

Mapping Clouds in Exoplanet Atmospheres

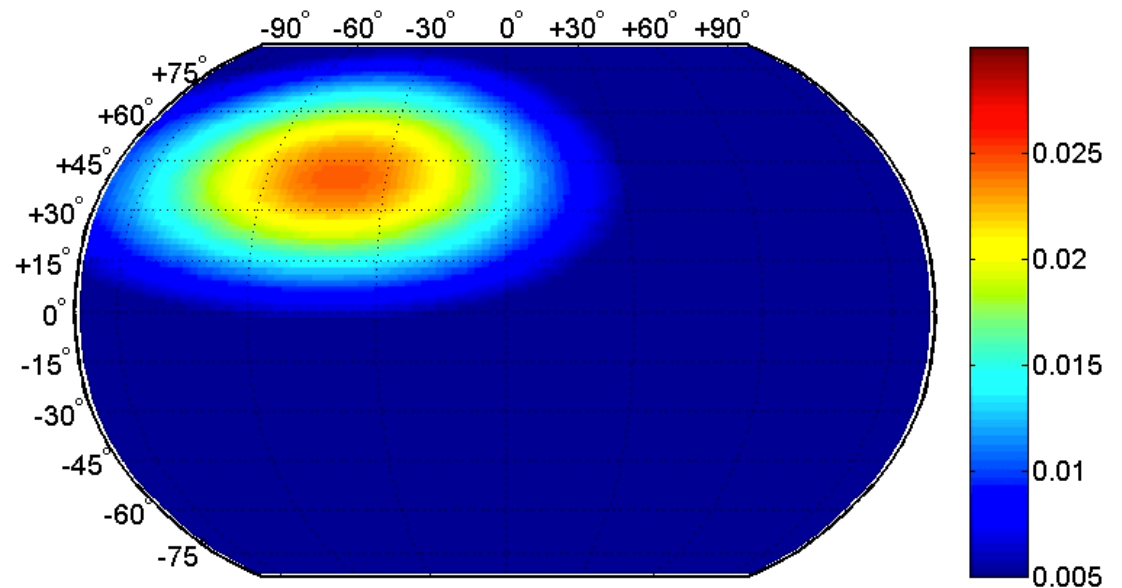
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Collaborators

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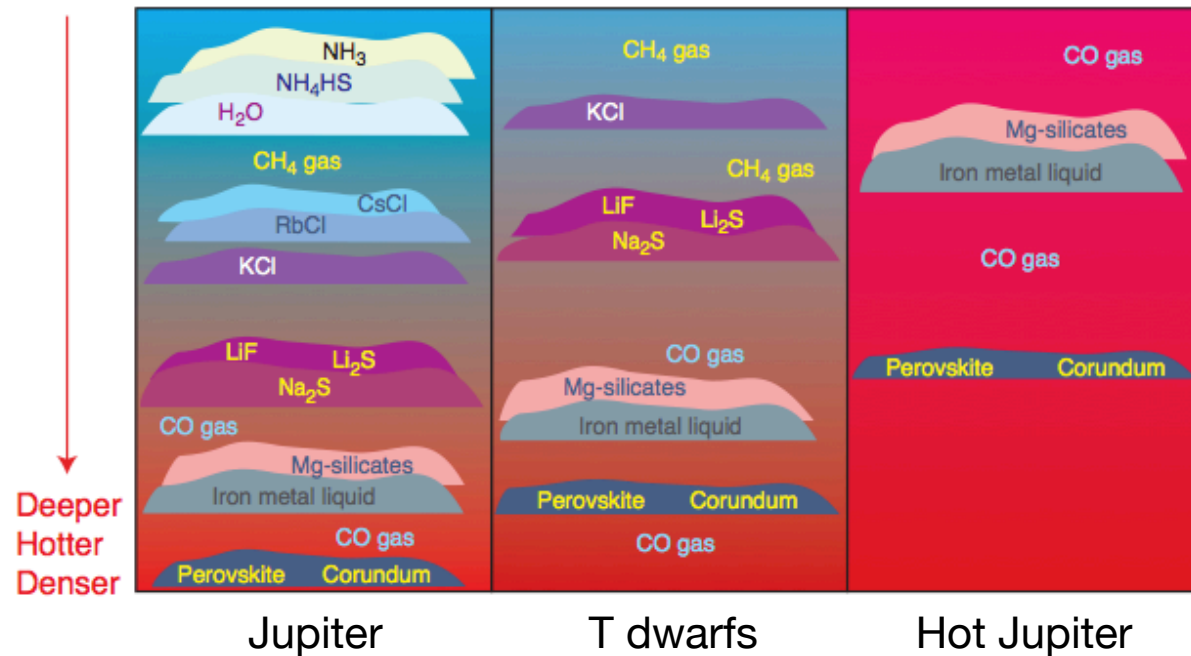


