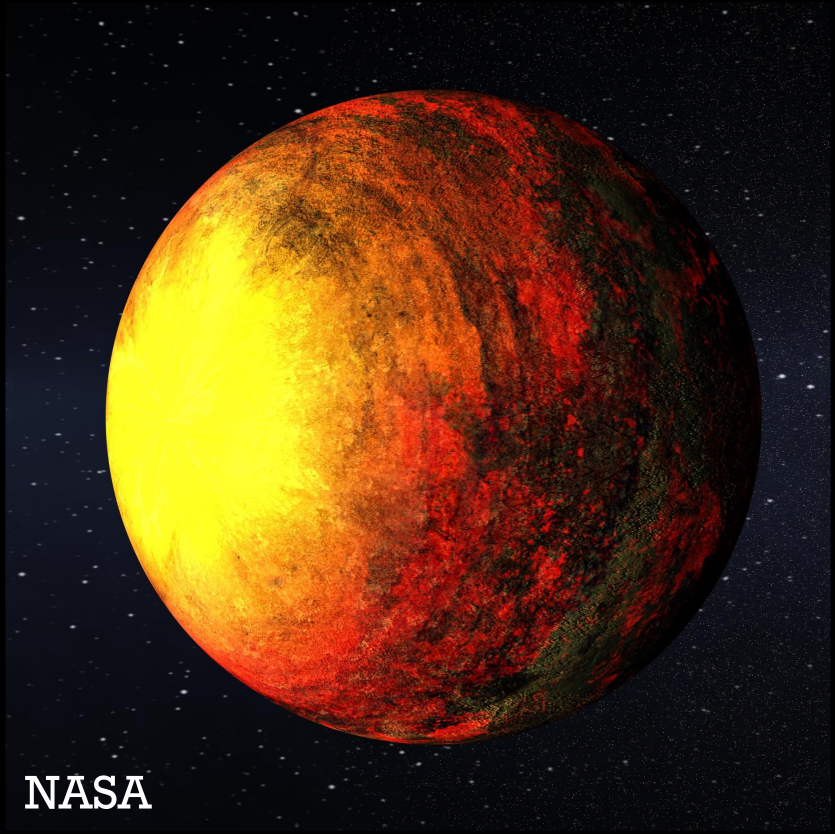
LOW ALBEDO SURFACES OF LAVA WORLDS

ZAHRA ESSACK, SARA SEAGER

TESS SCIENCE CONFERENCE I

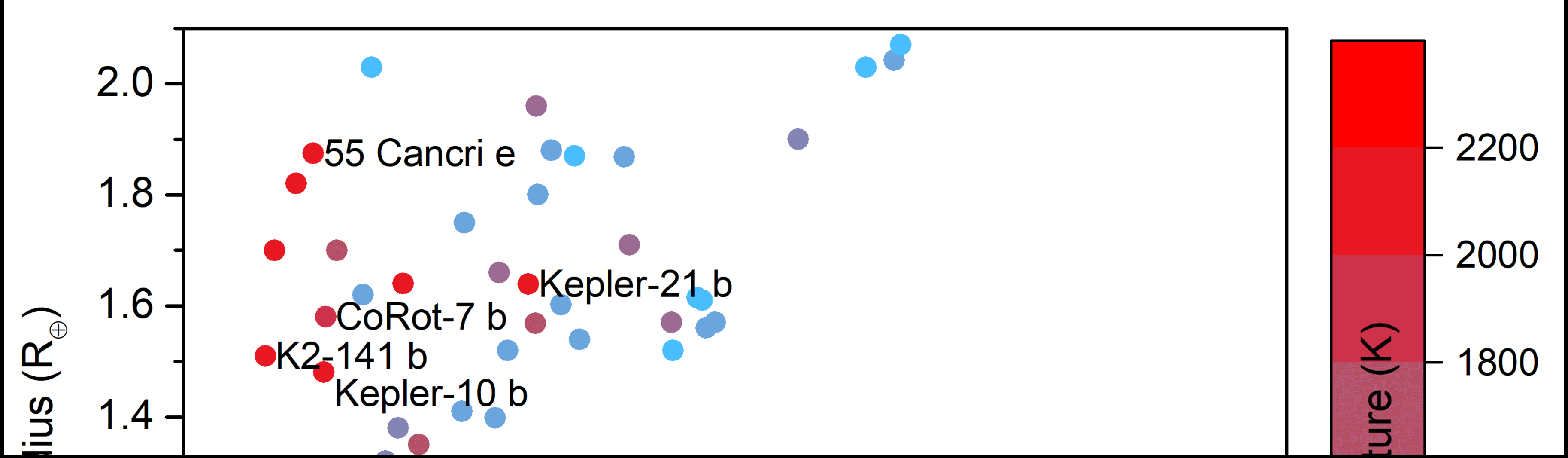
HOT SUPER EARTHS
LAVA-OCEAN EXOPLANETS

What causes the high geometric albedos on some hot super Earths?



- $R_{planet} < 1.6\ R_{earth}$
- Tidally locked
- Low pressure atmospheres (< 0.1 bar)
- Substellar temperature > 850 K
- Surface lava oceans due to intense stellar irradiation

