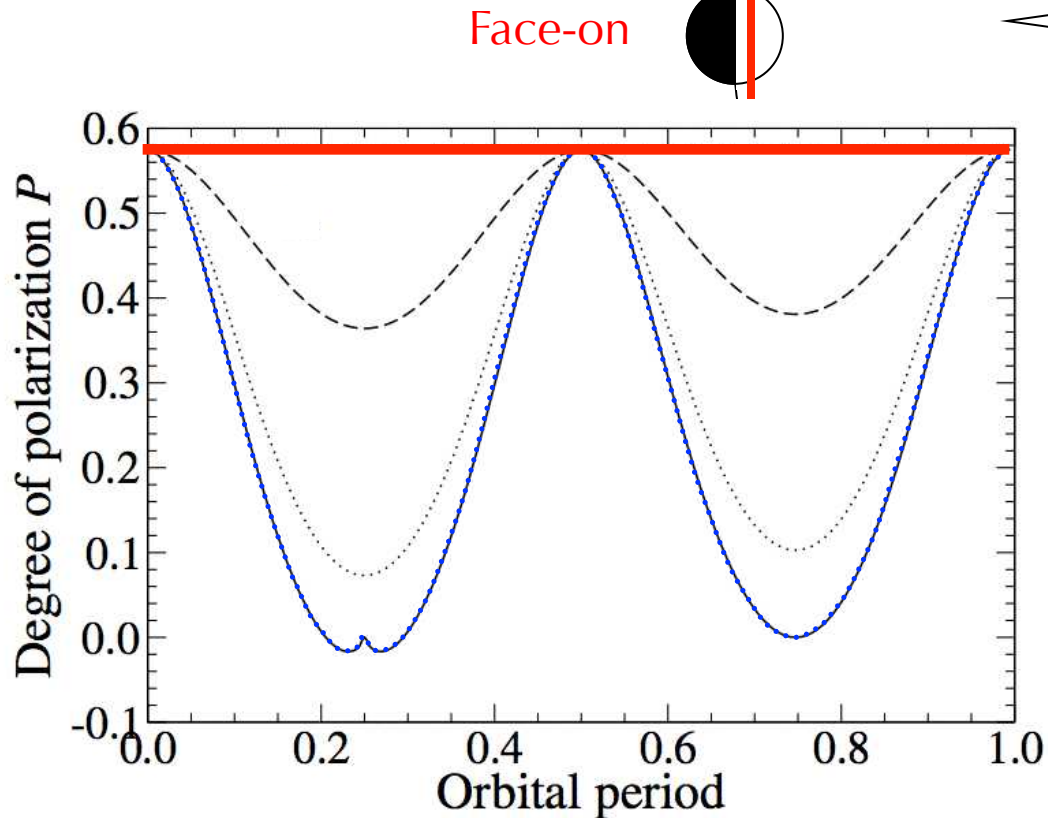




# Exoplanet Contrast



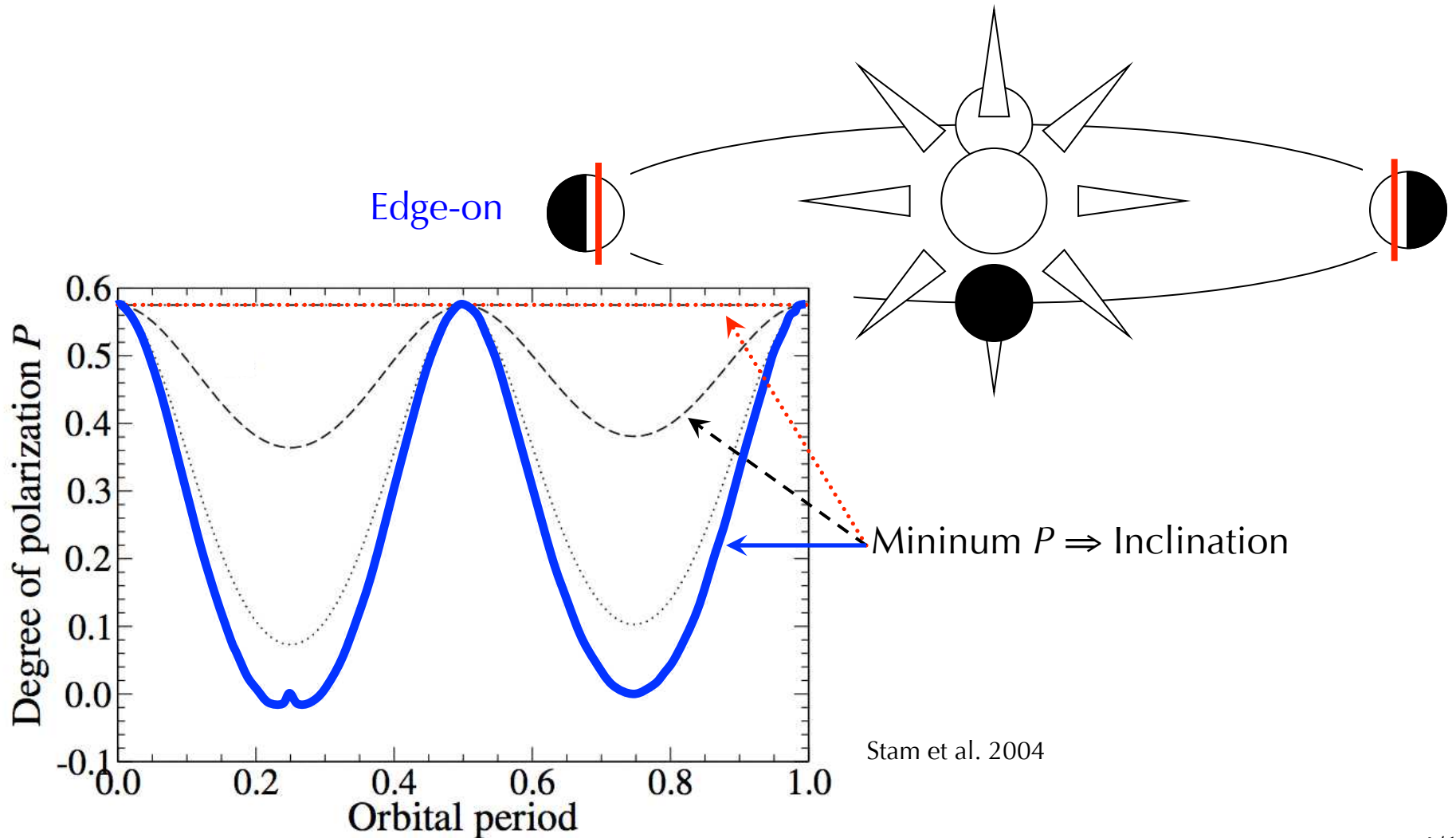
# Inclination from Polarimetry



Stam et al. 2004

