How changes in stars' speed gave away the most Earth-like planets ever observed

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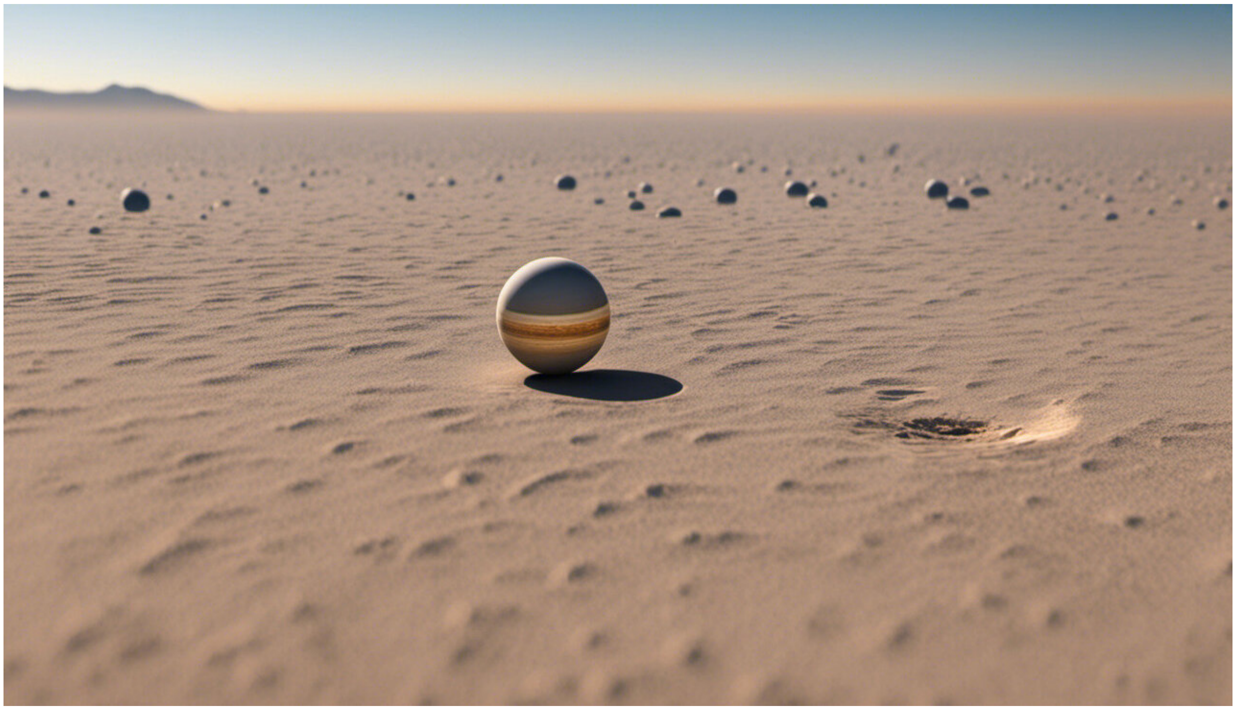

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When thinking about Earth-like exoplanet discoveries, the Kepler space telescope immediately comes to mind. Yet, it is not only Kepler, but also ground-based information from the HARPS-N spectrograph, that allowed the ETAEARTH consortium to obtain information on these planets with a degree of precision never reached before.

A joint initiative between Europe and the US, ETAEARTH (Measuring Eta_Earth: Characterization of Terrestrial Planetary Systems with Kepler, HARPS-N, and Gaia), was tasked with measuring the dynamical masses of terrestrial planet candidates discovered by the Kepler mission. The project delivered beyond expectations, being responsible for most of the Earth-like planet discoveries made over the past five years.

Dr. Alessandro Sozzetti, coordinator of the project and researcher at the National Institute for Astrophysics in Italy, discusses the project's outcomes.

There is much ongoing research dedicated to Earth analogues. What makes ETAEARTH stand out?

Over the five years of the project, ETAEARTH has combined the fantastic photometric precision of NASA's Kepler and K2 missions and the unrivalled quality of ground-based radial velocity measurements with the HARPS-N spectrograph on the Italian Telescopio Nazionale Galileo (TNG) in the Canary Islands. The point was to determine the physical properties of terrestrial extrasolar planets in orbit around stars similar in size to or smaller in size than the Sun, with unprecedented accuracy.