LAVA-OCEAN EXOPLANET CANDIDATES

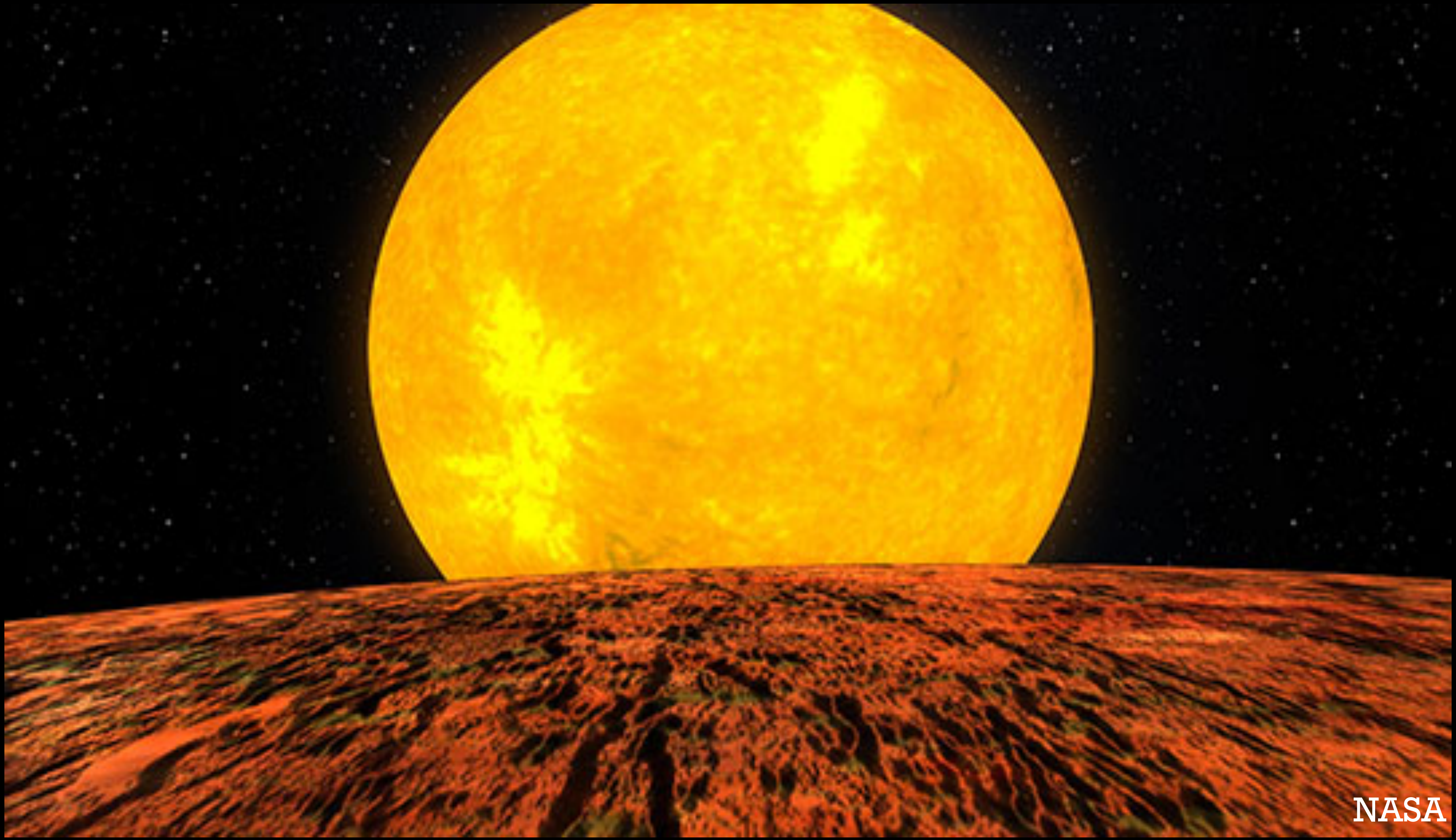


- Kepler-10 b $0.4 < A_g < 0.5$
- Kepler-21 b $0.4 < A_g < 0.5$
- K2-141 b $0.2 < A_g < 0.4$

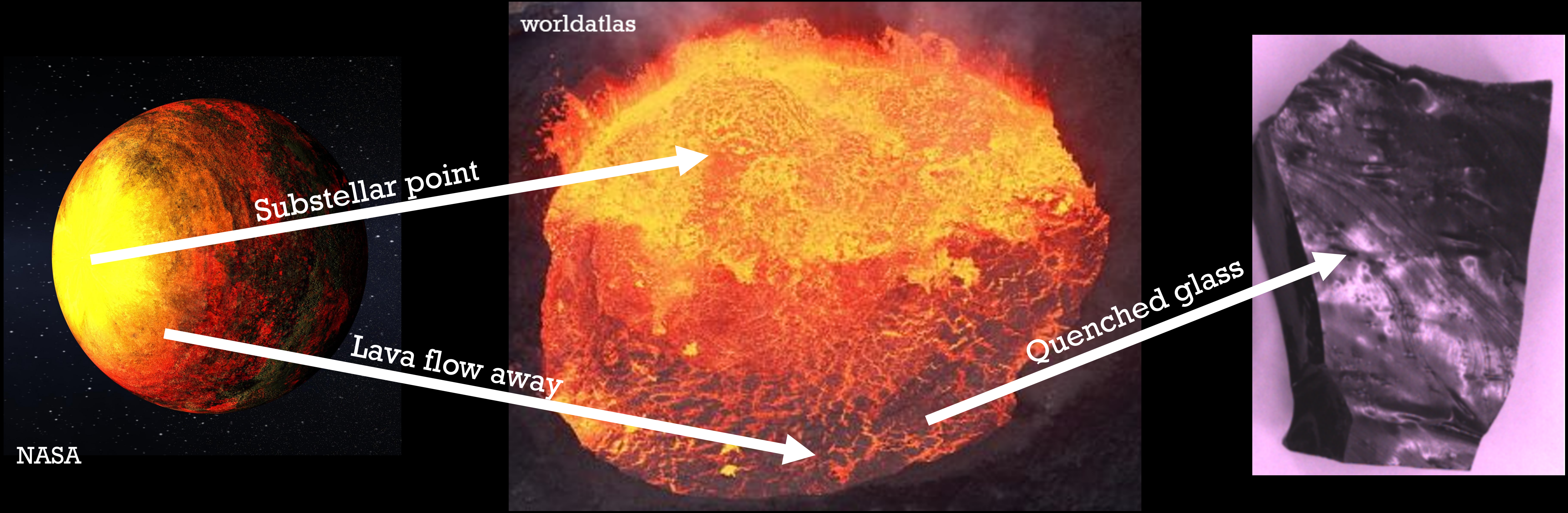
Demory (2014)

Malavolta et al. (2018)

SURFACES AS A SOURCE OF HIGH ALBEDOS



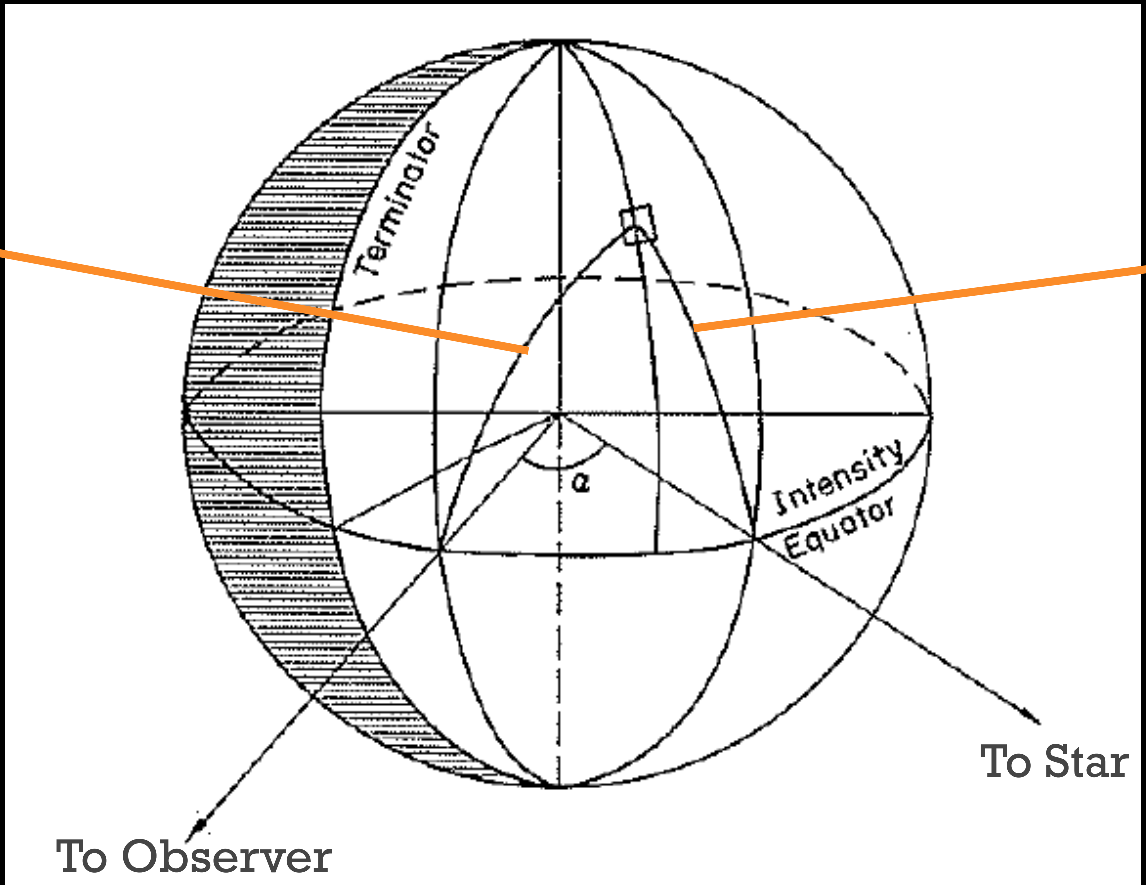
A (SIMPLE) THEORETICAL SURFACE OF A LAVA-WORLD