Suspected clouds on exoplanets

Planet	Method	Result	Reference
CoRoT-1b	Trans	Flat+noRay	Schlawin+2014
GJ436b	Trans	Flat+noRay	Knutson+2013
GJ1214b	Trans	Flat+noRay	Kreidberg+2013
GJ3470b	Trans	Flat+noRay	Fukui+2013, Crossfield+2013
HAT-P-12b	Trans	Flat+noRay	Line+2013
HAT-P-32b	Trans	Flat+noRay	Gibson+2013
HD189733b	Trans+Occ	Na+Ray	Evans+2013
HD209458b	Trans	H2O+clouds?	Deming+2013
HR8799bcd	DirectIma	IR EmPhot	Barman11, Madhu11, Lee13
Kepler-7b	PhaseCurve	Asymm	Demory+2013
WASP-6b	Trans	Flat+Ray	Jordan+2013
WASP-12b	Trans	Flat+Ray	Copperwheat+2013, Sing+2013
WASP-17b	Trans	Flat+noRay	Mandell+2013, Wood+2011
WASP-19b	Trans	H2O+clouds?	Huitson+2013
WASP-43b	Trans	Flat+noRay	Chen+2014
XO1-b	Trans	Flat	Deming+2013

Clouds might become our limiting factor in exoplanet characterisation.

