Stars and their variability observed from space
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THE SPACE PHOTOMETRY REVOLUTION

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Abstract. We look back to more than half a century of photometric measurements from space. They provided us with access to the full electromagnetic spectrum, atmospherically undisturbed spatial resolution and photometric quality as well as uninterrupted, high cadence measurements. By this our picture of the universe as a whole and its constituents changed drastically. This success story was not without setbacks but the future is promising.

Keywords: Space vehicles: instruments, Stars: variables, Asteroseismology

1 Introduction

The late 1960s and early 1970s saw the first space photometry focussed on the infrared and ultraviolet spectral ranges. Missions like OAO-2, ANS, TD1, COPERNICUS, and later IUE or HST, must be mentioned in that context. Some experiments were connected to manned missions like Spacelab. The expectations included the avoidance of atmospheric extinction, emission, seeing, scintillation, a much better sky coverage, the absence of day/night interruptions and favourable thermal conditions.

Reality was different: Low and short orbits reduced continuous viewing zones, reslted in short missions and did not allow for long-term studies, while uncertainties with technical and financial constraints did not allow reliable planning. The extremely strong competition prevented early space astronomy from becoming a regular tool for observational astronomy.

2 Great ambitions

Motivated by the great success of helioseismology in the 1970s and 1980s, similar approaches on stars became desirable. Ground-based work using world-wide telescope networks (e.g. Breger et al. (1990) demonstrated the potential, but it was clear that space-based observatories could have great advantages from their potentially uninterrupted and their atmospherically undisturbed time-series. Consequently, the 1990s saw several national attempts for devoted space instruments, like EVRIS (Baglin et al. 1993) on MARS96 or MONS (Kjeldsen et al. 2000). Several increasingly big proposals (40 to 120 cm apertures!) were submitted to ESA's Horizon 2000 programme, namely PRISMA (Appourchaux et al. 1993), STARS (Fridlund et al. 1995) and Eddington (Roxburgh & Favata 2004) While not successful for various reasons, the efforts built up a strong European community interested in space photometry. Several critical technical components were pre-developed, and the scientific interest in such missions broadened after detections of the first exoplanets around normal stars (Mayor & Queloz 1995).

3 The revolution starts

The first really successful demonstration of high-precision photometry from space was that of the WIRE 5 cm startracker (Schember et al. 1996) an (unfortunately) otherwise failed infrared mission. Then, with Canadian-led MOST (Matthews et al. 2000), asteroseismology becomes routine in a "suitcase" form factor with a 15-cm aperture and its revolutionary attitude control. The French-led CoRoT (Catala et al. 1995) with its 25-cm telescope initiated the final revolution. To put their first results in perspective: to find (e.g.) 10 modes in a δ-Scuti star Breger et al. (1995) needed 170 hrs of photometric data from a world-wide coordinated observational campaign. CoRoT enabled the identification to be made of several hundred modes in two months (Poretti et al. 2009). The next big step was *Kepler* (Borucki et al. 2010), which enabled a revolutionary census by monitoring some 150,000 (typically distant) stars with a 95-cm aperture.

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4 Now and then

Today, the ongoing *Gaia* (Gaia Collaboration et al. 2016) provides parallaxes, radial velocities, spectroscopy and long-term variability/activity monitoring for up to one billion stars. What an advance from the early days! With BRITE constellation (Handler et al. 2017), the first nanosats with miniaturized gyros, cheap fabrication using mostly off-the-shelf components and comparatively cheap launch and operation, provide hig- precision photometry for apparently bright stars in two filter bands. At present TESS (Ricker et al. 2016), a small 2-year explorer-class mission, is performing an all-sky survey of 200,000 stars within about 200 pc. In common with BRITE, the stars observed by TESS are bright and are therefore relatively easy to follow up at high spectral or spatial resolution than in the case of *Kepler*.

The future for space photometry is bright! After its launch on 2019 December 17,CHEOPS (Broeg et al. 2013), an fast and small ESA mission, will build on the significant CoRoT heritage and will enable detailed characterizations of both individual planets and host stars. After 2026 PLATO (Rauer et al. 2016), an ESA M-class mission, will carry out a census for up to 6 years (some 10^6 stars) down to earth-sized planets and accurate stellar and planetary masses, radii and ages, with a strong focus on more nearby objects in order to enable follow-ups with high-resolution spectroscopy and interferometry. Together with *Gaia* (see above) it is a perfect complement to carrying out galactic archaeology – many revolutions to come. We live in great times!

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