GEOMETRIC ALBEDO OF A PLANET

Reflected angle: η

$\cos(latitude)\cos(longitude)$



Incidence angle ζ

$\cos(latitude)\cos(longitude - \alpha)$

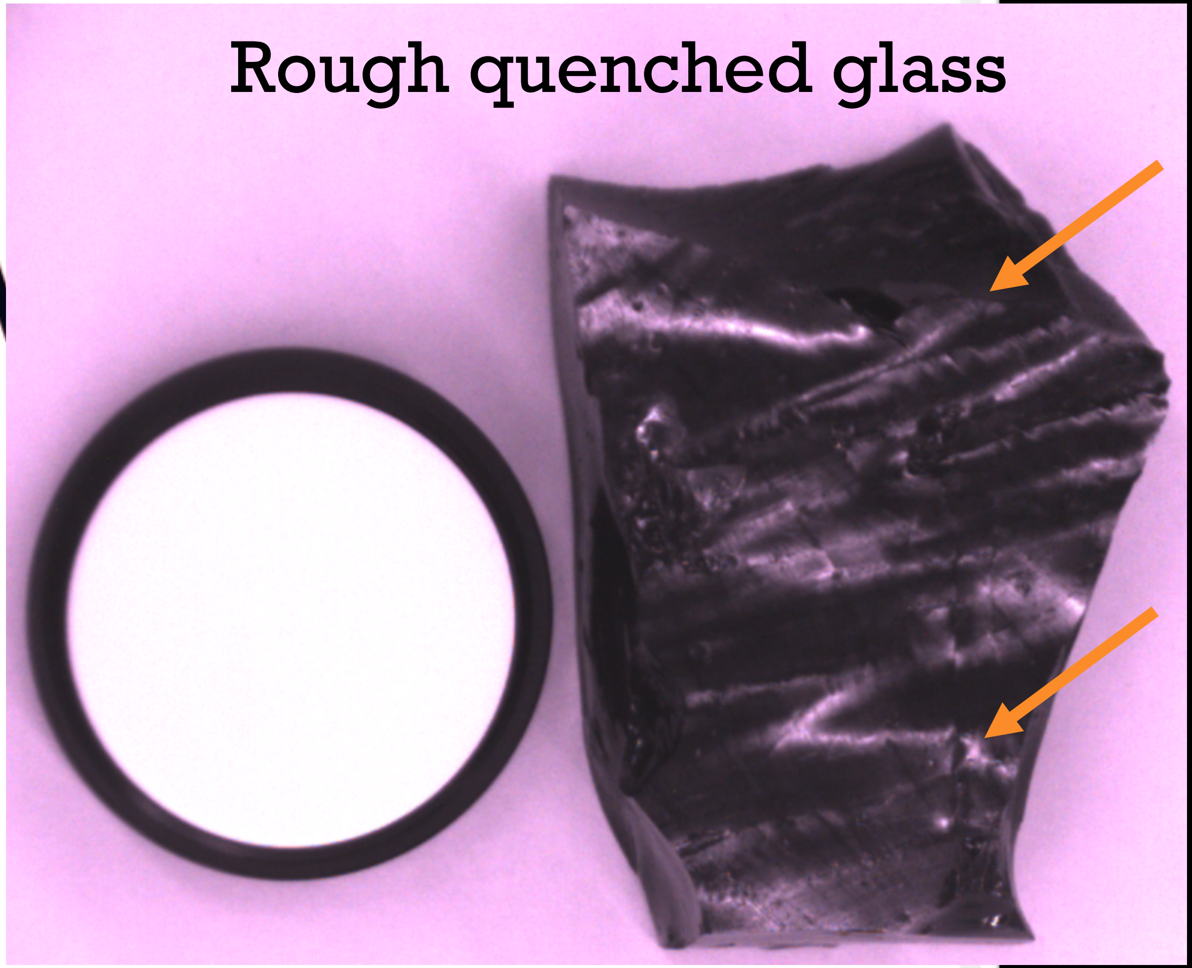
Reflection coefficient

$$\varrho(\eta, \zeta, \varphi)$$

$$A_g = 2\int_0^1 \varrho(\eta, \eta, \pi)\eta^2 d\eta$$

Sobolev, 1975

MEASURING SPECULAR REFLECTION FROM QUENCHED GLASS



Essack et al. (in prep)

SPECULAR ALBEDO VS. η (ROUGH GLASS)

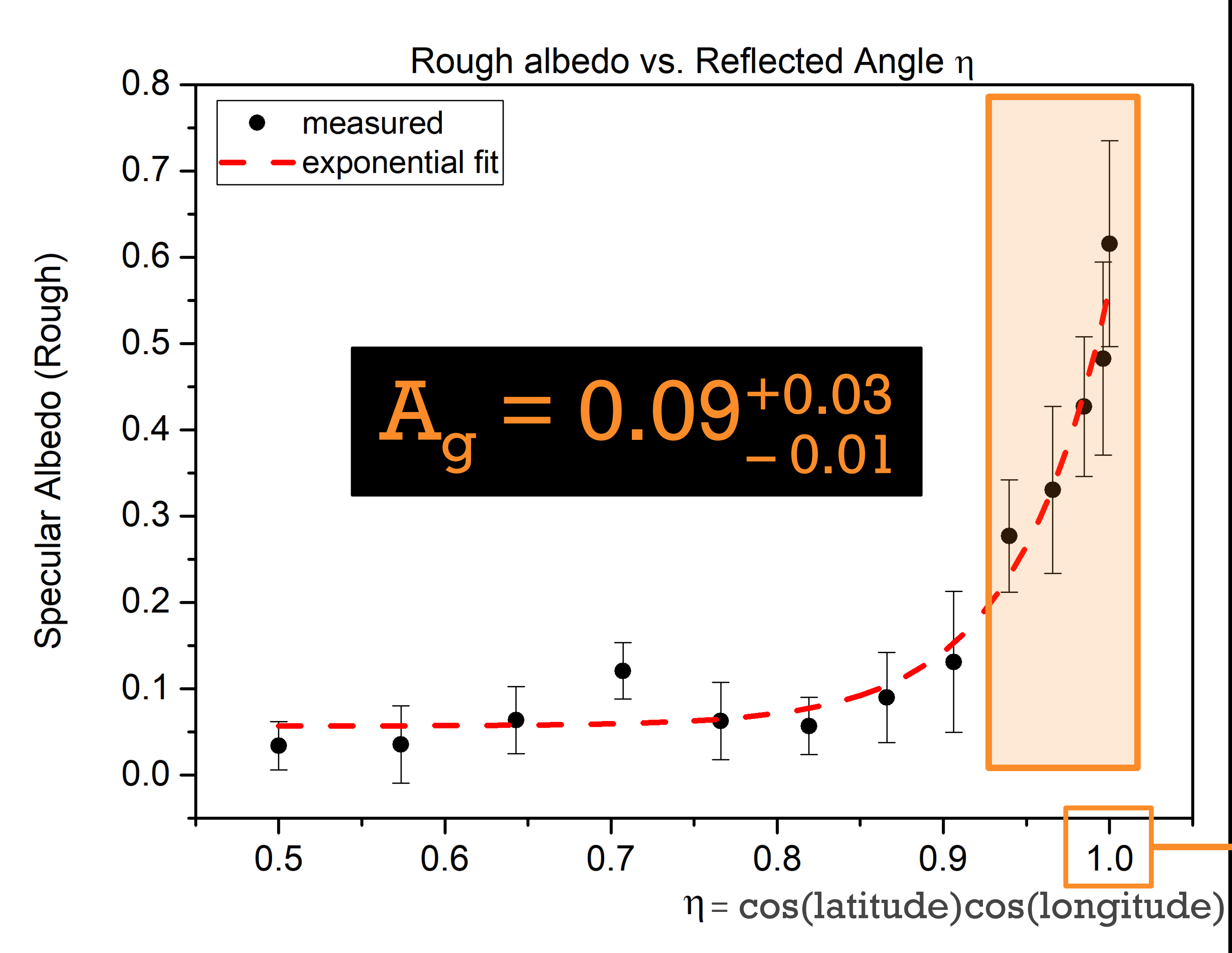
Lab measurements of reflection from quenched glass

