

A Wide Variety of Habitable Planets

Takanori Sasaki (Tokyo Tech)

A Wide Variety of Habitable Planets

≡ “Diversity of habitable planets” by D. Lin

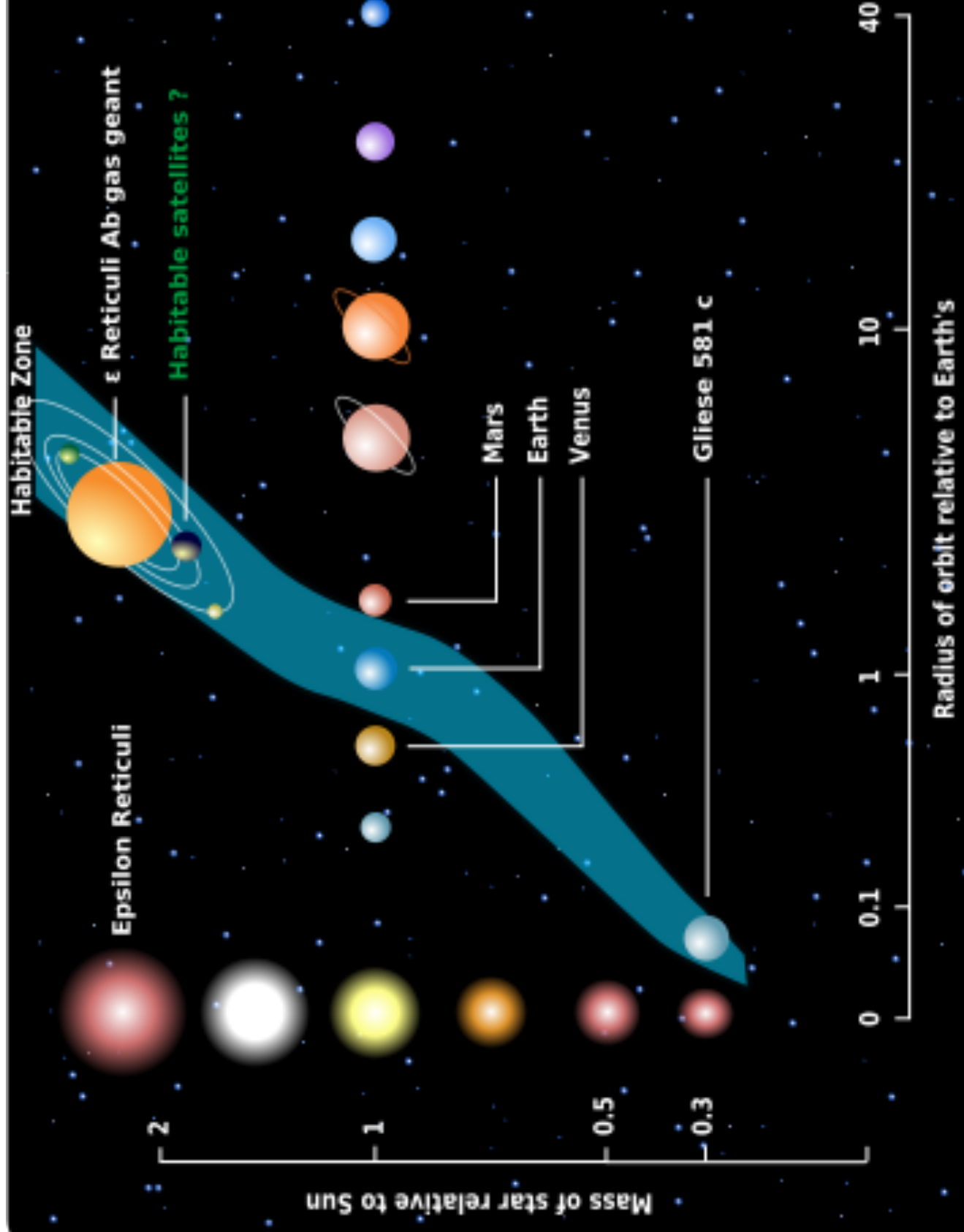
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Amount of Water to be Habitable