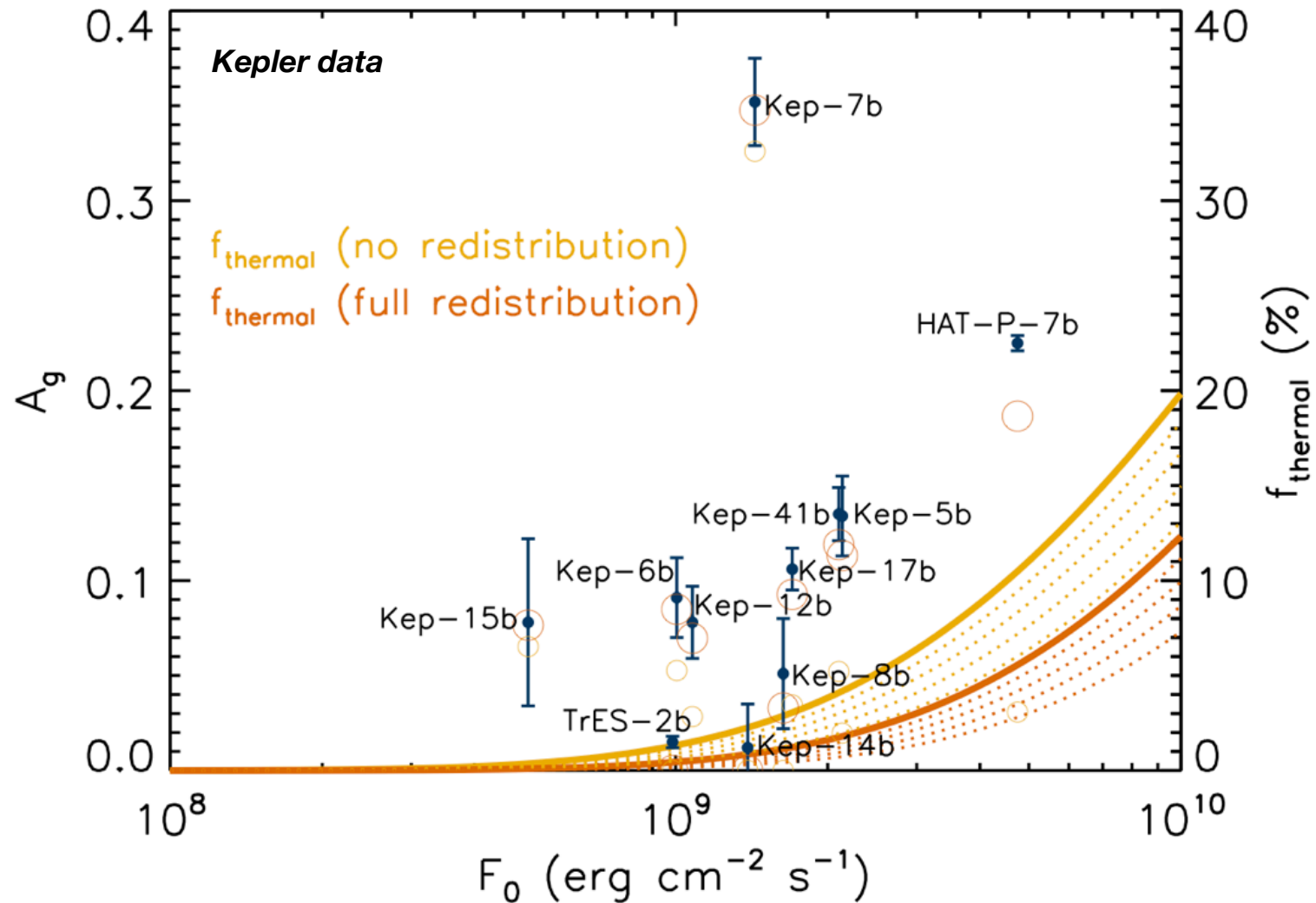
Basic properties of cloud formation



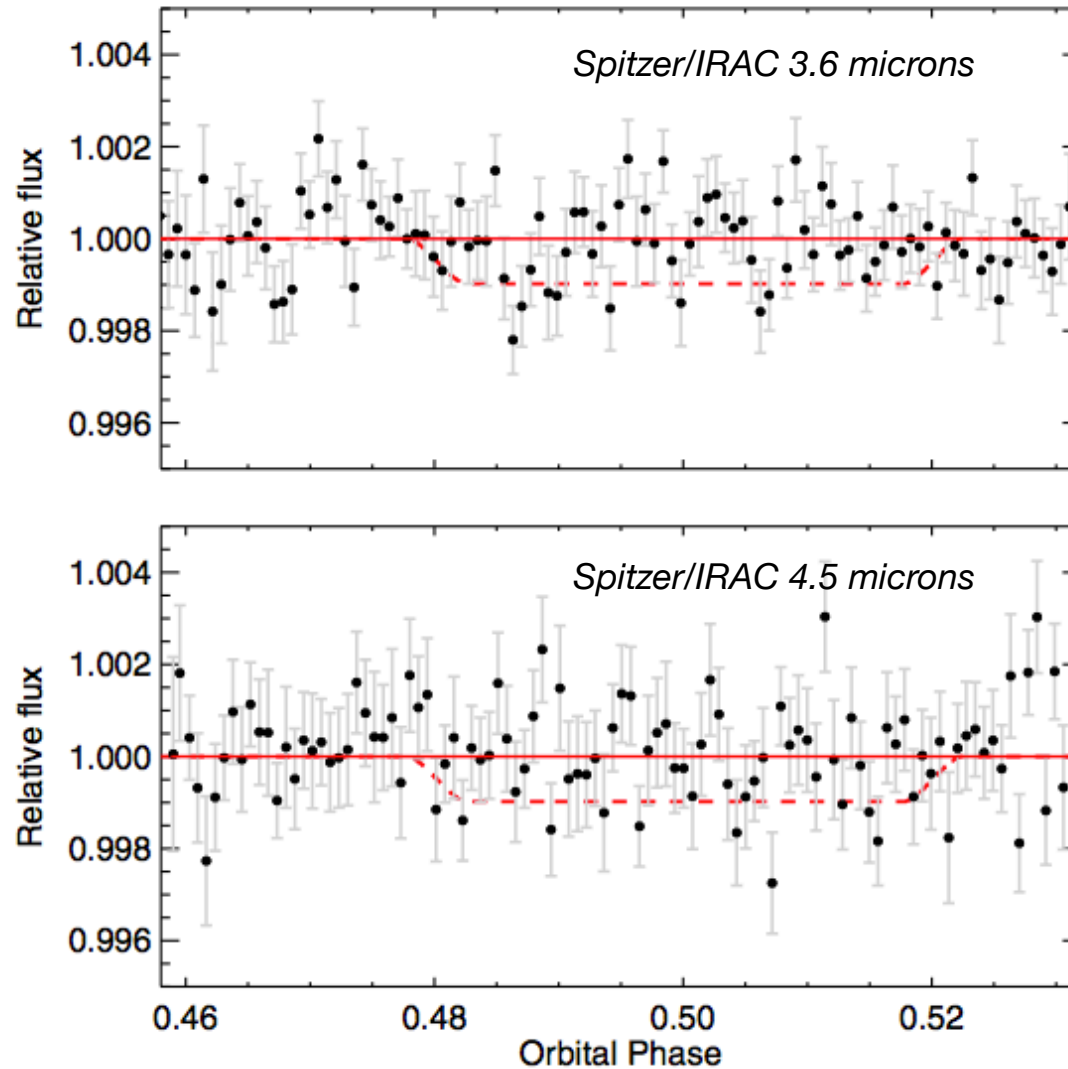
- Convective lift
- Photochemistry

Adapted from Lodders 2004

