SUPERHEROES 4 SCIENCE

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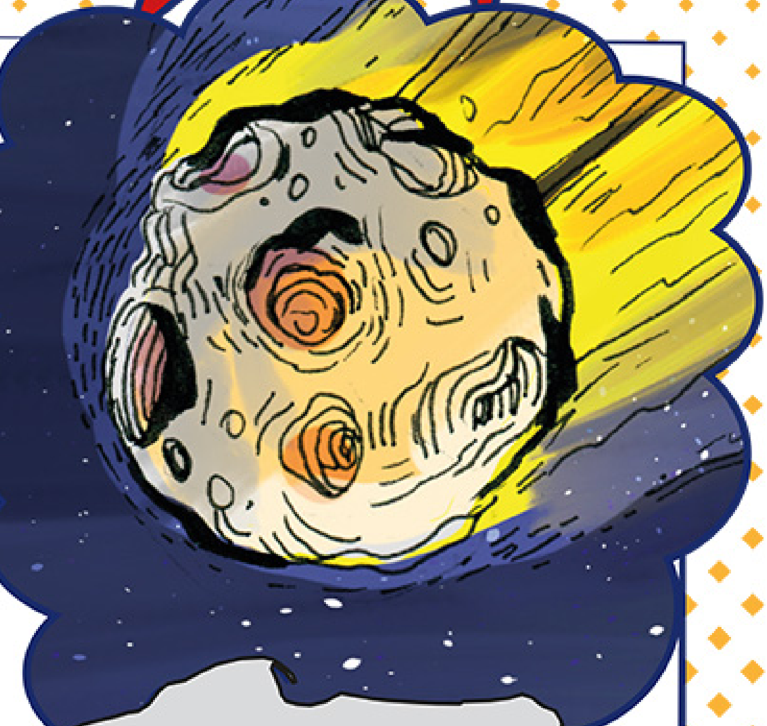
MODELLING OBSERVATIONS OF STARS

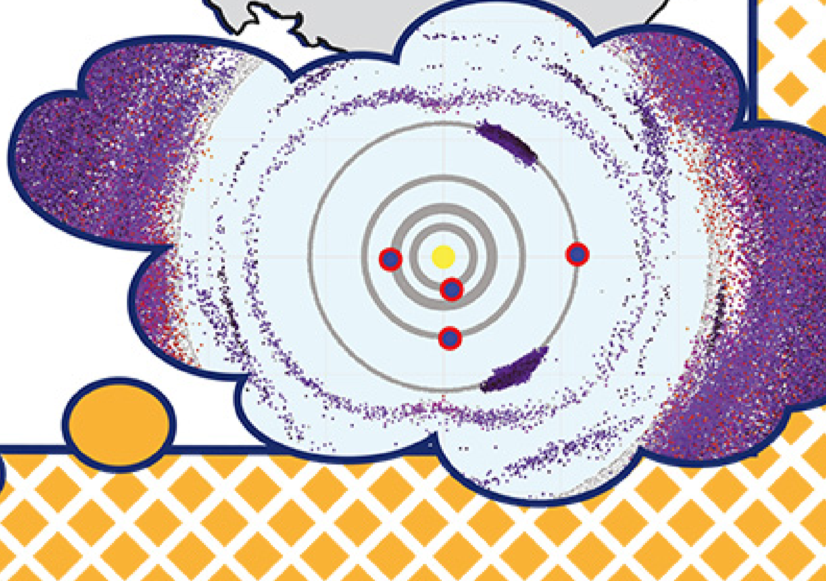
Modelling observations of stars with planetary systems

Mankind has been always fascinated by the sky, looking for answers to questions about where we came from, how the world was created, and what the nature of space is. Four centuries ago, the Italian philosopher and visionary cosmologist, Giordano Bruno predicted the existence of planetary systems besides our Solar System. He suggested that the stars are actually distant suns, like the Sun, surrounded by their own planets and moons, in a universe with no centre. The Inquisition punished Bruno for his cosmological theories. This great philosopher and thinker was burned alive as a heretic in Rome in 1600.