~~**A Wide Variety of Habitable Planets**~~

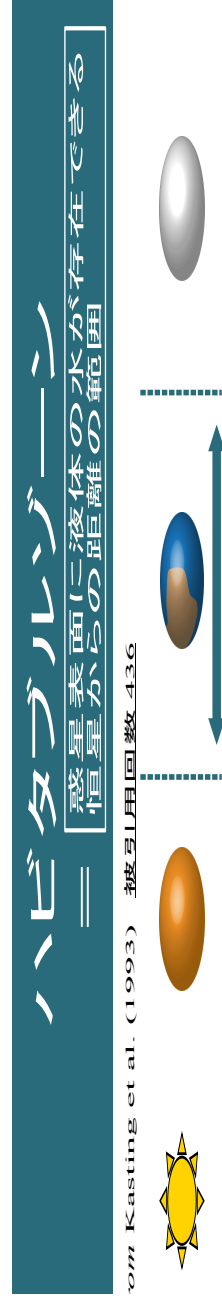
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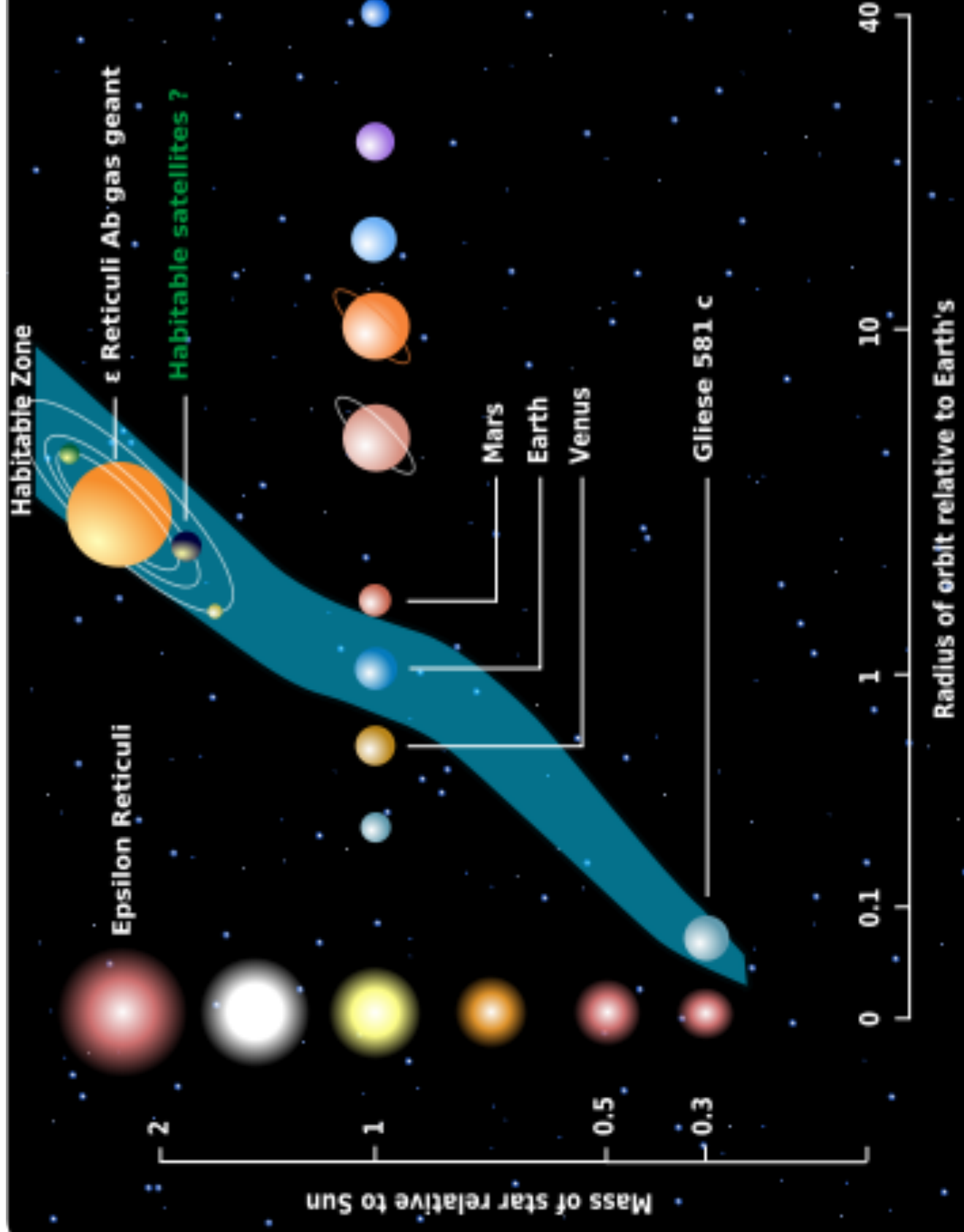
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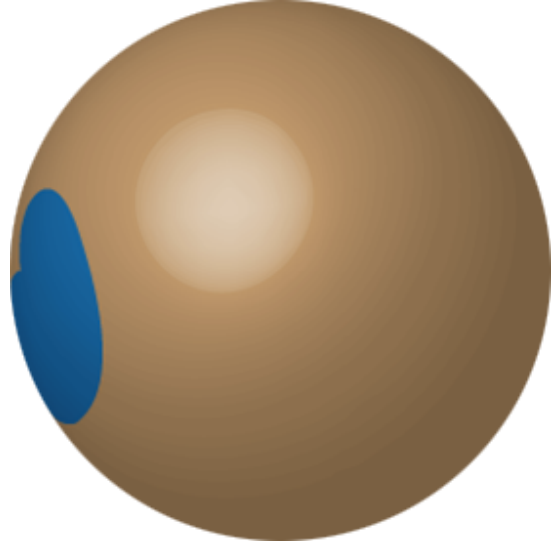
H.Z. for Ocean Planets

