Prioritizing the mass measurements of small planets with *Subaru*/IRD

John Livingston[1], Motohide Tamura[1,2]

[1]The University of Tokyo, [2]Astrobiology Center, National Astronomical Observatory of Japan

Problem

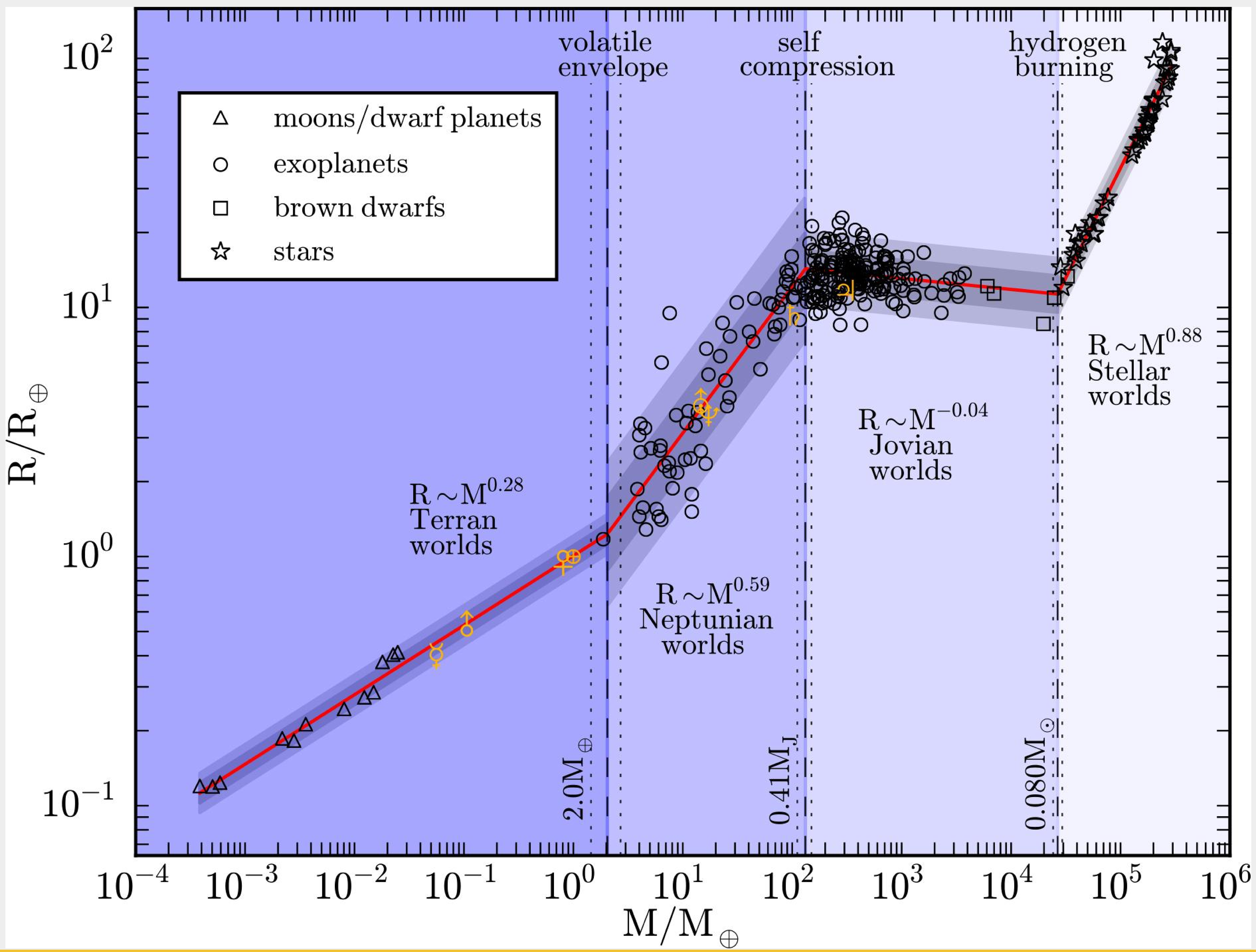
Significant uncertainties persist in the **mass-radius (M-R)** relation, in particular for the most interesting planets -- those of Terran to Neptunian size. Many small worlds can be equally well modeled as either **rocky or volatile-rich**. Planets in this size regime are high priority targets for future atmospheric study with ***JWST***, but large uncertainties in predicted atmospheric scale height complicates target prioritization, which is essential for optimal use of the ~$10B observatory.

