

CHES survey could detect exoplanets within a few dozen light-years of Earth using astrometry

May 23 2022, by Matt Williams



Artist's impression of the ESA's Gaia Observatory. Credit: ESA

NASA has indicated that 5,030 extrasolar planets have been confirmed in 3,772 systems, with another 8,974 candidates awaiting confirmation.

With next-generation instruments like the James Webb Space Telescope (JWST) coming online, the number and diversity of confirmed exoplanets are expected to grow exponentially. In particular, astronomers anticipate that the number of known terrestrial planets and super-Earths will drastically increase.

In the coming years, the opportunities for exoplanet studies will increase considerably as thousands more are discovered. In a recent study, a team led by the Chinese Academy of Sciences (CAS) described a new space-telescope concept known as the Closeby Habitable Exoplanet Survey (CHES). This proposed observatory will search for Earth-like planets in the habitable zones (HZs) of [sun-like stars](#) within approximately 33 light-years (10 parsecs) using a method known as micro-arcsecond relative astrometry.

The branch of astronomy known as astrometry consists of taking precise measurements of the positions and proper motions of celestial bodies by comparing them to background reference stars. Examples of this method include the ESA's Gaia Observatory, which has been measuring the motion of 1 billion stars in the Milky Way (as well as 500,000 distant quasars) since 2013. This data will be used to create the most precise three-dimensional map of our galaxy ever made.

In this case, researchers from the Chinese Academy of Sciences (CAS) and multiple Chinese observatories and Universities propose a [space telescope](#) that could take high-precision astrometry measurements of sun-like stars to detect exoplanets orbiting them. The proposed CHES mission will operate at the sun-Earth L2 Lagrange point—where NASA's James Webb Space Telescope (JWST) currently resides—and observe target stars for five years. These targets will include 100 stars within 33 light-years of the solar system that fall into the F, G, and K types.

Whereas F-type stars (yellow-white dwarfs) are hotter, brighter, and

more massive than our sun, G-type stars (yellow dwarf) are consistent with our sun—a main-sequence G2V star. Meanwhile, K-type stars (orange dwarf) are slightly dimmer, cooler, and less massive than our sun. For each star it observes, CHES will measure the small and dynamical perturbances induced by orbiting exoplanets, which will provide accurate estimates of their masses and orbital periods.

As a space-based observatory, CHES will not be subject to interference due to Earth's precession and atmosphere and will be able to make astrometry measurements accurate enough to fall into the micro-arcsecond domain. Dr. Jianghui Ji is a professor at the CAS Key Laboratory of Planetary Sciences in Nanjing, the University of Science and Technology, and the lead author on the study. As he told Universe Today via email:

"For an Earth-mass planet at 1 AU around a solar-type star at 10 pc, the astrometry wobble of the star caused by the Earth Twin is 0.3 micro-arcsecond. Thus the micro-arcsecond level measurement is required. The relative astrometry for CHES can accurately measure micro-arcsecond level angular separation between one target star and 6-8 reference stars. Based on the measurements of these tiny changes, we can detect whether there are [terrestrial planets](#) around them."

Specifically, CHES will make the first direct measurements of the true masses and inclinations of Earth analogs and super-Earths that orbit within their stars' HZ and are considered "potentially habitable." The primary payload for this mission, said Dr. Ji, is a high-quality mirror with a diameter of 1.2 meters (ft) and a field of view (FOV) of $0.44^\circ \times 0.44^\circ$. This mirror is part of a coaxial three-mirror anastigmat (TMA) system, where three curved mirrors are used to minimize optical aberrations.