- Inner edge of habitable zone
runaway greenhouse limit: **0.84AU**@present S.S.
[Kasting 1988; Nakajima et al. 1992]
- Outer edge of habitable zone
Forming CO₂ clouds: **1.37AU** [Kasting 1993]





3 Types of Water Planets



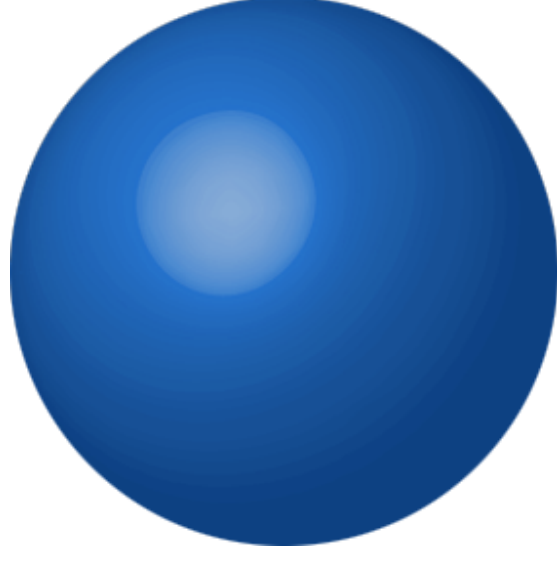
“Land Planet”

unconnected lakes
on a land



“Aqua Planet”

connected oceans
and lands



“Ocean Planet”

an ocean
without lands

H.Z. for Land Planets

- Inner edge of habitable zone
 - Dry low latitude can emit above the “critical flux”
 - Runaway greenhouse limit of solar flux is larger
- Outer edge of habitable zone
 - Lower albedo by smaller area of ice and cloud
 - Freezing limit of solar flux is smaller