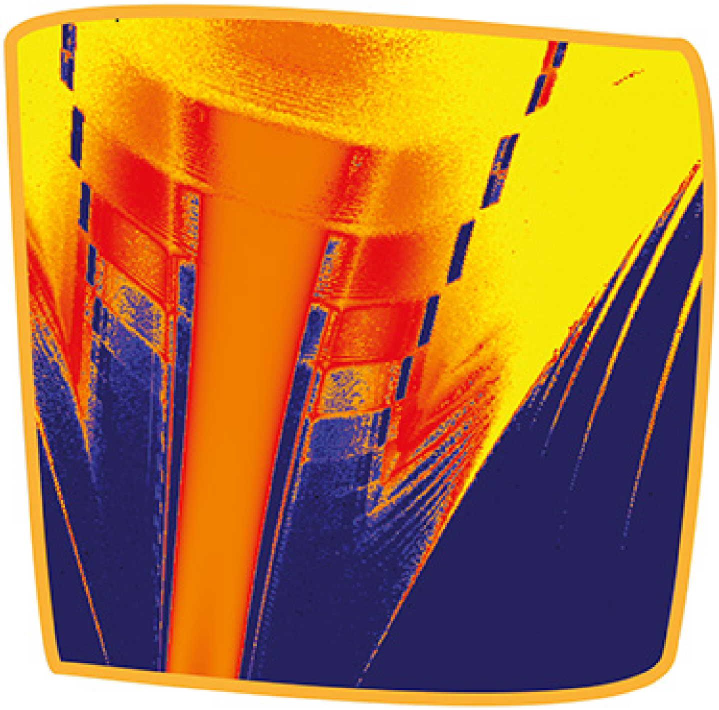


But Giordano Bruno was right. Nowadays technologies used for observing the sky have reached a level of precision that makes it possible to confirm that other planets around stars other than the Sun really exist. The past three decades have seen rapid development of this new area of science: the astrophysics of extrasolar planets. According to the NASA archives, more than 3,800 extrasolar planets, some as small as the Earth and Mars, have been detected so far. Approximately 600 multiple systems were found around single and binary stars of different spectral characteristics.

Many recent space (e.g., KEPLER and TESS of NASA, GAIA of ESO) and ground surveys, involving the largest optical telescopes and radio-interferometric facilities, such as the Large Atacama Milimeter Array (ALMA), and the European radiotelescopes network including a 32-m instrument located in Piwnice, near Torun in Poland, provide an enormous volume of observational time series. The data concerning planetary systems must be interpreted in terms of the orbital architectures, physical parameters of the planets such as their masses, as well as their formation and long-term evolution. Planet detection statistics indicate that about 20% or more of stars host a planet comparable to the Earth orbiting in the star's habitable zone. In this zone, liquid water and particular atmospheric conditions are present which are the main ingredients for supporting biological life.

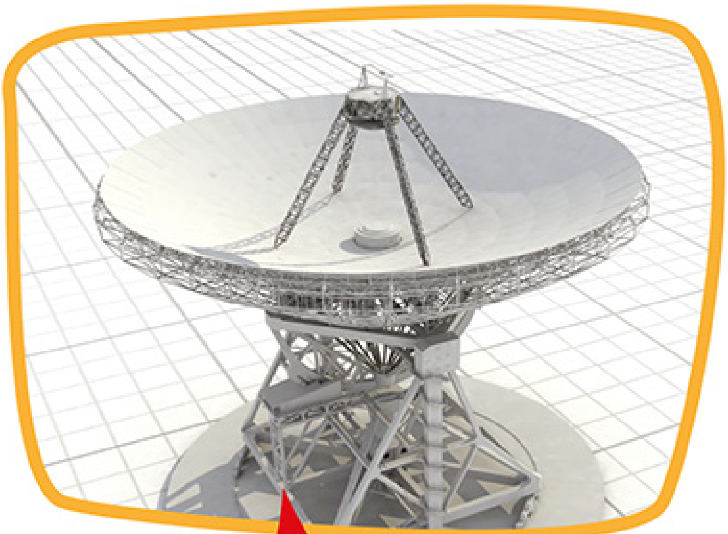


It appears that efficient searching for new planets in the vicinity of a selected star may rely on observation and analysis of its brightness, which astronomers call the photometric technique. When a putative, dark planet transits the shiny star's disk, the brightness of this star decreases by a tiny amount, which nevertheless may be measured to a fraction of a percent. One of the projects conducted by the researchers of the Centre for



Astronomy, Nicolaus Copernicus University in Torun, Poland is devoted to a comprehensive analysis of multiple planetary systems detected with the transit method, which also exhibit mutual gravitational interactions. Photometric light-curves (time series) gathered by the KEPLER and TESS space telescopes are the data sources making it possible to determine the orbits and masses of the planets, with the help of complex numerical codes. It is also very important to check whether the constructed models of these systems comply with the Copernican principle: they are stable at present, and also long term stable, for hundreds of Myr timescales. In this project, it is possible to indirectly "weigh" the planets (determine their masses), like the three planets in the Kepler-30 system, up to a few percent uncertainty, with photometric measurements only.

The required computations are complex, since the modelling codes must involve theoretical astrophysics and astronomy, statistics, mathematical optimisation, and celestial mechanics. The codes are CPU-demanding and time-consuming applications. Most of the results that have been published in high-impact astronomical journals were achieved thanks to long-term numerical simulations conducted at the Eagle/Orzeł Supercomputer and computing facilities of the Poznan Supercomputing and Networking Center. Many such simulations used several thousand CPUs. Thanks to the Eagle Supercomuter, it is possible to translate raw observational data into meaningful astrophysical models and gain knowledge on how the planetary systems formed, how they are built, and indeed what they look like.



Based on real research led by Prof. Krzysztof Goździewski, Torun Center for Astronomy at Nicolaus Copernicus University, in collaboration with Poznan Supercomputing and Networking Center (PSNC).

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