# Inclination from Polarimetry

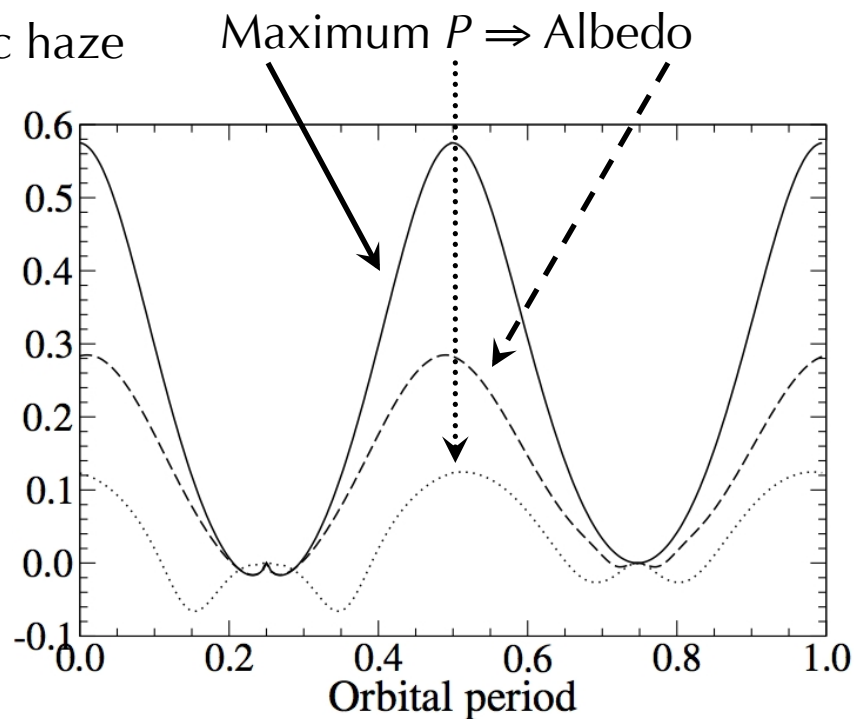
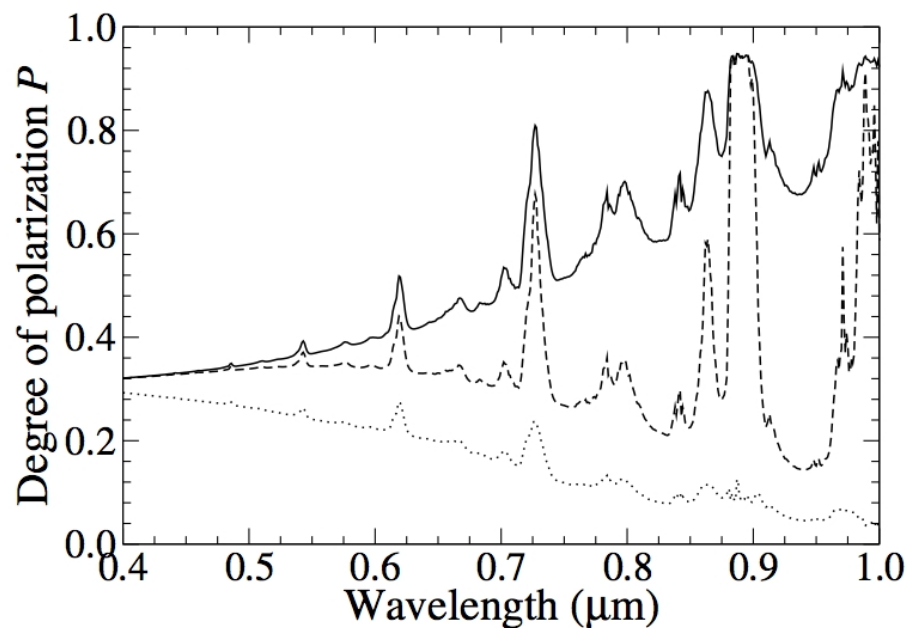
$< 10^{-5}$  precision  
( $> 10^{10}$  photons)