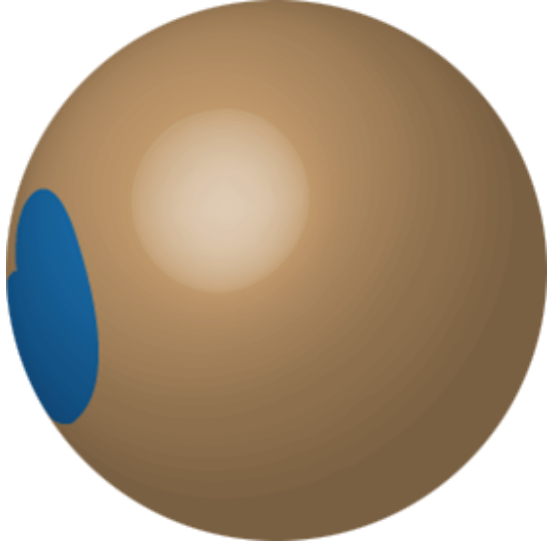
H.Z. is wider for “land planets” than “aqua planets”

[Abe et al. 2011]

C.H.Z. for Various

Planets

= the region in which liquid water can exist over the lifetime of a host star



“Land Planet”

~0.73-1.3AU

[Abe et al. 2011]



“Aqua Planet”

0.9-1.1AU

[e.g., Kasting et al.
1993]



“Ocean Planet”

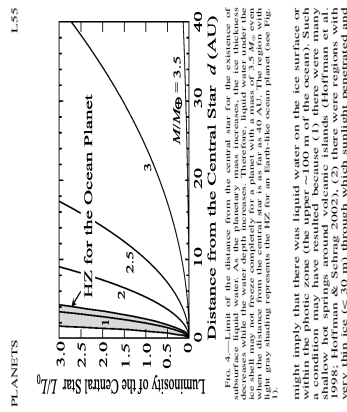
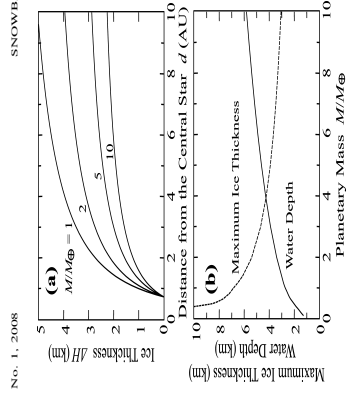
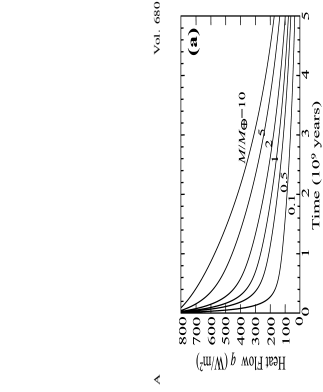
Evolution of H.P.



[Kodama, Genda & Abe, in

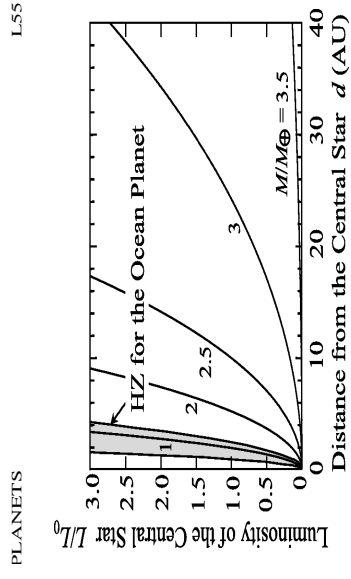
Habitable Snowball Planets

Snowball planets could have an **internal ocean** with geothermal heat flow from the planetary interior