CHES also relies on Mosaic Charge-Coupled Devices (CCDs) and the

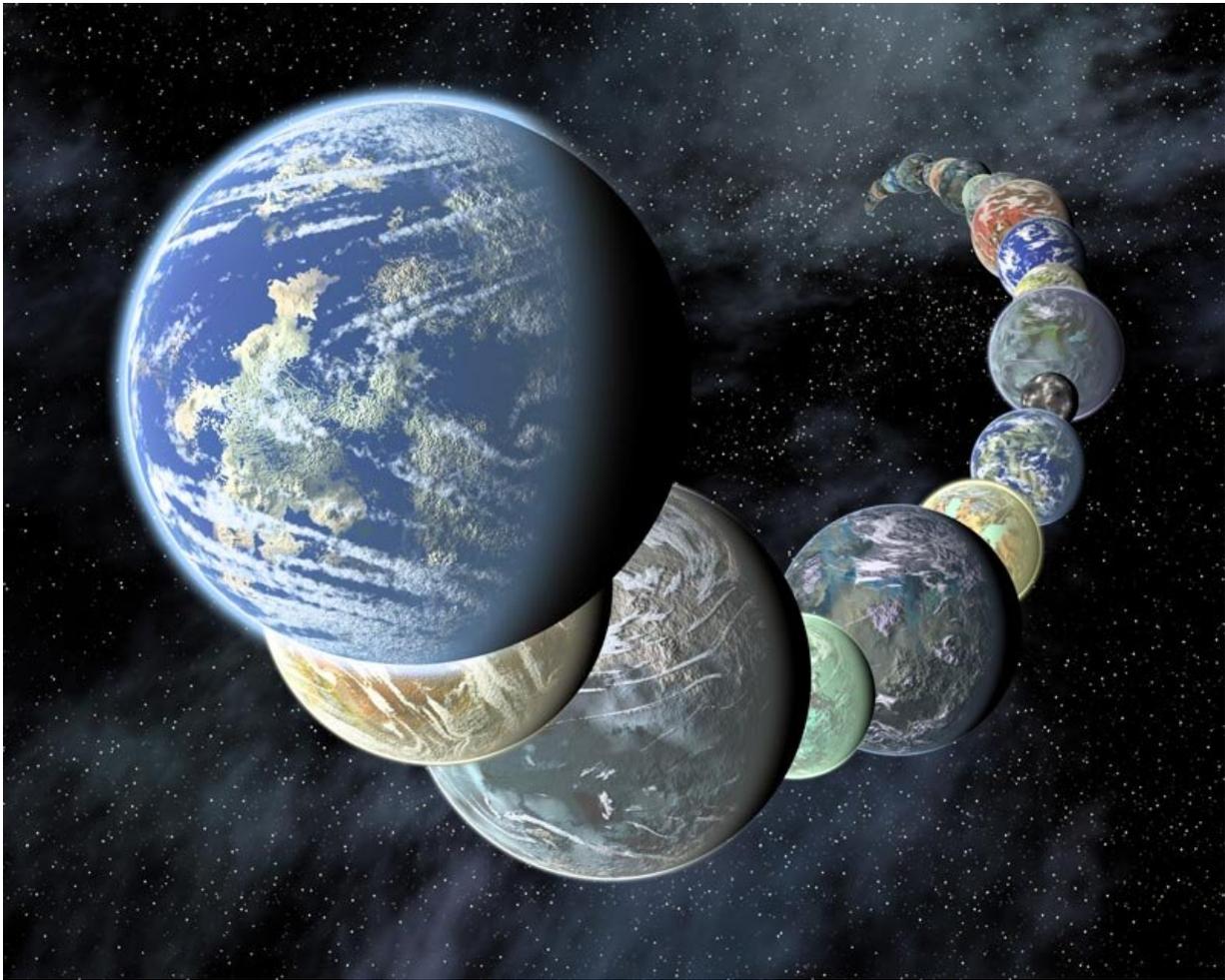
laser metrology technique to conduct astrometric measurements in the 500nm~900nm range—encompassing visible light and the near-infrared spectrum. These capabilities will offer significant advantages compared to the [transit method](#), which remains the most widely used and effective means for detecting exoplanets. In this method, stars are monitored for periodic dips in luminosity, which are possible indications of planets passing in front of the star (aka. transiting) relative to the observer.

In addition, CHES will assist in the transition currently taking place in exoplanet studies, where the focus is shifting from the process of discovery to characterization. As Dr. Ji explained:

"First, CHES will conduct an extensive survey of the nearby solar-type stars at 10 PC away from us and detect all the Earth-like planets in the habitable zone via astrometry, in the case where the transit method cannot do (such as TESS or PLATO). [This] requires the edge-on orbits for the planets with respect to the line of sight of the observers.

"Second, CHES will offer the first direct measurements of true masses for 'Earth Twins' and super-Earths orbiting our neighbor stars, in which the planetary mass really matters to characterize a planet. In comparison, the [transit method] can generally provide the radius of the planet and should be confirmed by other ground-based methods, such as radial velocity.

"Finally, CHES will provide three-dimensional orbits (e.g., inclinations) of terrestrial planets, which also act as another crucial index involved in planetary formation and characterization."



Artist's impression of Earth-like exoplanets. Credit: NASA/JPL-Caltech

These capabilities will help astronomers vastly expand the current census of exoplanets, which consists predominantly of gas giants (Jupiter or Saturn-like), mini-Neptunes, and super-Earths. But with the improved resolution and sensitivity of next-generation instruments, astronomers anticipate that the number of Earth analogs will grow exponentially. It will also improve our understanding of the diverse nature of planets that orbit sun-like stars and shed light on the formation and evolution of the solar system.

But the benefits of a next-generation space-based astrometry mission don't stop there. As Dr. Ji indicated, it will be able to assist with surveys that rely on the second-most-popular and effective exoplanet detection method, known as the radial velocity method (aka. Doppler spectroscopy). For this method, astronomers observe stars for signs of apparent motion back and forth ("wobble") resulting from the orbiting planets' gravitational influence. Dr. Ji said, "In addition, CHES can conduct joint measurements with high-precision radial-velocity instruments such as the Extremely Large Telescope (ELT) and Thirty Meter Telescope (TMT). [It can also] verify habitable planet candidates discovered by [this method], and accurately characterize planetary masses and orbital parameters."

Beyond that, CHES will help advance the frontiers of astronomy and cosmology by aiding in the search for dark matter, the study of black holes, and other research fields. This research will provide new insights into the physics that govern our universe, the formation and evolution of planetary systems, and the origins of life itself. Other observatories, such as the Nancy Grace Roman Space Telescope (and the ELT and TMT), will be able to conduct direct imaging studies of smaller exoplanets that orbit more closely to their stars—precisely where rocky HZ [planets](#) are expected to be found.

Combined with astrometry measurements that could reveal hundreds of rocky exoplanets in neighboring systems, astronomers could be on the verge of finding life beyond Earth.

More information: Jianguhui Ji et al, CHES: a space-borne astrometric mission for the detection of habitable planets of the nearby solar-type stars. arXiv:2205.05645v1 [astro-ph.EP], arxiv.org/abs/2205.05645

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