# Atmospheric Structure

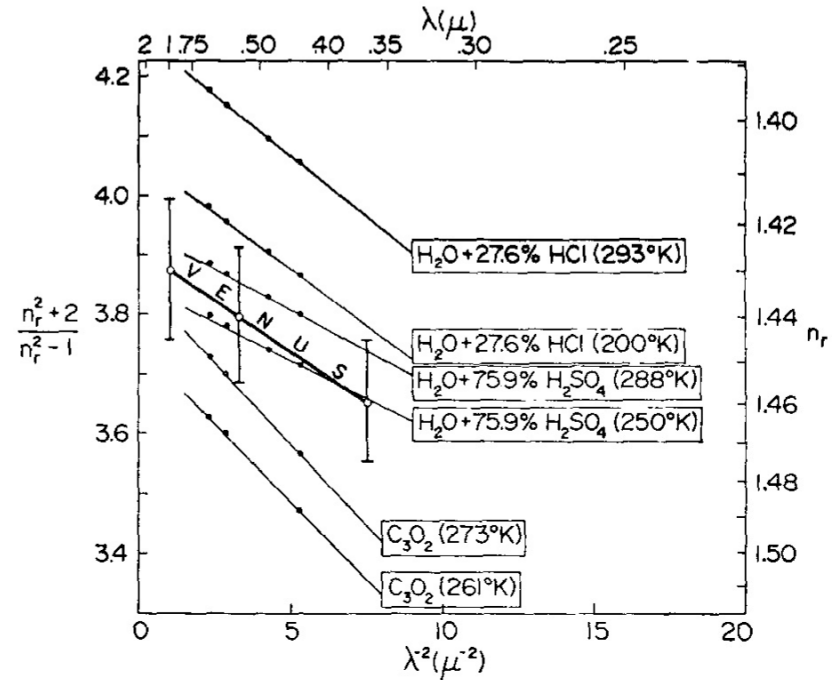
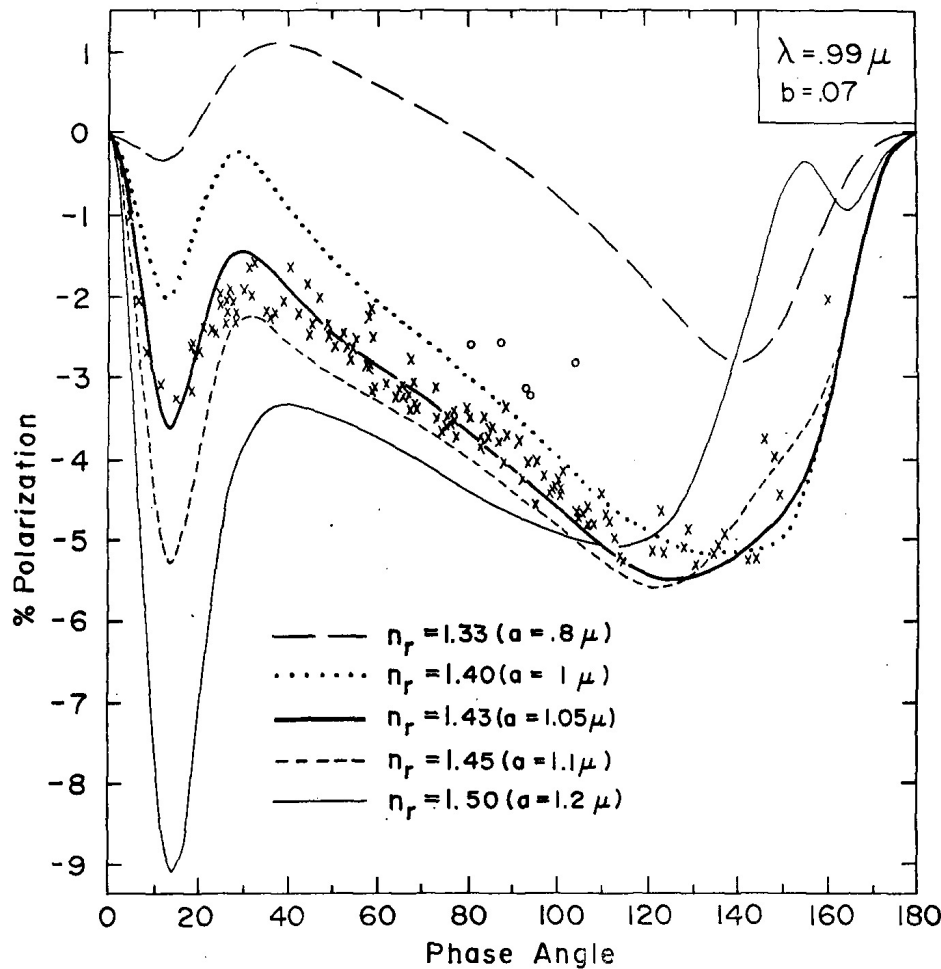
- Clear
- - - Tropospheric cloud
- ..... Tropospheric cloud + stratospheric haze