↓

Fit data from lab measurements to get **reflection coefficient function: $\varrho(\eta, \eta, \pi)$**

↓

Integrate reflection coefficient function over all latitudes and longitudes on the planet dayside hemisphere to get **albedo: A_g**



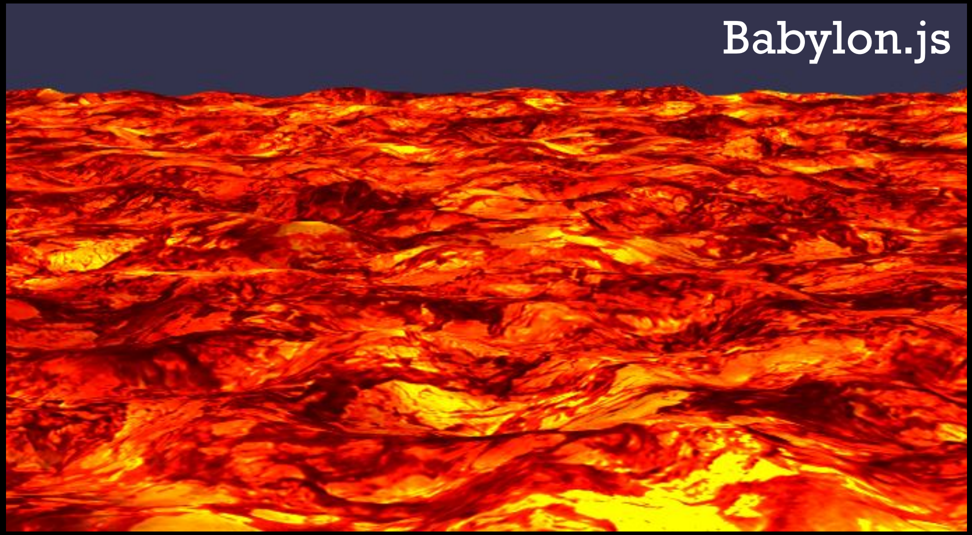
$$A_g = 0.09^{+0.03}_{-0.01}$$

Incidence Angle = Reflected Angle (η)

Substellar point

Essack et al. (in prep)

GEOMETRIC ALBEDO OF A COMBINATION LAVA-GLASS PLANET



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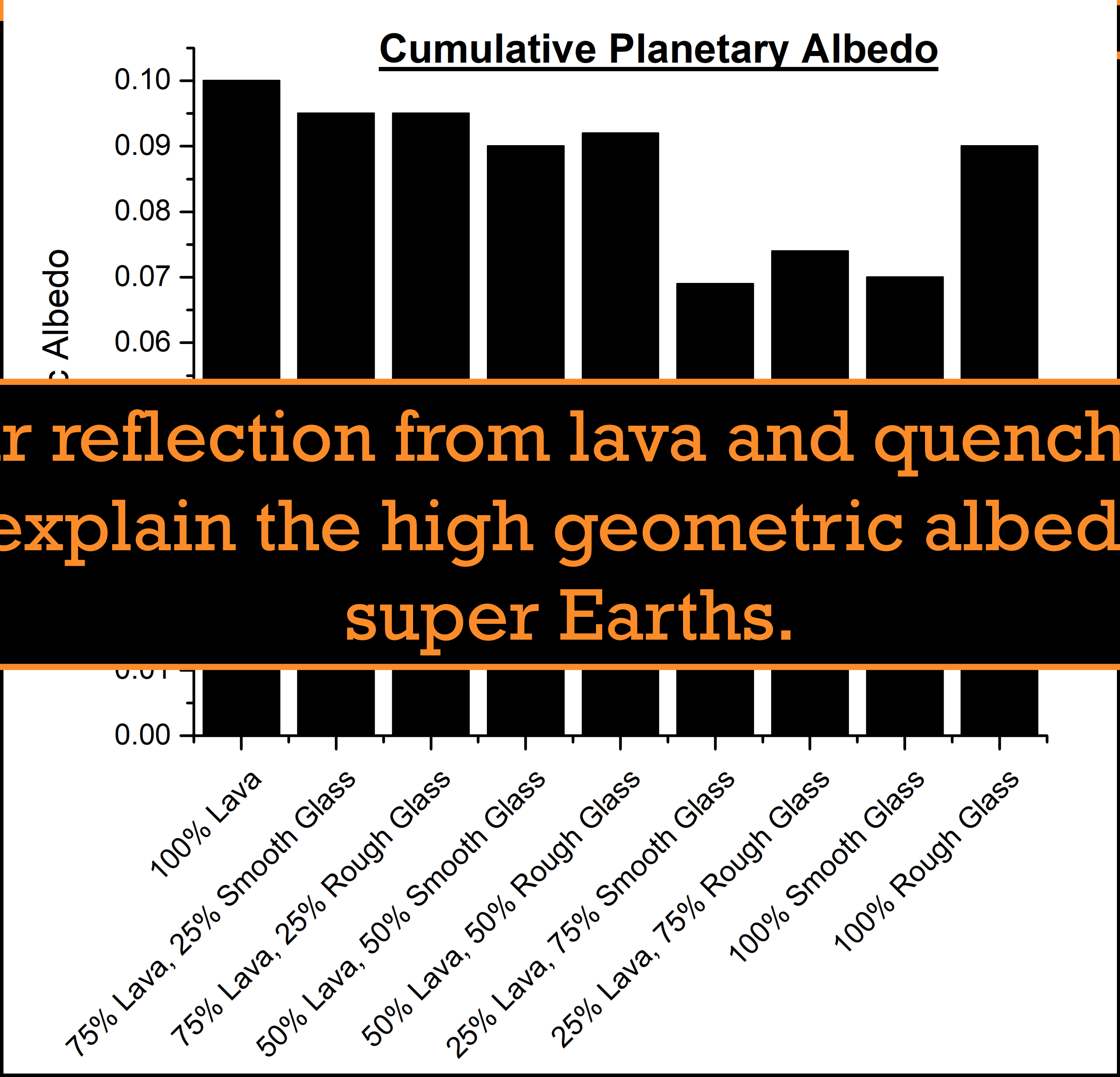
Lava: Specular reflection value from non-crystalline solids **literature.**