The surprisingly large albedo of Kepler-7b



Reflected light as the dominant source of A_g

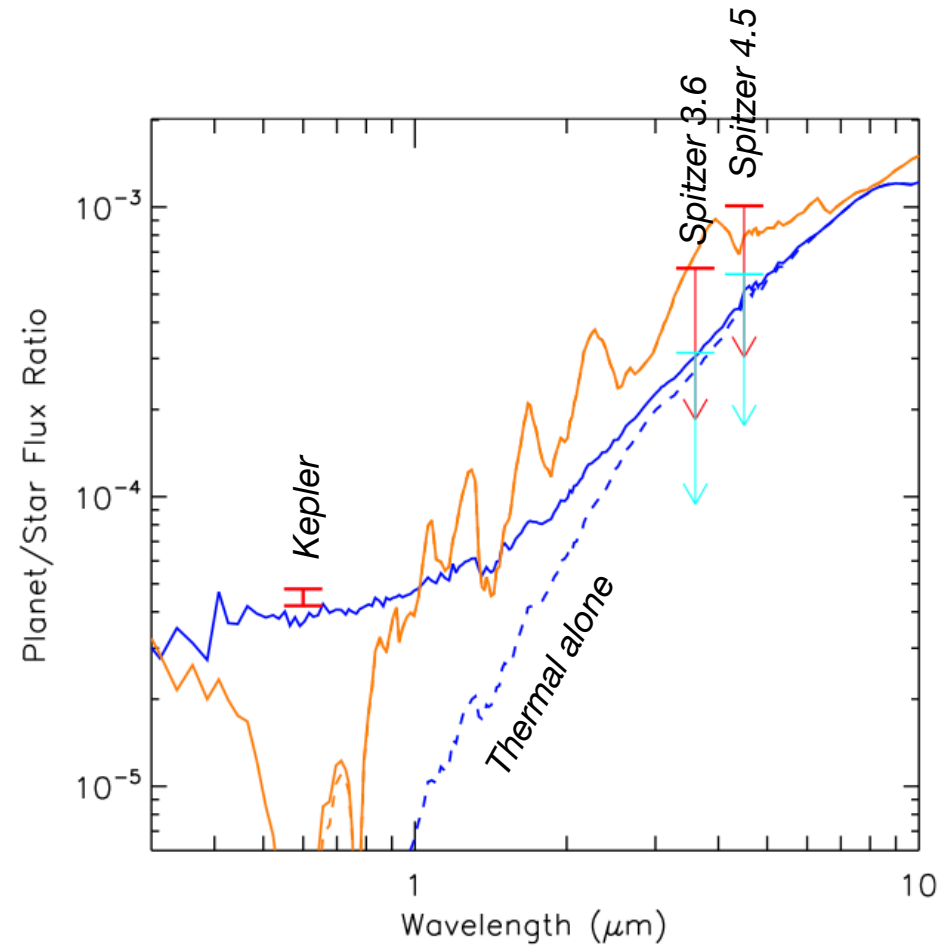
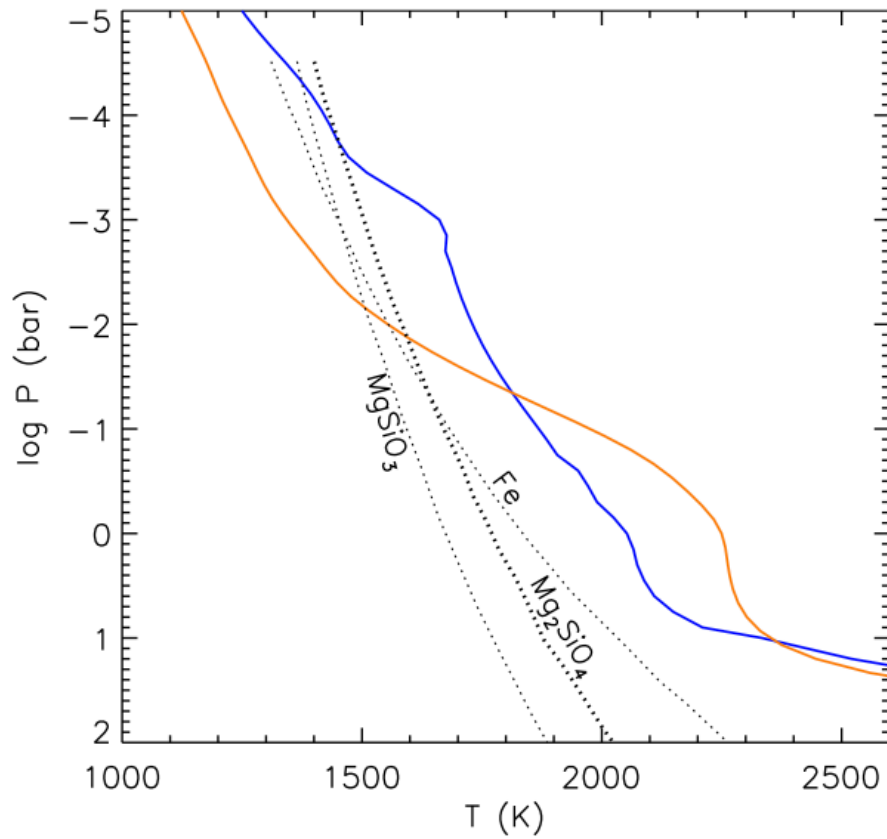