Stam et al. 2004



# Sulfuric Acid in Venus

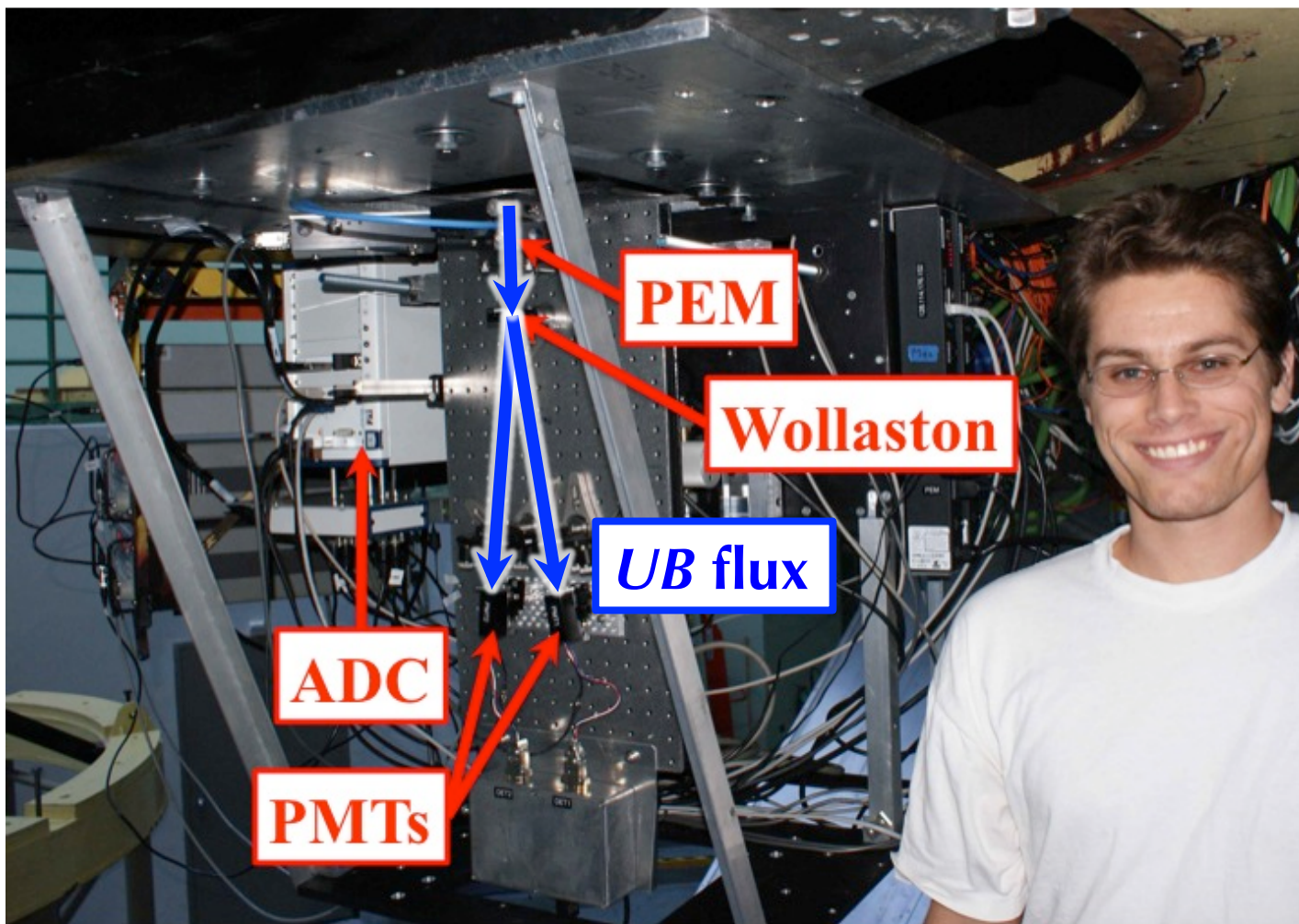


Coffeen & Gehrels 1969  
Hansen & Hovenier 1974



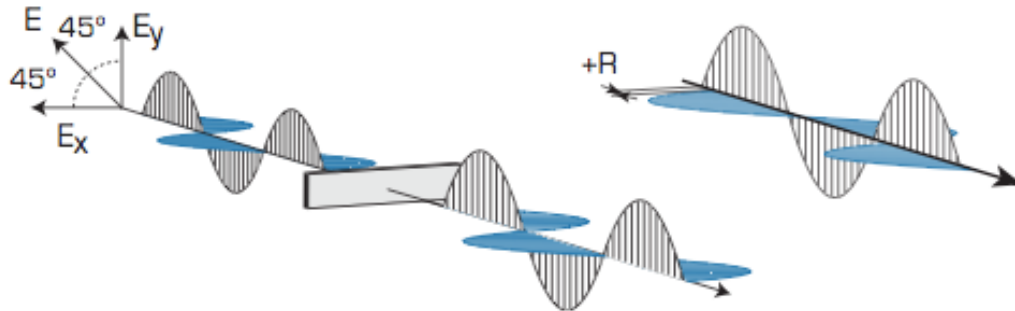
# POLISH2

Wiktorowicz & Matthews, 2008, PASP, 120, 1282

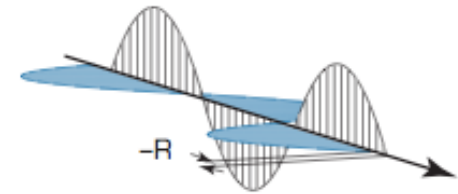




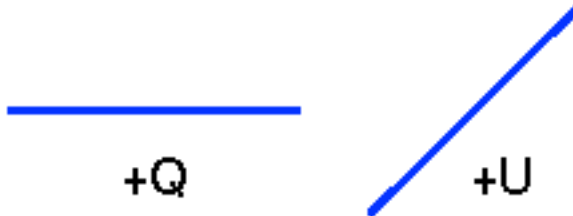
