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Early science results from the Next Generation Transit Survey (NGTS)

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Abstract

The Next Generation Transit Survey (NGTS) is a new wide-field, ground-based exoplanet survey designed to detect Neptunes and super-Earths transiting bright stars, which are amenable to precise radial velocity confirmation and mass determination. NGTS comprises an array of twelve independent robotised 20-cm telescopes located at ESO's Paranal Observatory in Chile, and has been operational since early 2016. While monitoring ∼10% of the southern sky during it's survey time, the facility achieves sub-mmag photometric precision, which is unprecedented for wide-field ground-based transit surveys. We will introduce NGTS, describe our novel planet detection and vetting pipeline, and present early science results: new confirmed and candidate exoplanets, low-mass eclipsing binaries, variable stars and stellar flares.

1 Motivation

The radii of transiting exoplanets can be determined from photometric time-series given a radius estimate for the host star. Ground- and space-based wide-field transit surveys have discovered ∼2700 confirmed exoplanets to date, yet only ∼500 of these possess mass estimates. In the Neptune regime and below, only ∼40 planets boast mass determinations to 20% or better.

The primary goal of NGTS is to detect Neptunes and super-Earths transiting solar and late-type stars, which are bright enough for precise radial velocity confirmation and mass determination (Wheatley et al., 2013). The densities and hence bulk compositions for these planets will be attainable, and furthermore, they will be favourable targets for detailed characterisation of their atmospheric structure and composition. Gaining this understanding is crucial as the field moves towards the search for habitable planets.

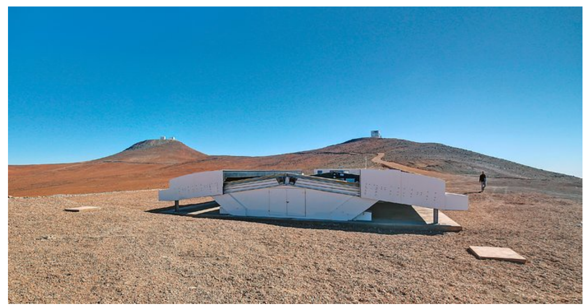

Figure 1: The NGTS facility is located at ESO's Paranal Observatory in Chile and comprises 12 independent 20-cm robotised telescopes. Credit: ESO/R. Wesson.

1.1 Design and expected yield

Detecting small transiting planets requires precise time-series photometry. NGTS comprises twelve independent robotised 20-cm telescopes located at ESO's Paranal Observatory in Chile (see Fig. 1) and obtains flux measurements of thousands of stars with a cadence of 12 seconds every clear night. With an instantaneous field of view of 100 square degrees, NGTS will cover ∼10% of the southern sky during its nominal mission. Building on the legacy of previous ground-based surveys, and combining precise autoguiding (McCormac et al., 2013) with Paranal's favourable observing conditions, NGTS routinely achieves 0.1 per cent precision in 1-hour for stars brighter than $I < 13$.

In Günther et al. (2017) we developed a comprehensive simulation to investigate the impact of observing strategies, target fields and noise properties on the planet and false-positive yields of NGTS. We predict that NGTS will discover ∼240–320 planets and will provide a new sample of tens of small planets orbiting bright stars, which are suitable for further detailed characterisation.

2 Early science with NGTS

2.1 Automated planet candidate vetting

Photometric transit-like signals can originate from planets, but also from correlated noise and variable astrophysical objects. The latter are known as *false positives* and can be up to two orders of magnitude more prevalent than planets (see e.g. Cameron, 2012).

The automated candidate vetting pipeline of NGTS is designed to ensure robustness, repeatability and computational performance, and employs a range of both established and novel algorithms using the NGTS photometry. In addition to photometric vetting, we also successfully employ the centroiding technique for the first time from the ground (Günther et al. *in prep*). This measures any shift in the centre-of-flux position during a transit event which, if detected, implies the presence of a third light source in the photometric aperture. NGTS can reach a centroiding precision as low as 0.25 milli-pixel, which should identify $> 50\%$ of background EBs without requiring further follow-up telescope time. Additionally, for diluted planet transits, this technique allows the true transit depth to be computed, preventing the underestimation of planet radii. Candidates passing the photometric and centroiding tests are spectroscopically followed-up with a combination of the CORALIE, FEROS and HARPS spectrographs (all located at La Silla, Chile) to obtain precise masses for bona fide planets.

2.2 Precise time-domain astrophysics

Obtaining precise high-cadence (12 s) time-series photometry of millions of stars with NGTS opens up a wide range of time-domain astrophysics. Firstly, we are characterising new transiting planets (e.g. Bayliss et al. *in prep*). Fig. 2 displays the power of NGTS in this regard, where a single NGTS transit of WASP-4b (top) is compared to the original WASP discovery photometry (bottom). NGTS is clearly able to detect single transits of Jupiter-sized planets, which allows long-period systems to be characterised.

In addition to planet science, NGTS is well-suited to characterising new eclipsing binaries (e.g. Casewell et al. *in prep*). Detached, double-lined EBs are valuable objects as they provide direct observational tests of stellar evolution theory which, especially at low-masses and young ages, are currently scarce (e.g. Gillen et al. *submitted*). Characterising stellar variability offers a window onto the structure, composition and evolution of stars. With 12 s cadence, NGTS is a powerful facility for such work; for example, it is able to reveal the detailed structure of stellar flares (e.g. Jackman et al. *in prep*).

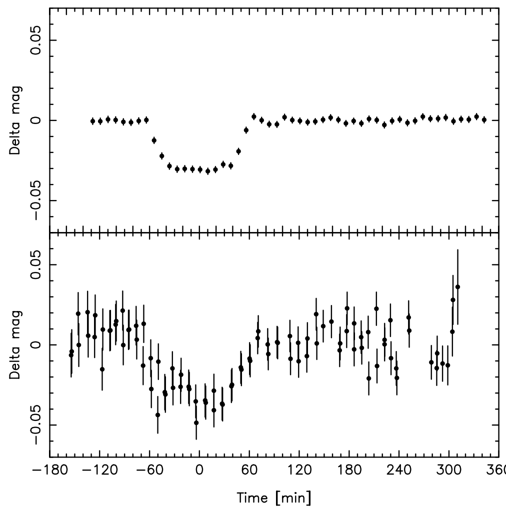

Figure 2: Single transit observations of WASP-4b, a hot Jupiter transiting a G-dwarf, with one NGTS telescope unit (top) and original WASP discovery data (bottom). Figure from Wheatley et al. (*in prep.*).

Acknowledgements

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