Kepler-7b

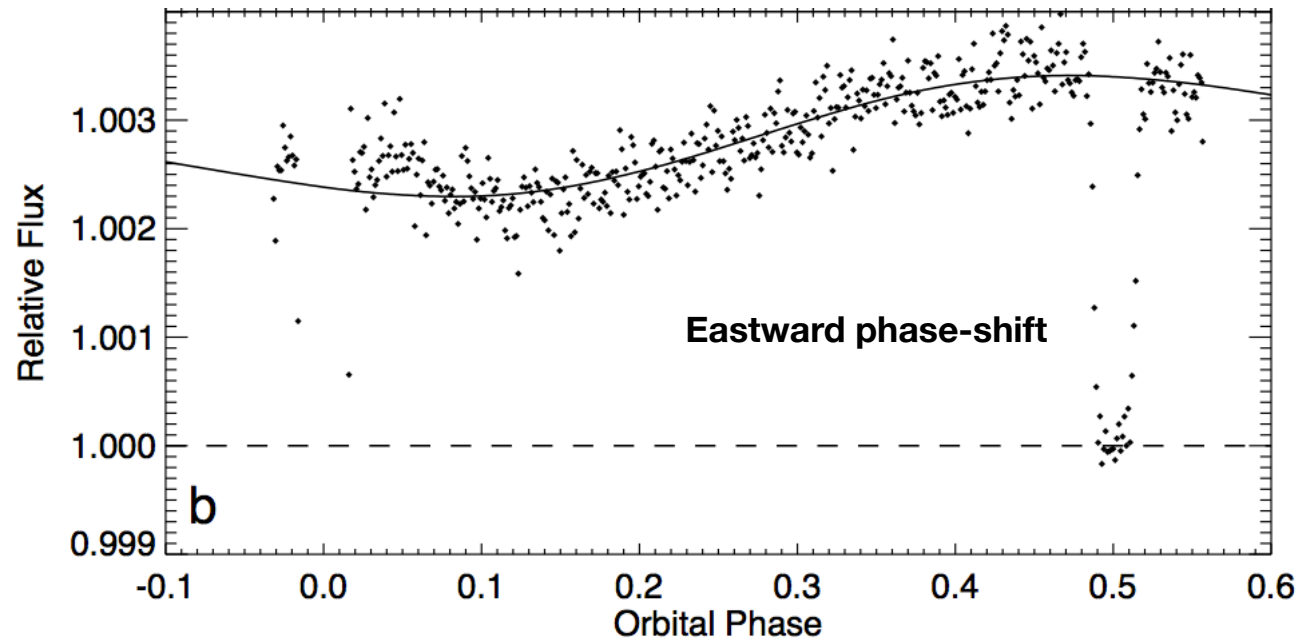
IR occultations with depths $\sim 2\text{mmag}$ were expected.

Therefore the origin of planetary light seen in the visible is not primarily of thermal origin.