# Photoelastic Modulator



$t = 0 \mu s$

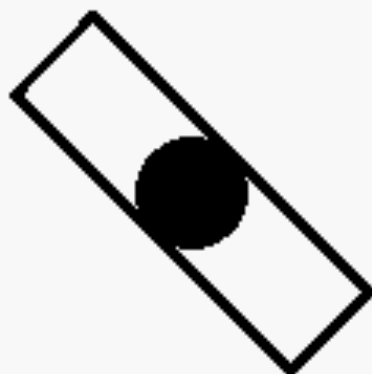


Hinds Instruments

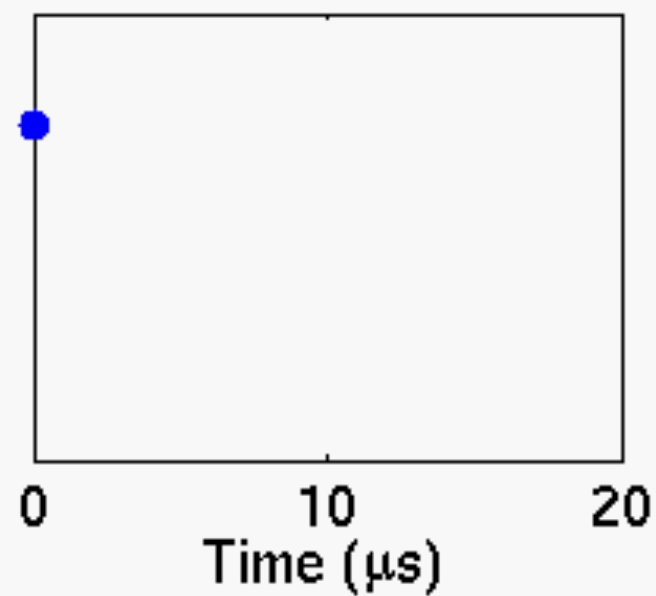
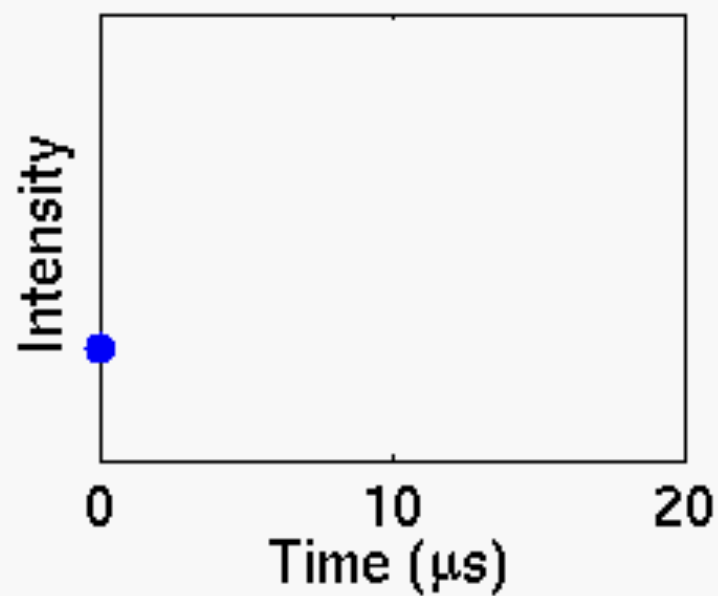
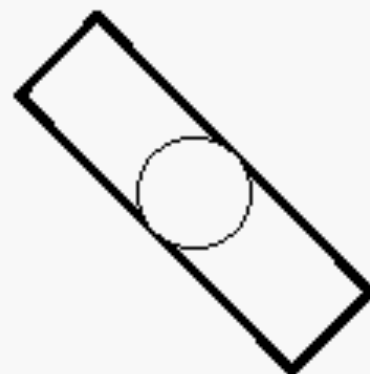


- Birefringence:  
horizontal E field  
lags/leads vertical
- Non-birefringent  
material stressed  $\Rightarrow$   
birefringence