Quenched Glass: Specular reflection values measured **experimentally.**

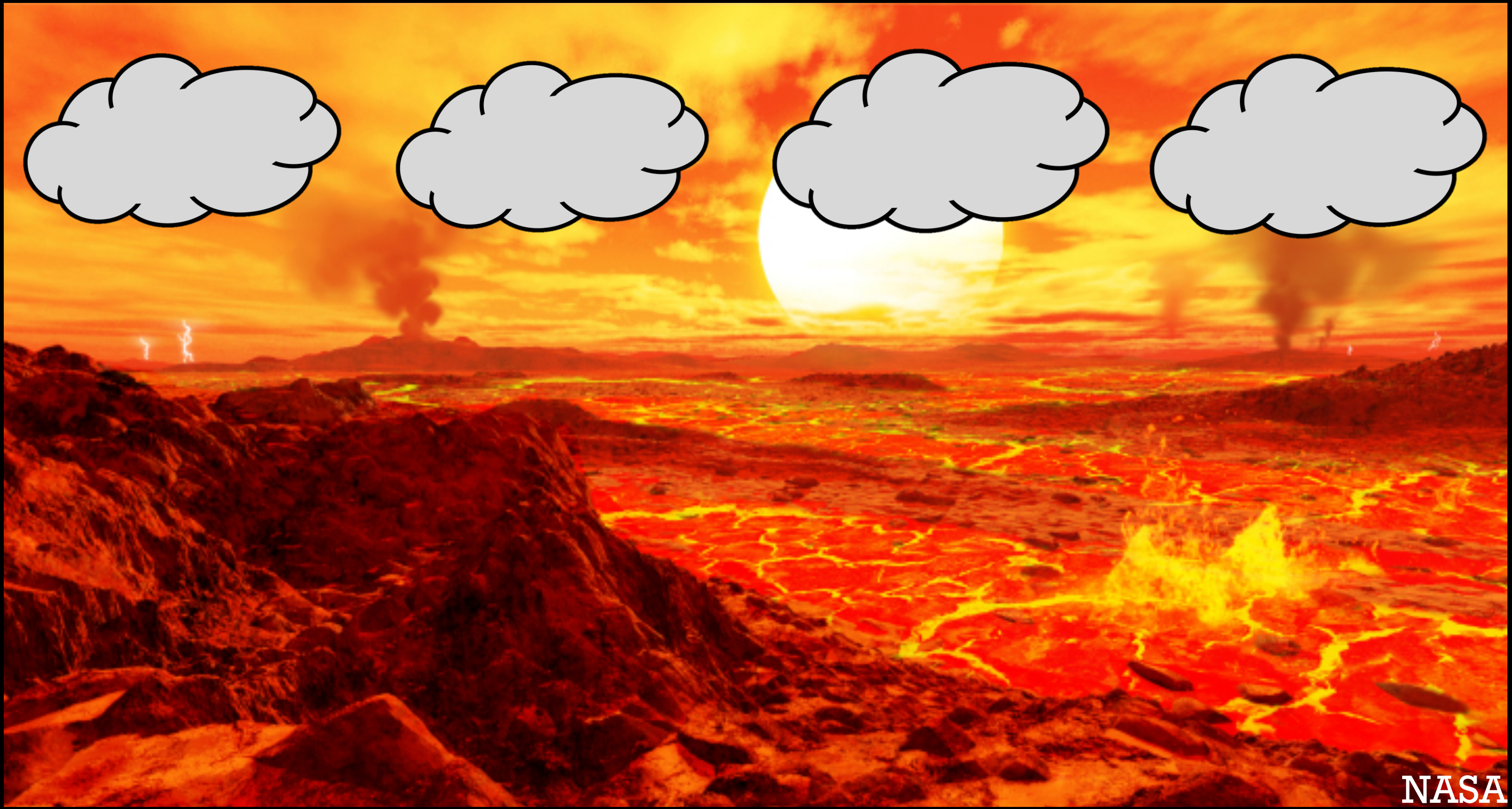
GEOMET… INATION



Specular reflection from lava and quenched glass cannot explain the high geometric albedos of hot super Earths.

Essack et al. (in prep)