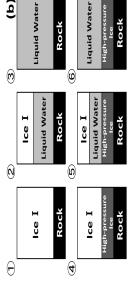
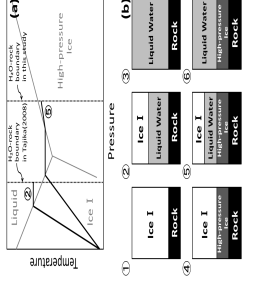
[Tajika 2008]

H.Z. for Snowball Planets

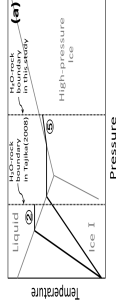


[Tajika 2008]

High-pressure Ice



- High-pressure ices appear if the planet has **larger amount of water** than the Earth
- High-pressure ices are **denser** than liquid water



S.P. w/ High-pressure Ice

$$M_{\text{water}} = 5 \times 0.023 \text{ wt.}\%$$

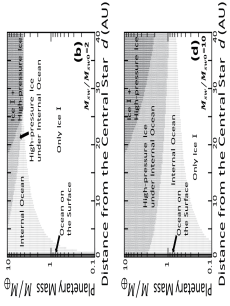
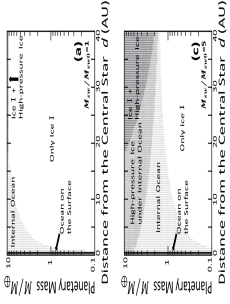


Habitable?



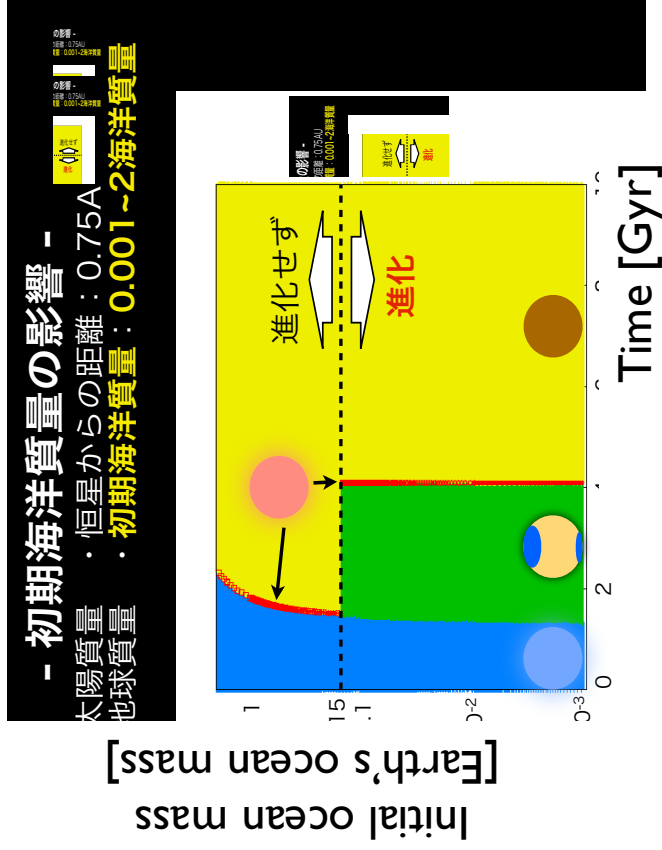
- 25 -

Not Habitable?

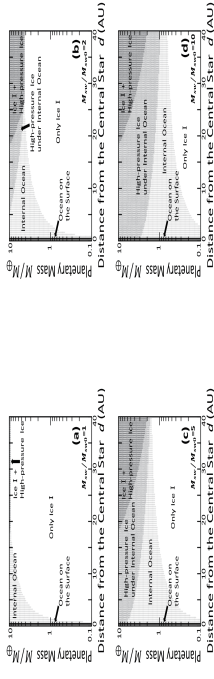


[Ueta & Sasaki, submitted to
AnI7

Summary



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- Amount of water changes the range of H.Z.
- Too much water could prevent the habitability.
- **How much water do they have?** is a key question.