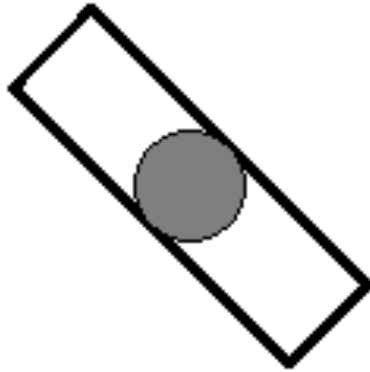
Left Beam



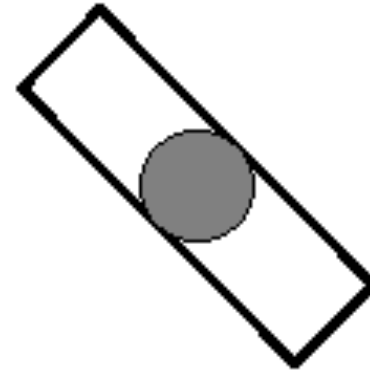
Right Beam



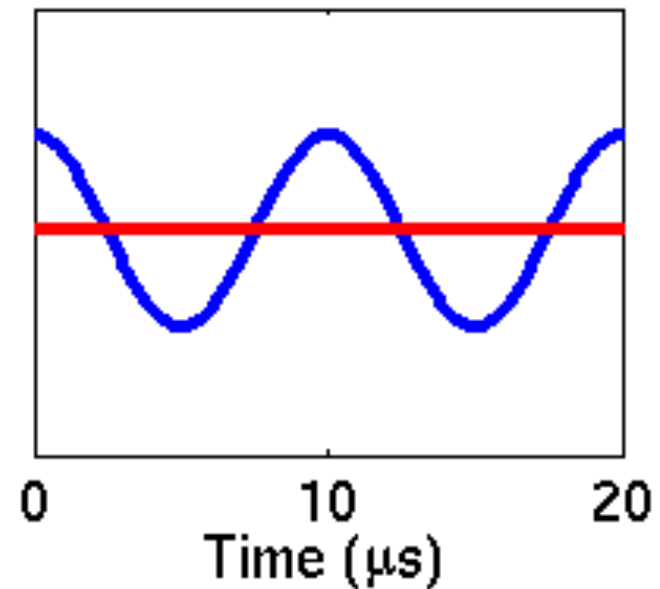
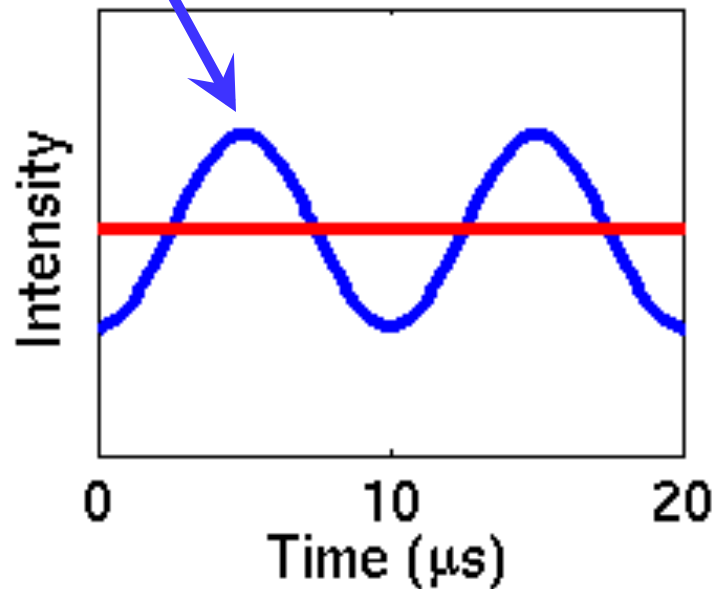
Left Beam



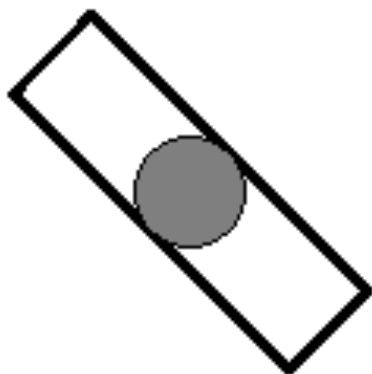
Right Beam



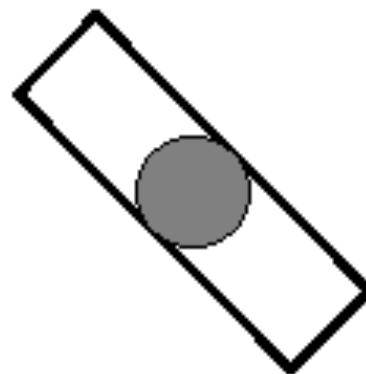
Nearly sinusoidal:  $50 + 150 \text{ kHz} + \dots + (2n-1)f = \text{Stokes } V/I$   
 $100 + 200 \text{ kHz} + \dots + (2n)f = \text{Stokes } Q/I, U/I$



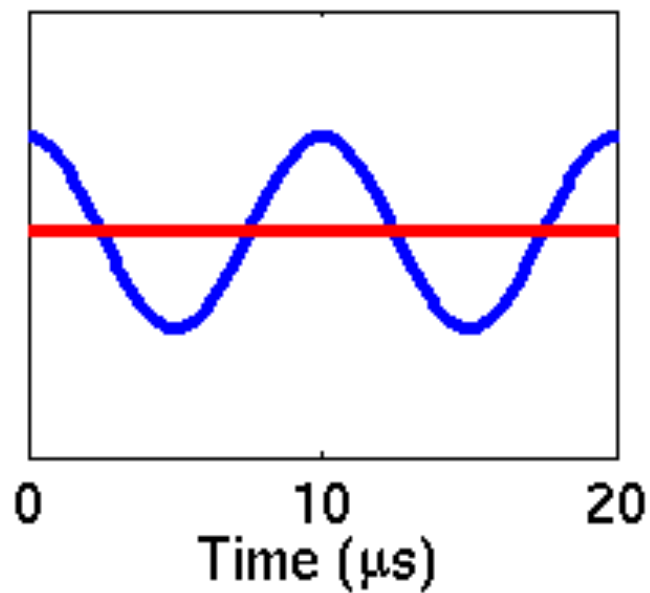
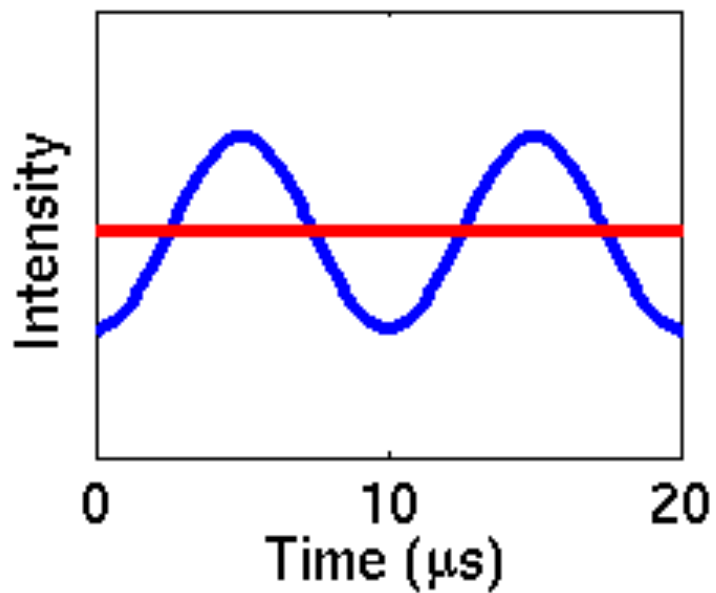
Left Beam



