Expected Occurrence Rates and Types of Planets Possible in the Alpha Centauri AB System

Ruslan Belikov[1], Eduardo Bendek[1], Dan Sirbu[1], Billy Quarles[2]
[1]NASA Ames Research Center
[2]Georgia Institute of Technology

Introduction: Alpha Centauri AB system contains the closest Sun-like stars to the Sun, by a large margin (factor of 2.4). Thus, they are important targets for the search of Earth-like planets. A critical question is whether such planets can exist in the system, and what their expected occurrence rate is. This paper surveys the current knowledge of occurrence rates, limits from non-detections, constraints from observations, and dynamical stability simulations, in order to answer this question.

Occurrence Rates of Planets around GK dwarfs: The knowledge of planet occurrence rates around Sun-like stars has improved dramatically over the past decade, helped especially by the data from the Kepler mission. Literature agreement is good for large and short period planets, and continues to improve for potentially habitable planets (SAG13 final report). The uncertainty for η_Earth is still high, ranging from about 20% to 50%. Better estimates require further analysis of observational data, especially that of Kepler. In particular, the impact of reliability of Kepler potentially habitable planet candidates remains to be fully analyzed. Gaia updates to Kepler stellar parameters is also expected to impact η_Earth estimates somewhat.

Alpha Centauri A and B stars are G- and K- type, respectively. Therefore, if they were single stars, we estimate the probability of a potentially habitable planet occurring around at least one of them to be in the ~40-80% range, subject to the above caveats.

Limits on Planet Types Imposed by Non-Detections:

As of this writing, no confirmed planets exist in the Alpha Centauri AB system. However, non-detections form very useful limits. Some of the strongest limits currently come from radial velocity non-detections from the CHIRON and HARPS instruments (Zhao et al. 2018) and impose a limit of about 53 Earth masses (0.17 Jupiter masses) on the habitable zone of star A and 8.4 Earth masses for Alpha Centauri B. In other words, giant planets cannot exist in the habitable zone (HZ) of the two stars.

Effects of Binarity:

Theoretical limits on long-term orbital stability.

The question of long-term orbital stability in the system has been studied by many authors, with general agreement. One of the most recent studies (Quarles and Lissauer 2016) showed that orbits with semi-major axes lower than 2.5 AU and inclinations less than about 45 degrees from the binary plane are stable on Gy time scales. With these limits, the entire habitable zones of both stars are still stable.

Constraints from observations

Long-term orbital stability by itself does not imply that planets can form in binary star systems with the same efficiency as in single stars. Kraus et al. 2016 compared Kepler candidates around binary vs. single star systems, and found that planet occurrence around binaries with semi-major axes < ~47AU is suppressed by a factor of ~0.34 (with large uncertainties). However, Matson et al. 2018 do not see evidence of such suppression. Whether or not suppression of planets in binaries is real, many planets have been found in binary star systems, proving that planets can form in binary star systems.

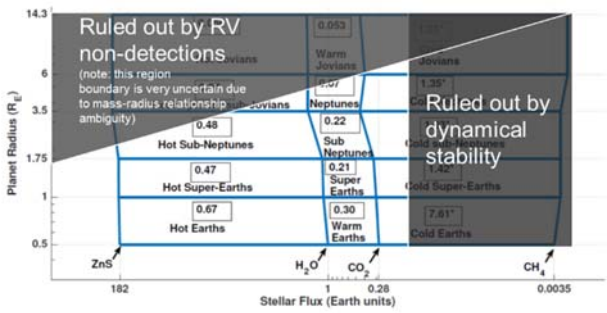

Figure 1. Summary of limits on possible planet types around Alpha Centauri A and B, superimposed on a chart of occurrence rates for different types of planets from Kopparapu et al. 2018. Giant planets and cold planets cannot exist in the system, but potentially habitable planets are possible. Note: because of large uncertainties, this chart is somewhat qualitative (with uncertainties described in the text)

Conclusions

The different effects and constraints surveyed in this paper are summarized in Figure 1, which shows the limits due to RV detections, dynamical stability, and expected occurrence values (based on SAG13 model) for different planet types (as defined by Kopparapu et al. 2018). Giant planets and cold planets cannot exist in the Alpha Centauri system, but potentially habitable planets are possible.

References:

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