Discovery of a rare quadruple gravitational lens candidate with Pan-STARRS

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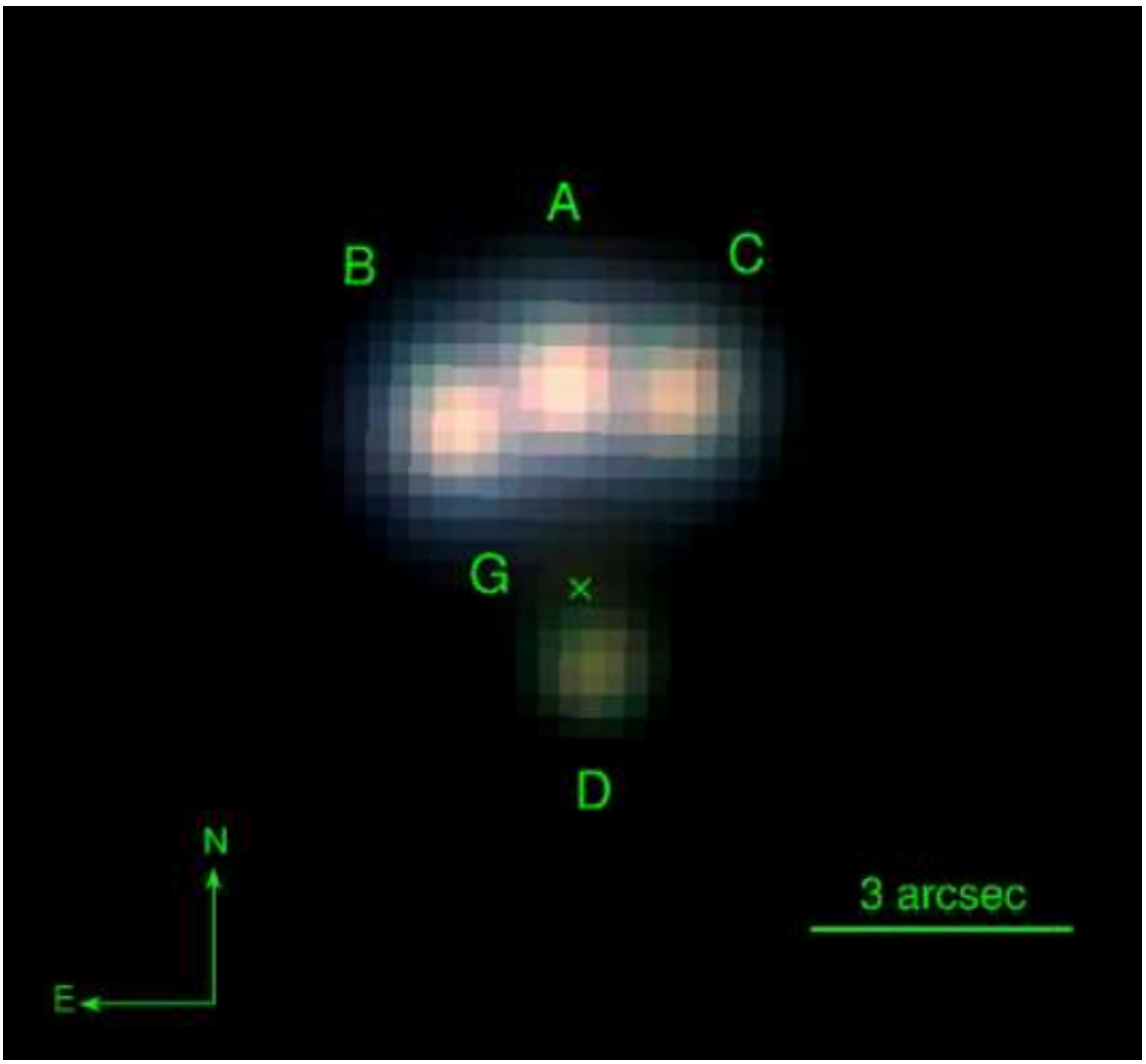

Pan-STARRS image of the quadruple gravitational lens candidate. The four images of the quasar are marked A-D. The lensing galaxy is very faint and it was discovered only after careful analysis of the image, its position is marked with an x. Credit: United States Naval Observatory (USNO)

Astronomers from the United States Naval Observatory (USNO) in conjunction with colleagues from the University of California, Davis, and Rutgers University have discovered the first quadruple gravitational lens candidate within data from the Panoramic Survey Telescope and Rapid

Response System (Pan-STARRS) using a combination of all-sky survey data from the USNO Robotic Astrometric Telescope (URAT) and the Wide-field Infrared Survey Explorer (WISE).

USNO graduate student George Nelson, who was performing a URAT variability study of the brightest quasars identified by USNO astronomers using WISE colors, discovered the lens while investigating the optical properties of a bright quasar sample. The paper describing this serendipitous discovery has been accepted for publication in the

Astrophysical Journal. A preprint of the paper may be found at arxiv.org/abs/1705.08359. A paper confirming the discovery by a separate team of astronomers using the Keck Cosmic Web Imager has been submitted to the *Astrophysical Journal Letters*. A preprint of this paper may be found at arxiv.org/abs/1707.05873.

Since the discovery of the first gravitationally lensed quasar in 1979, gravitational lenses have become powerful probes of astrophysics and cosmology. Because they require a very specific configuration between a background quasar (a bright, distant object powered by a supermassive black hole) and a foreground lensing galaxy, quadruply lensed quasars are especially rare. In fact, to date there are only about three-dozen such objects known over the entire sky.

Gravitational lenses are a manifestation of gravity's ability to bend light,

which was predicted by Einstein's general theory of relativity in 1915. Since then many experiments have been carried out to test this theory starting with Sir Arthur Eddington's observations of light bending during a solar eclipse in 1919. When a galaxy acts as a gravitational lens to a background quasar, the lensed quasar appears as dual or quadruple images, depending on the relative location of the lens and the source. Lenses are rare because they require that the galaxy and the quasar be located within a few arcseconds of each other on the sky.

Gravitational lenses are at the forefront of current research in cosmology and astrophysics. In astrophysics, they have been used to uncover the structure of massive galaxies, to study how supermassive black holes relate to their host galaxies, and to gain insight into quasar accretion disks as well as their black hole spin. In cosmology, they have contributed to measuring the distribution of dark matter around galaxies and the expansion history of the universe.

Future radio, X-ray, Hubble Space Telescope and adaptive optics imaging, as well as spectroscopic studies, are already planned to further the study of this lens and to contribute to fundamental research.

More information: Discovery of the first quadruple gravitationally lensed quasar candidate with Pan-STARRS. *arXiv*. arxiv.org/abs/1705.08359

Provided by United States Naval Observatory (USNO)