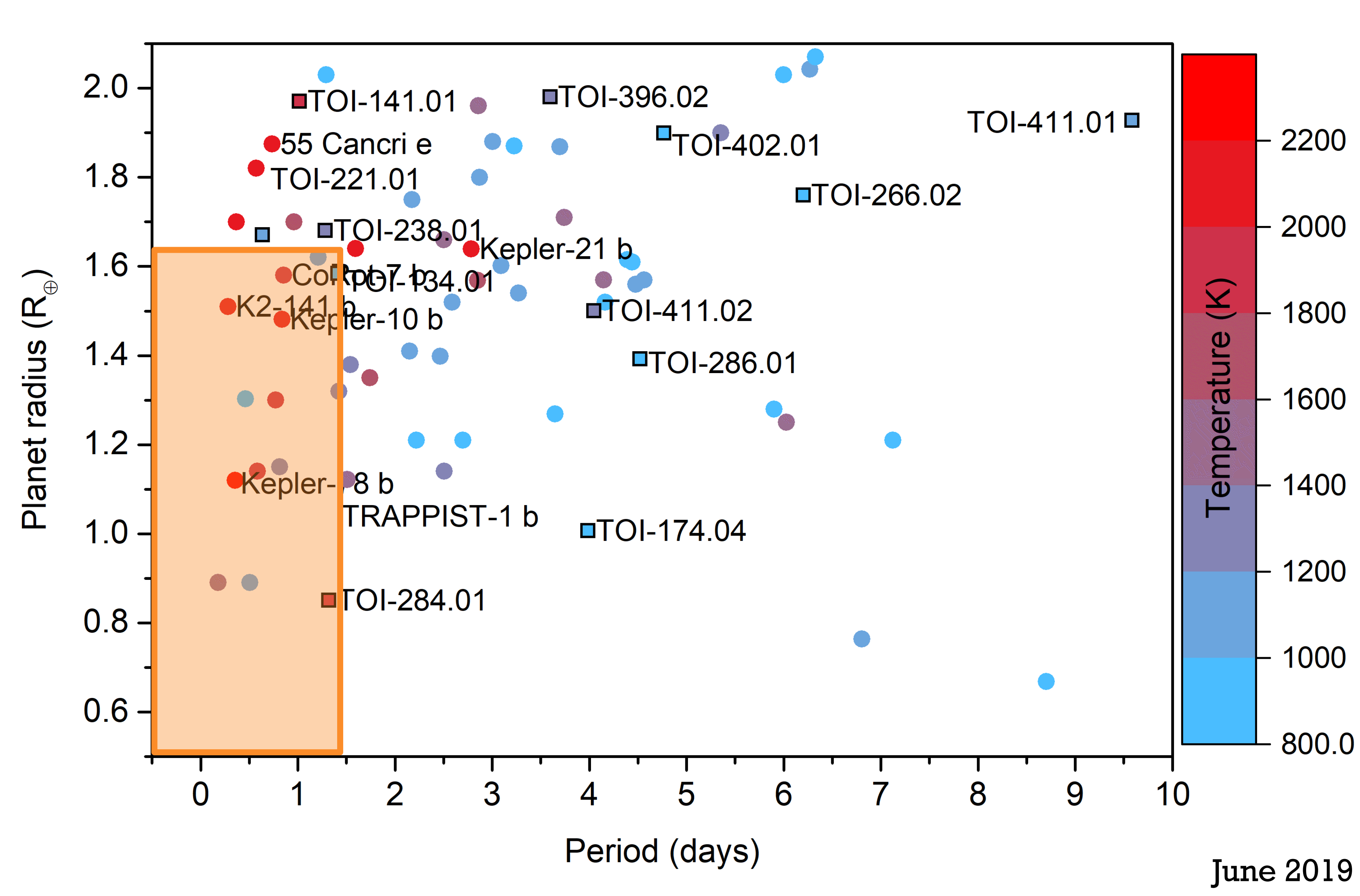
REFLECTION FROM ATMOSPHERES



Combining results from Zebger et al. (2005); Hu et al. (2012).

FUTURE WORK: MEASURING THE ALBEDO OF LAVA

FUTURE WORK: LAVA WORLDS FROM TESS

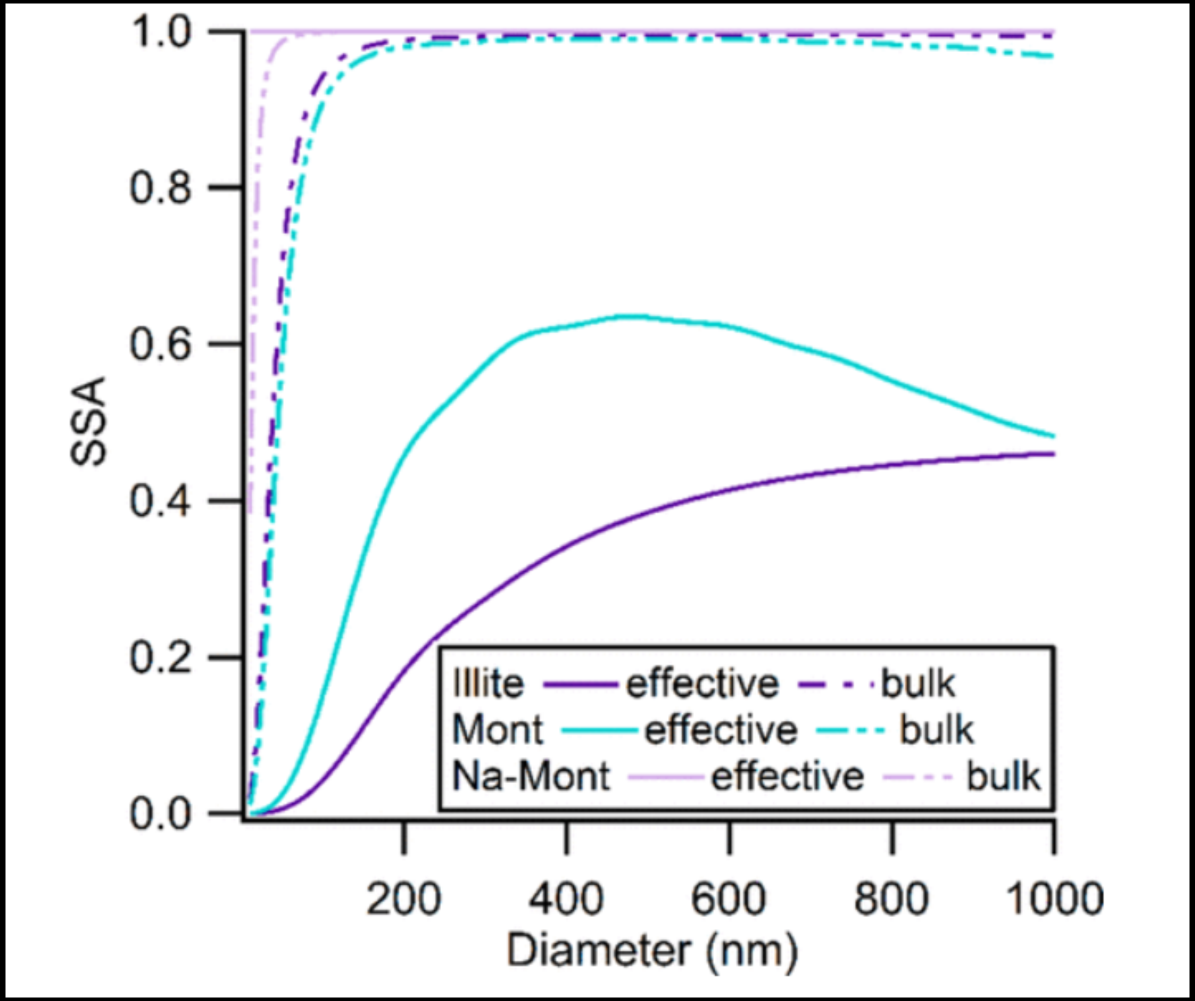


CONCLUSION

- Lava worlds with solid (quenched glass) or liquid (lava) surfaces have low specular albedos (< 0.1), and hence a negligible contribution to the high geometric albedos of some hot super Earths.
- The high geometric albedos of hot super Earths are likely explained by atmospheres with reflective clouds.
- Validating and characterizing lava planet candidates from TESS will allow us to better understand their atmospheres, surfaces, and other properties.