Right Beam

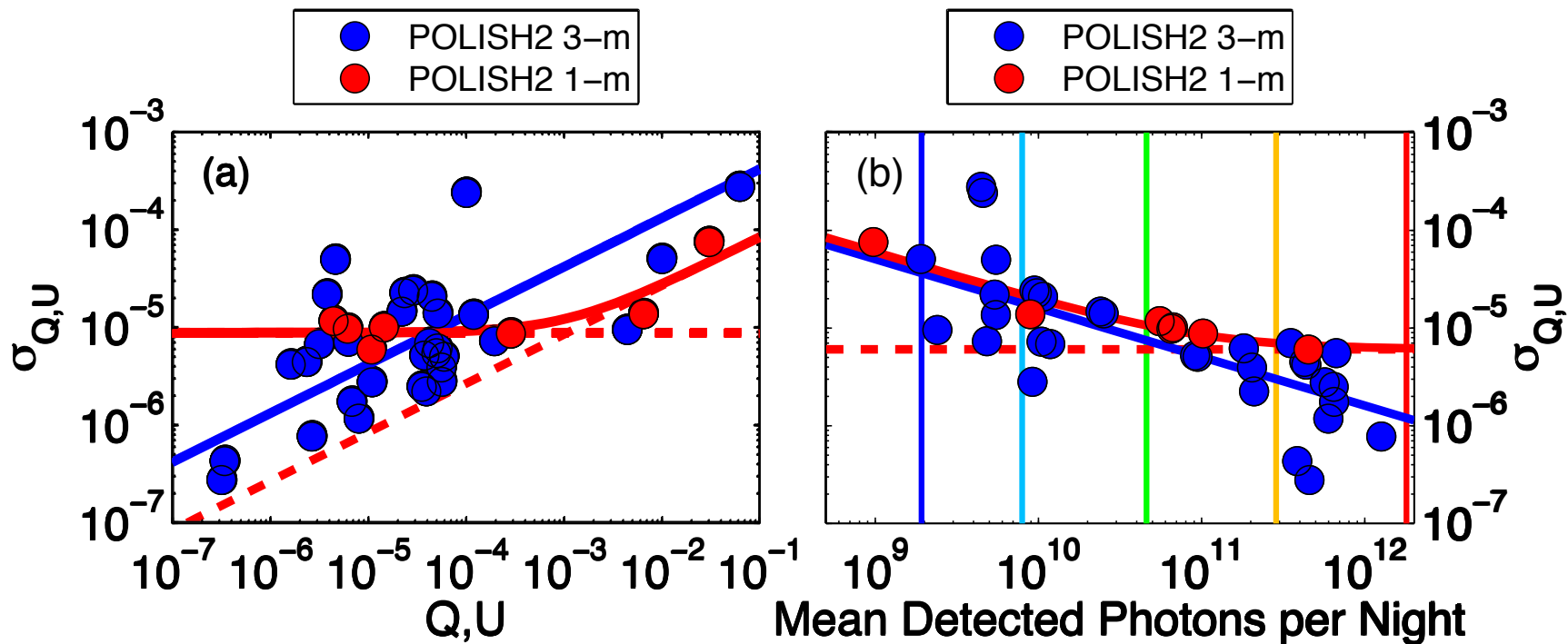


$$P \propto \frac{AC}{DC}$$





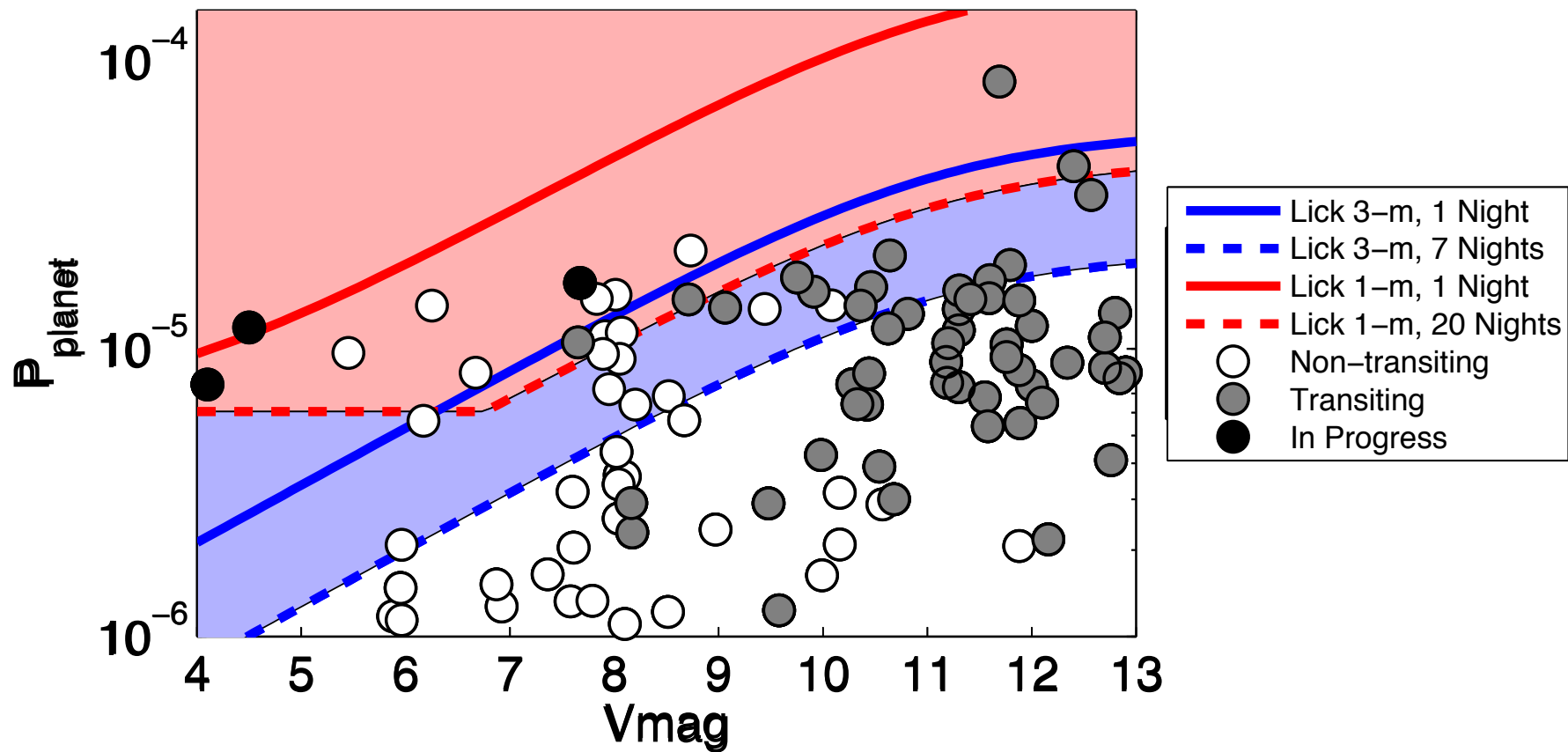
# POLISH2 Performance



Photon shot noise addition  $(Q,U)^{1/2} \propto F^{1/2}$   
 Quantization noise addition



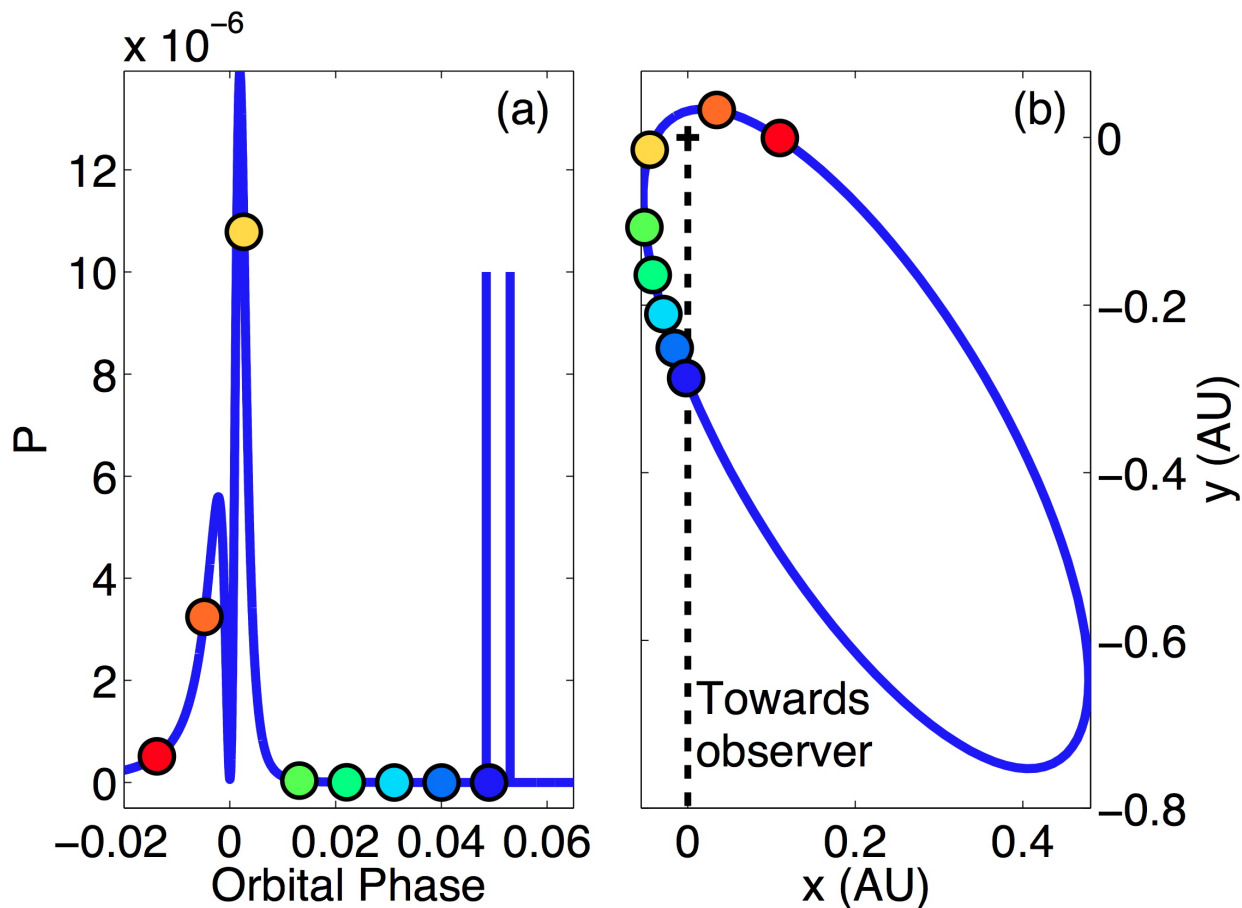
# Exoplanet Detectability





# Eccentric Planets

HD 80606,  $e = 0.934$ ,  $a(1-e) = 0.03$  AU





# Exoplanet Conclusions



- Scattered light from exoplanets will be polarized
- Allows direct detection even in face-on systems
- Albedo, inclination, and scattering properties (cloud structure, composition) will be probed
- Upgraded POLISH2 capable of detecting up to >30 exoplanets at Lick 3-m, up to 11 at Lick 1-m
- No conclusive detections yet, next 3-m run July 18



polish2