ETAEARTH scientists had a considerable advantage over other research teams because we had access to a conspicuous Guaranteed Time Observations (GTO) program with HARPS-N@TNG, for a total of 400 observing nights over five years. Such a large telescope time investment was key to the spectacular successes of the project.

What's the added value of combining KEPLER and HARPS-N data?

Kepler and K2 exploit the technique of planetary transits: They measure the dip in the light from a star as a planet crosses it, revealing the planet's size. HARPS-N, on the other hand, measures changes in the star's speed due to the gravitational pull from an orbiting planet, allowing us to determine its mass.

From the combination of these two observations, we can calculate the planet's density and determine its bulk composition (e.g., rocky, water-rich, gas-rich, etc.) with high accuracy.

Can you tell us more about your methodology?

ETAEARTH carefully selected Kepler and K2 small-radius exoplanet candidates based on their chances of having their masses measured accurately with HARPS-N. We then designed adaptive observing strategies tailored to each system, depending for example on the magnitude of the signal sought with HARPS-N and on the orbital period of the candidate.

Once an observing campaign for a given target was completed, we accurately determined the fundamental physical parameters of the central star – that is, its mass and radius – as only precise knowledge of these quantities allows us to derive accurate estimates of the planetary parameters.

The next step in our methodology entailed a sophisticated combined analysis of the available Kepler/K2 and HARPS-N data to derive all the system's orbital and physical parameters (for both single and multiple transiting planets). Finally, our measurements of planetary densities were compared with predictions from theory to underpin the actual composition of the planet(s).

What were the main difficulties you faced in this process and how did you overcome them?

The biggest challenge we had to face arose from dealing with stellar activity. This phenomenon, produced primarily by spots on the surface of the star that come in and out of view as the star rotates (just like our Sun), introduces complications in the interpretation of the data – particularly those gathered with HARPS-N. It can sometimes mask entirely or even mimic a planetary signal. So you think you are seeing a planet, but you are instead accurately measuring the star acting up!

Our learning curve was steep, but ultimately we succeeded, using a twofold approach: First, we adapted our observing strategies with HARPS-N to make sure we could sample both stellar and planetary signals well enough. With the best-possible temporal distribution of our observations, we then developed sophisticated analysis tools that allowed us to effectively disentangle planetary signals and those produced by stellar activity.

What would you say were your most important findings?

We could learn for the first time about the physics of these objects' interiors. We have notably determined with high precision (20 percent or better) the composition of 70 percent of currently known planets with masses between one and six times that of the Earth and with a rocky composition similar to that of Earth.

Among these, we discovered Kepler-78b, the first planetary object that has a similar mass, radius and density to Earth. We have also found the two closest transiting rocky planets, orbiting the solar-type star HD219134 only 21 light years away. This golden sample of planets with well-constrained parameters allowed us to infer that all dense planets with masses below six Earth masses (including Earth and Venus) are well-described by exactly the same rocky composition (in technical terms, the same fixed ratio of iron to magnesium silicate).

Most notably, ETAEARTH provides the first-ever constraints on the density of K2-3d, a planet in a multiple transiting system that is similar to Earth in mass and orbits within the Habitable Zone of the star known to-date to be closest in mass to the Sun. K2-3d appears to belong to the still elusive class of 'water worlds', with a density somewhat lower than Earth's.

Finally, using information from the full sample of objects found by Kepler, we have determined that one in five solar-like stars host an Earth-like planet, i.e. an object with a size similar to Earth orbiting within the Habitable Zone of its solar-type parent star.

What are your follow-up plans, if any?

Our post-ETAEARTH plans will primarily focus on tapping the huge potential that is about to be unleashed by the new important player in the exoplanet arena, NASA's TESS mission which was successfully launched just a few weeks ago.

TESS will find transiting planets over most of the observable sky with radii not much bigger than Earth's, and around stars typically five to ten times brighter than those observed by Kepler. Some of these small planets will orbit at Habitable Zone distances from their central stars (typically of lower mass than the Sun).

We plan to invest large amounts of observing resources from both hemispheres whilst continuing to use HARPS-N and the new ultra-high-precision European planet hunter ESPRESSO on the Very Large Telescope in the Chilean Andes in order to measure masses and densities of the best candidates provided by TESS. Doing this could dramatically increase the sample of optimal targets amenable for investigations of their atmospheres.

Provided by CORDIS

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