ADDITIONAL SLIDES

HIGH ALBEDO SURFACE MATERIALS

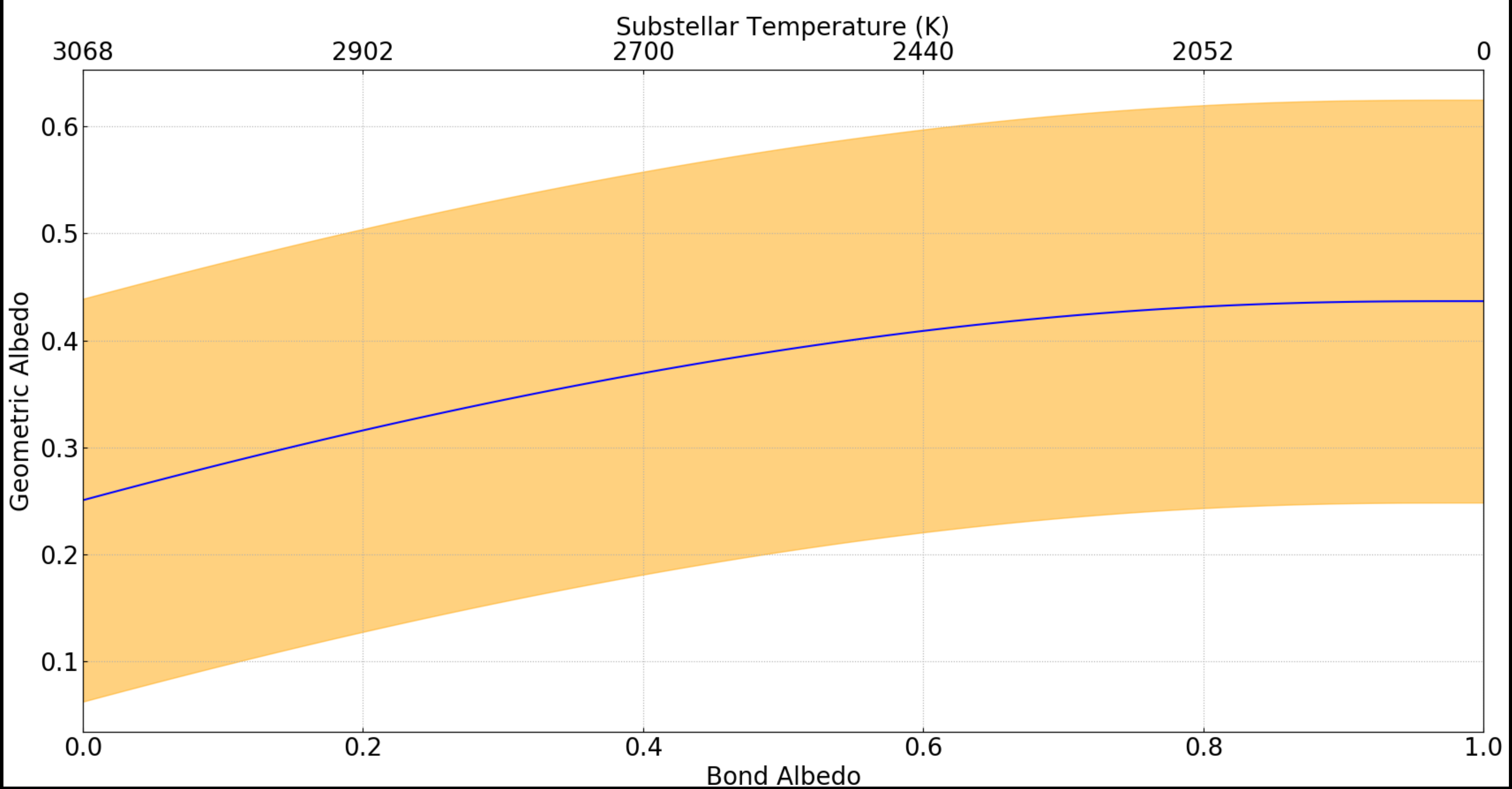


Clay minerals
(illite, kaolinite, montmorillonite)

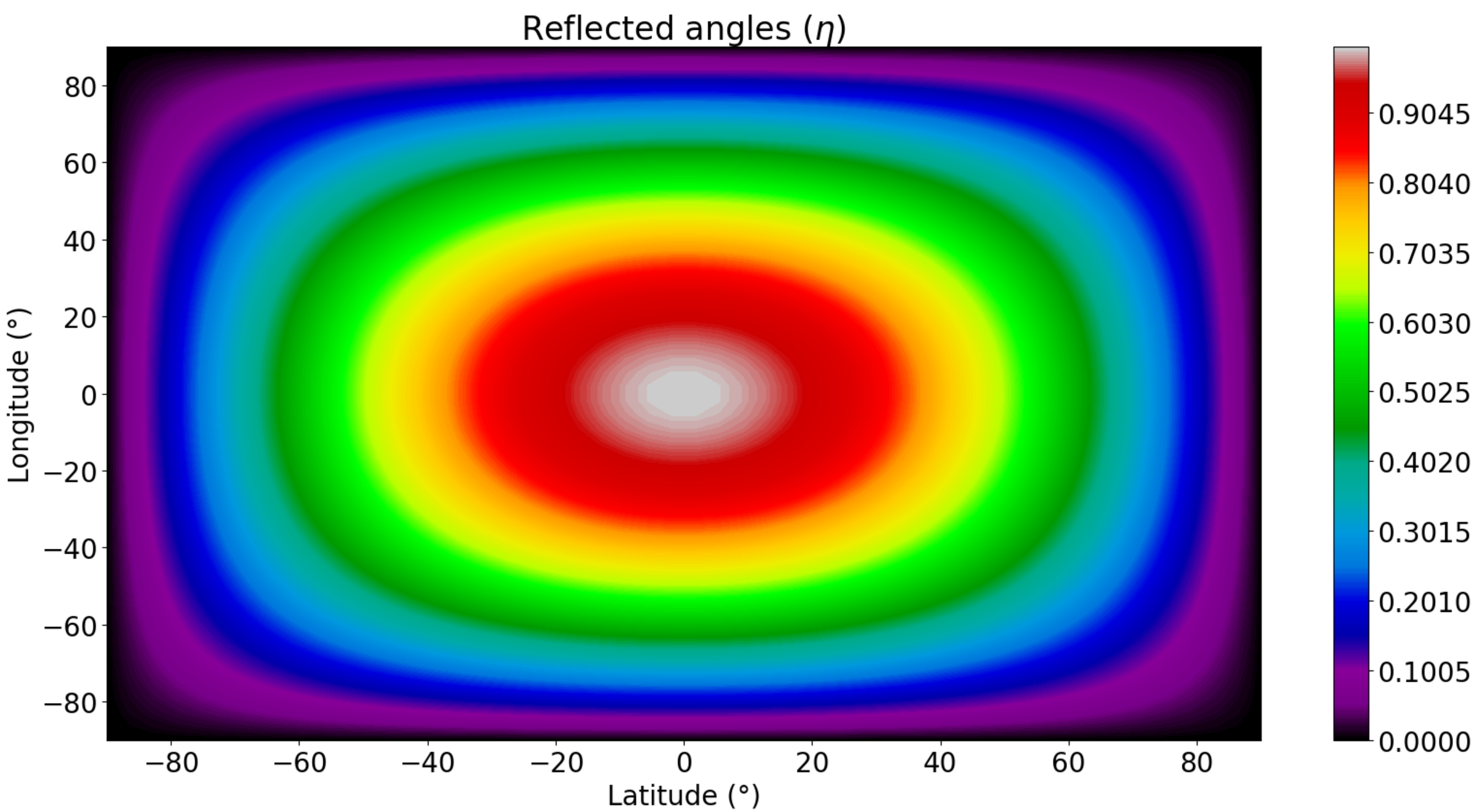
Rouan et al. (2011); Morang et al. (2018)