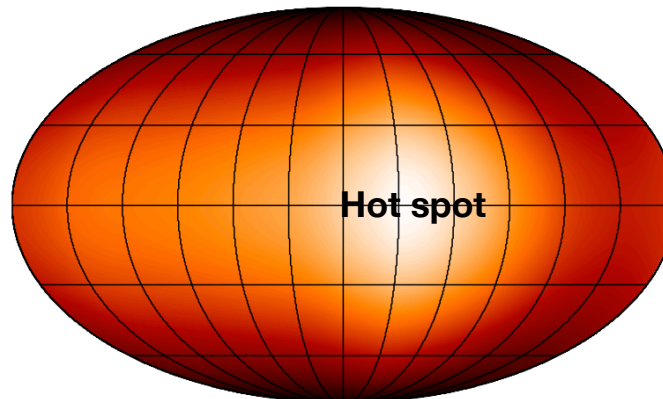
Occultations: 1D nature of clouds



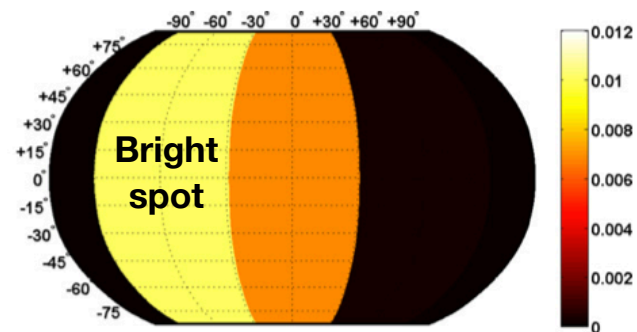
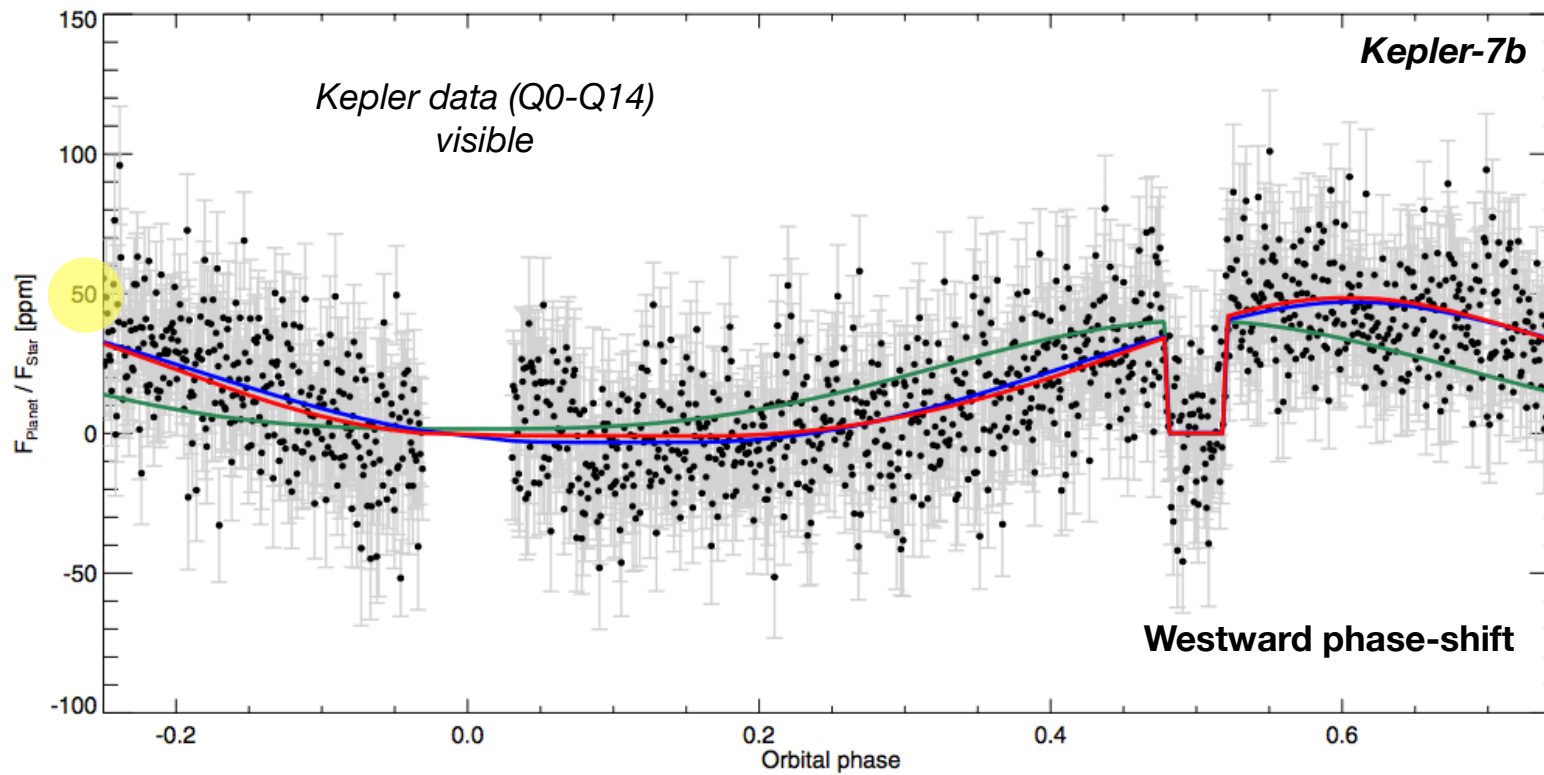
Infrared phase-curves: HD189733b