Goal

We wish to optimize use of the InfraRed Doppler (IRD) instrument on *Subaru* for the purpose of improving the mass-radius (M-R) relation for small planets. **Late-type** stars have low mass and frequently host small planets, thus they are ideal targets for this purpose. **IRD is uniquely positioned** to precisely determine the masses of the smallest known transiting exoplanets due to the combination of its sensitivity in the IR and *Subaru's* large aperture.

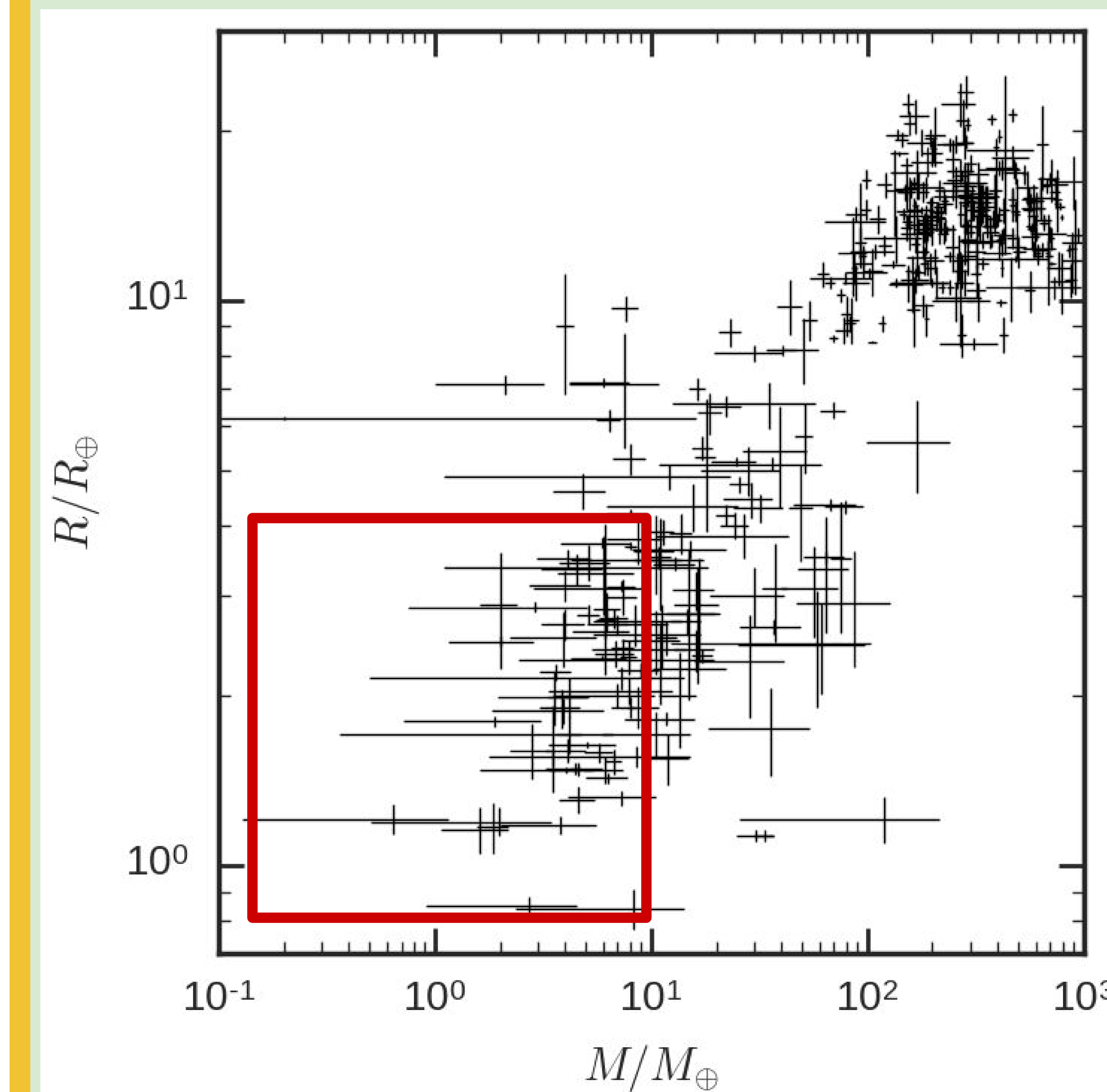
Current knowledge

Recently Chen & Kipping (2016) updated the M-R relation across the full range of planetary to stellar regimes using a large calibration sample of known bodies with precisely measured masses and radii:



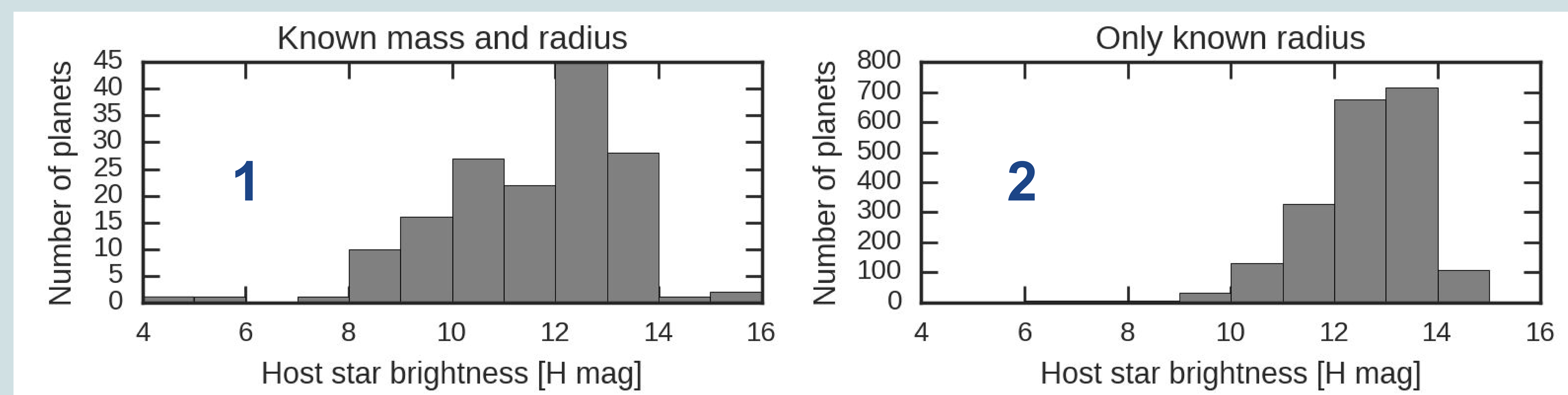
Approach

Low mass host stars are ideal targets because they are IR-bright and the expected radial velocity (RV) semi-amplitude (K) is maximized for a given planet size. Currently known exoplanets with measured masses and radii have large uncertainties, in particular for planets near the Terran/Neptunian transition (red region).



- Factors which impact overall SNR:
  - Host star **brightness** (*more photons → more signal*)
  - Host star **variability** (*stellar jitter limits RV precision*)
  - Host star **v*sin(i)** (*broader line profiles limit RV precision*)
- Factors which impact RV semi-amplitude:
  - Host star **mass** (*lower mass star → more reflex motion*)
  - Planet **radius** (*more planet mass → more reflex motion*)
- Two reasons to straddle the Terran/Neptunian transition:
  - Large scatter about the mean model for Neptunian planets, especially near the transition to Terran worlds.
  - Small number statistics for Terran planets due to the inherent difficulty of precise mass measurements for small semi-amplitudes.
- Taken together, the above means we should target **super-Earths and mini-Neptunes orbiting low mass, slowly rotating stars with low levels of stellar activity**.
- Improving the precision of previously measured planet masses will significantly improve the M-R relation.

Results



Two avenues for improving the M-R relation using IRD (including Subaru's observability constraints):

1. Planets straddling the Terran/Neptunian transition which already have measurements of both mass and radius (left). The benefit to the M-R relation is entirely due to the improvement in measurement precision.
2. Planets to be straddling the Terran/Neptunian transition which only have radius measurements (right). The benefit to the M-R relation is entirely due to the addition of new data points, which is especially important for the smallest planets which currently suffer from low number statistics.

The much smaller number of planets with known mass and radius mean that option 1 will be limited to only a few targets once other considerations are taken into account (i.e. activity, rotation, current precision). However, after eliminating faint/active stars from option 2, there will still be a large number of good targets.