SECONDARY ECLIPSE DEPTH DEGENERACY

KEPLER-10 b



GEOMETRIC ALBEDO OF A COMBINATION LAVA-GLASS PLANET

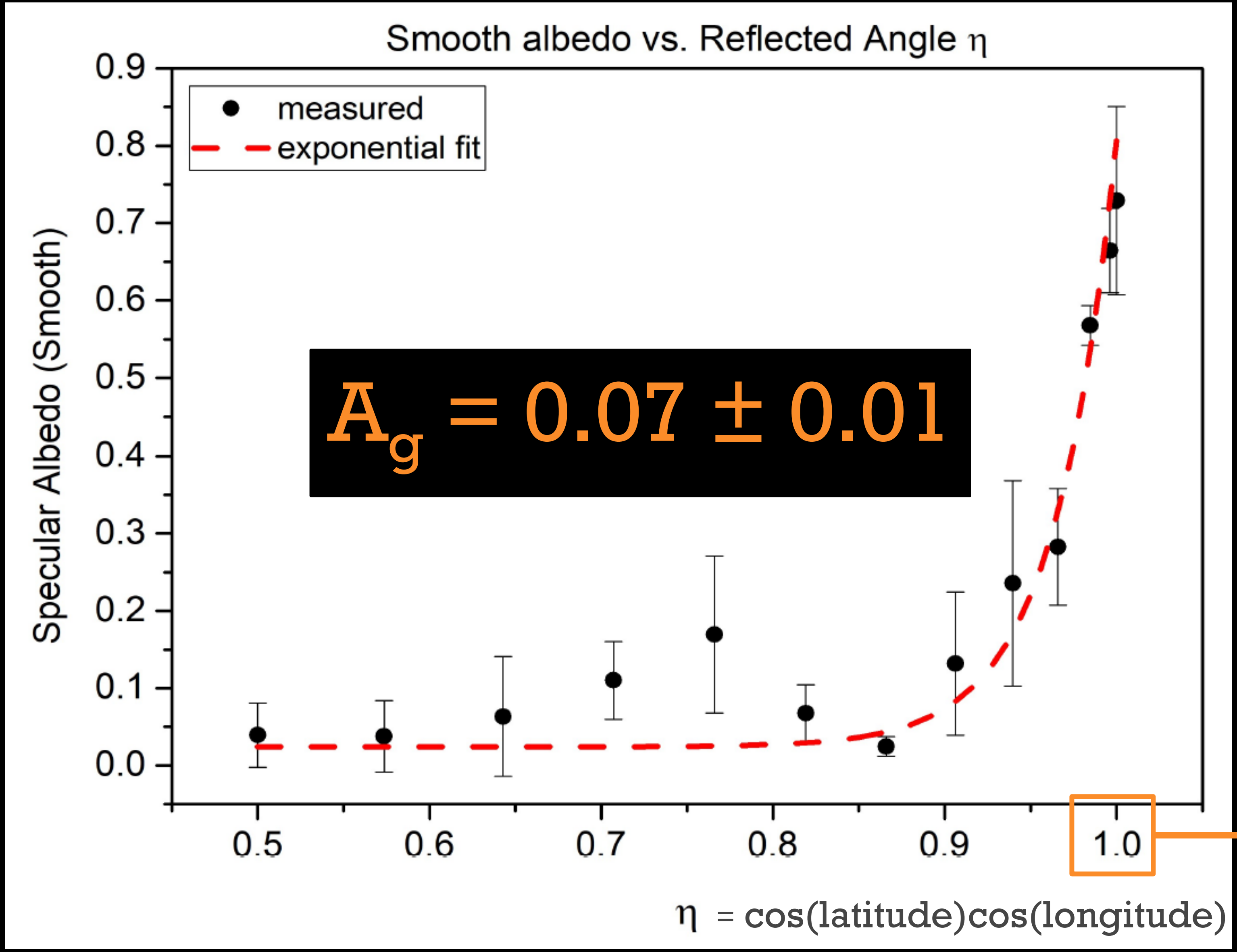


SPECULAR ALBEDO VS. η (SMOOTH GLASS)

Lab measurements of reflection from quenched glass

Fit data from lab measurements to get **reflection coefficient function: $\varrho(\eta, \eta, \pi)$**

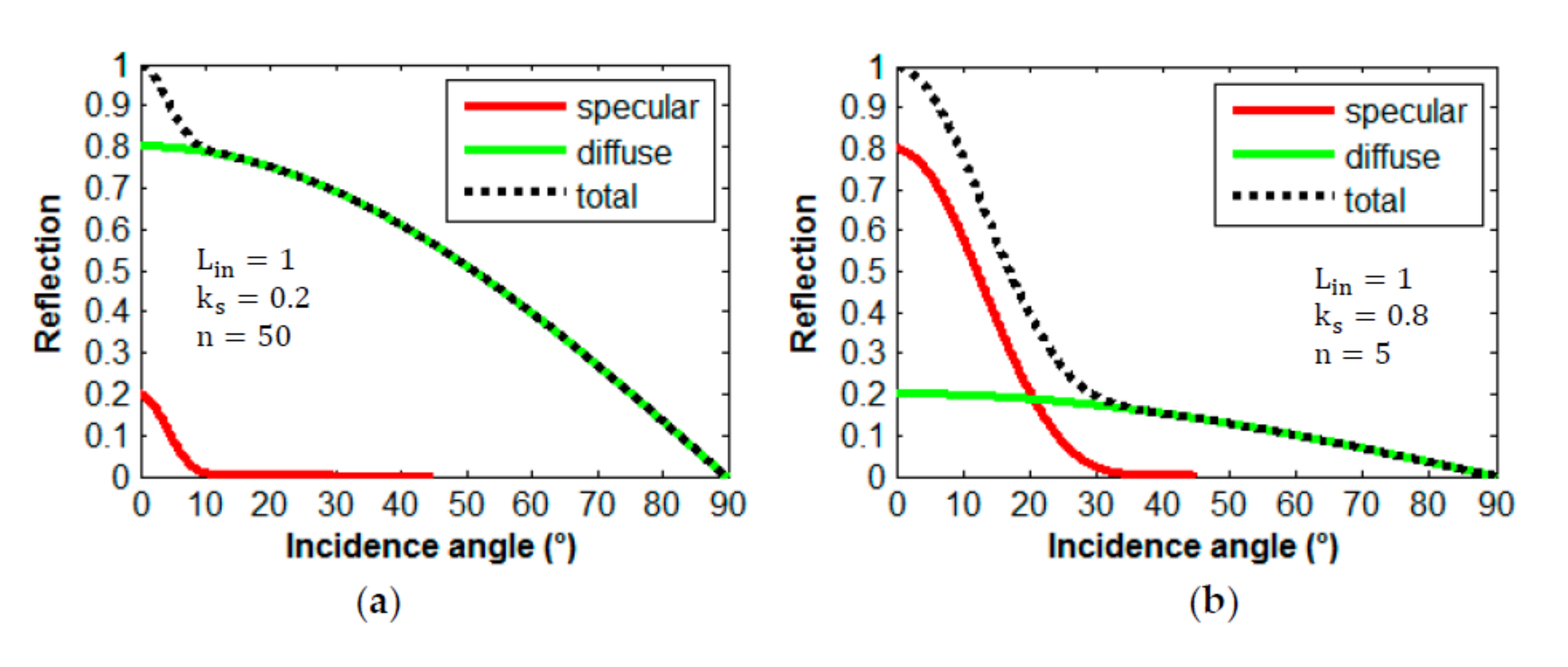
Integrate reflection coefficient function over all latitudes and longitudes on the planet dayside hemisphere to get **albedo: A_g**



Incidence Angle = Reflected Angle (η)

Substellar point

EXPONENTIAL MODEL FIT: MOTIVATION



$$I_{out} = I_{in}[(1 - k_s)\cos\theta + k_s \cos^n(2\theta)]$$