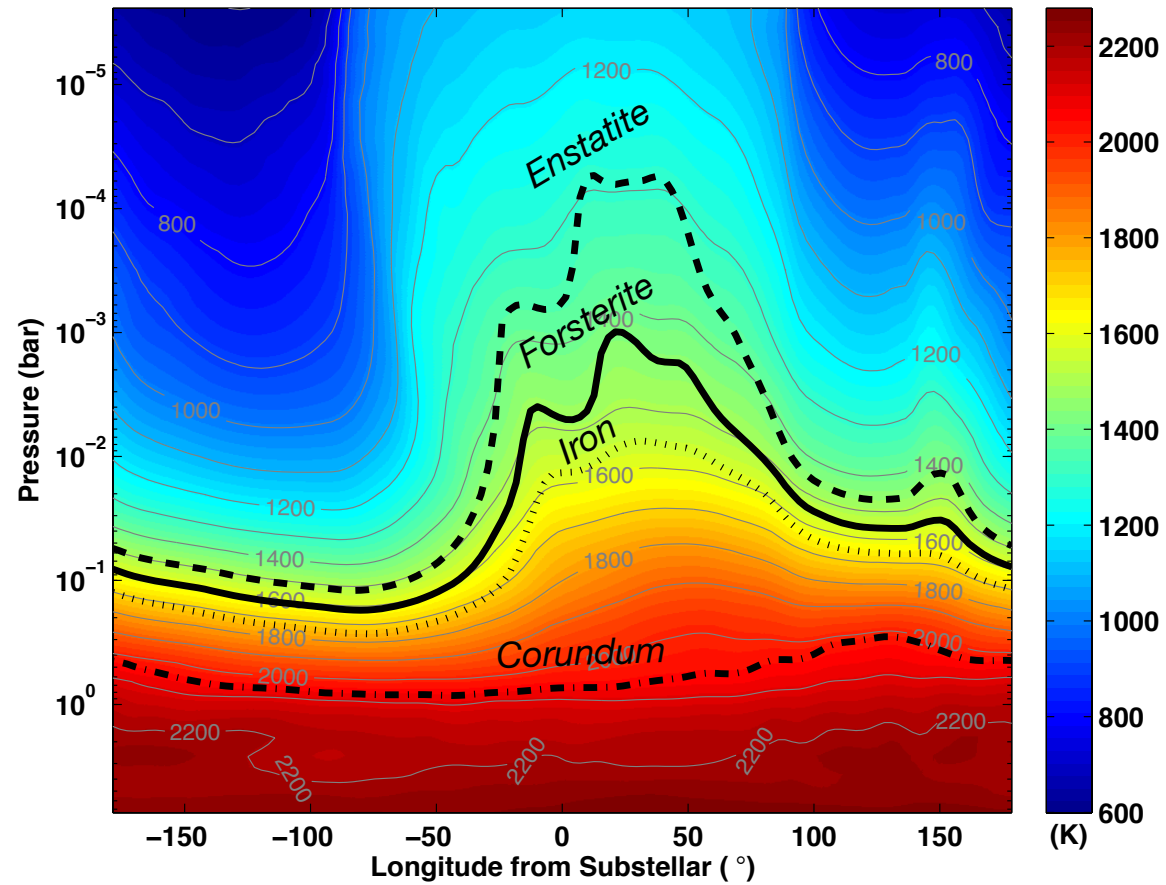
*Spitzer data
infrared (8 microns)*



Optical phase-curves: 2D cloud distribution



GCMs: toward the 3D nature of clouds

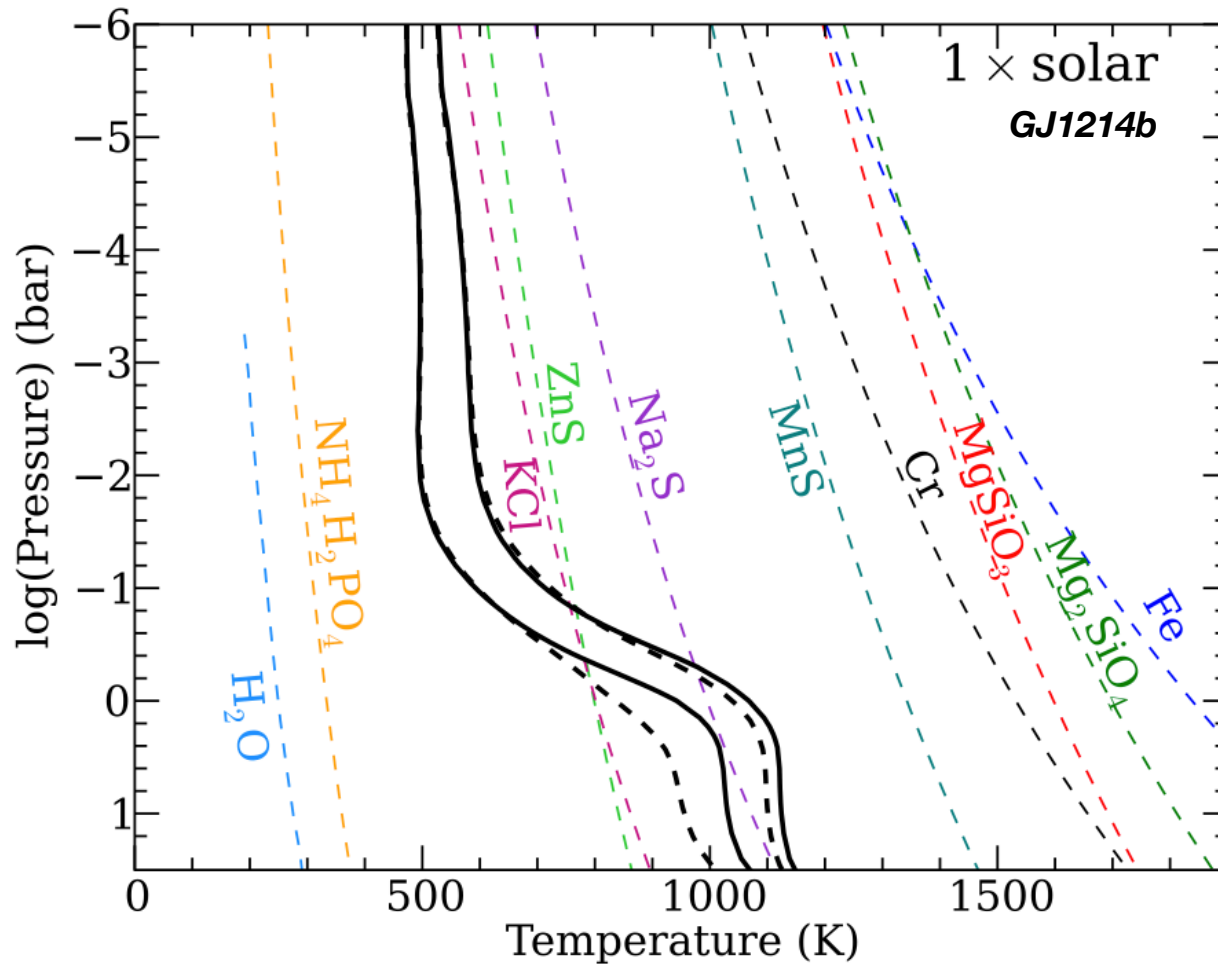


ELT: Key questions

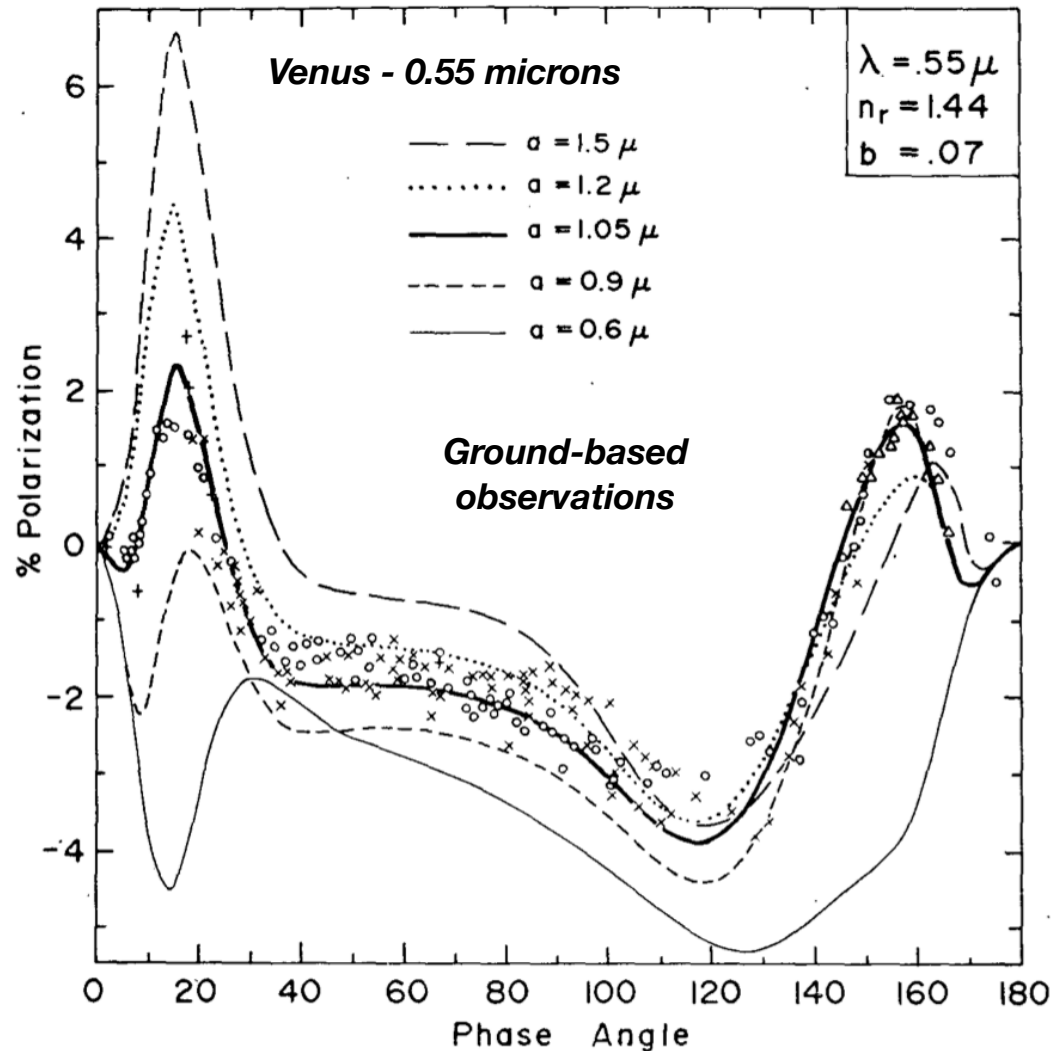
- How common are clouds on exoplanets?
- What is the range of planetary albedos?
- What are exoplanet clouds composition?

All of this for different planetary regimes, surface gravities, irradiation levels, etc.

ELT: Precise occultation photometry



ELT: the next step? polarimetry



- Refractive index and dispersion
- Particle shape
- Size distribution
- Pressure at the cloud tops

Multi-wavelength observations probably necessary to lift most degeneracies.

See also pioneering work on HD189733b (Berdyugina+2011, Wiktorowicz 2011)