Ultra-High Precision Photometry with NGTS Multi-Telescopes

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Summary

Bright stars provide the best targets for exoplanet spectroscopic mass measurement and atmospheric characterisation. We have been using the Next Generation Transit Survey (NGTS) [1] to obtain photometric follow-up of the brightest exoplanet candidate hosts. This follow-up is vital for TTV analysis, robust ephemeris determination and blend rejection. We have been primarily following-up candidates from TESS [2], selecting targets from the TESS Objects of Interest (TOIs). Our target list is defined by the following criteria:

1) **TESS mag < 10.5**
2) **Transit depth > 1000 ppm**

1: Next Generation Transit Survey (NGTS)

NGTS is a exoplanet hunting facility which consists of 12 robotic telescopes and is located at ESO's Paranal Observatory in Chile. The NGTS telescopes each have a field-of-view of 8 deg^2 which allows us to have a wide selection of comparison stars, which is crucial for obtaining the highest precision light curves. This makes NGTS uniquely suited to observe the brightest exoplanet host stars. NGTS benefits from milli-pixel level auto-guiding which, combined with the excellent observing conditions at Paranal, provides high precision light curves.

	NGTS	TESS
Telescope Diameter (*cm*)	20	10
Nominal Cadence (*s*)	13	120
Plate scale (*arcsec*)	4.97	21

Table 1: NGTS and TESS telescope and observing comparison.

Figure 1: The NGTS facility at ESO's Paranal Observatory in Chile.

2: Multi-Telescope Observations

NGTS light curves for bright (V < 10) stars are dominated by **scintillation noise**. By utilising **multiple telescopes** to obtain **simultaneous observations** of a transit event we can achieve **ultra-high precisions**, especially in relation to the scintillation limit for a single telescope. As is shown in the plot below, we achieve very close to the ideal white noise level. We have also achieved **the same precision as TESS** for the same bright star - WASP-166 (V=9.3).

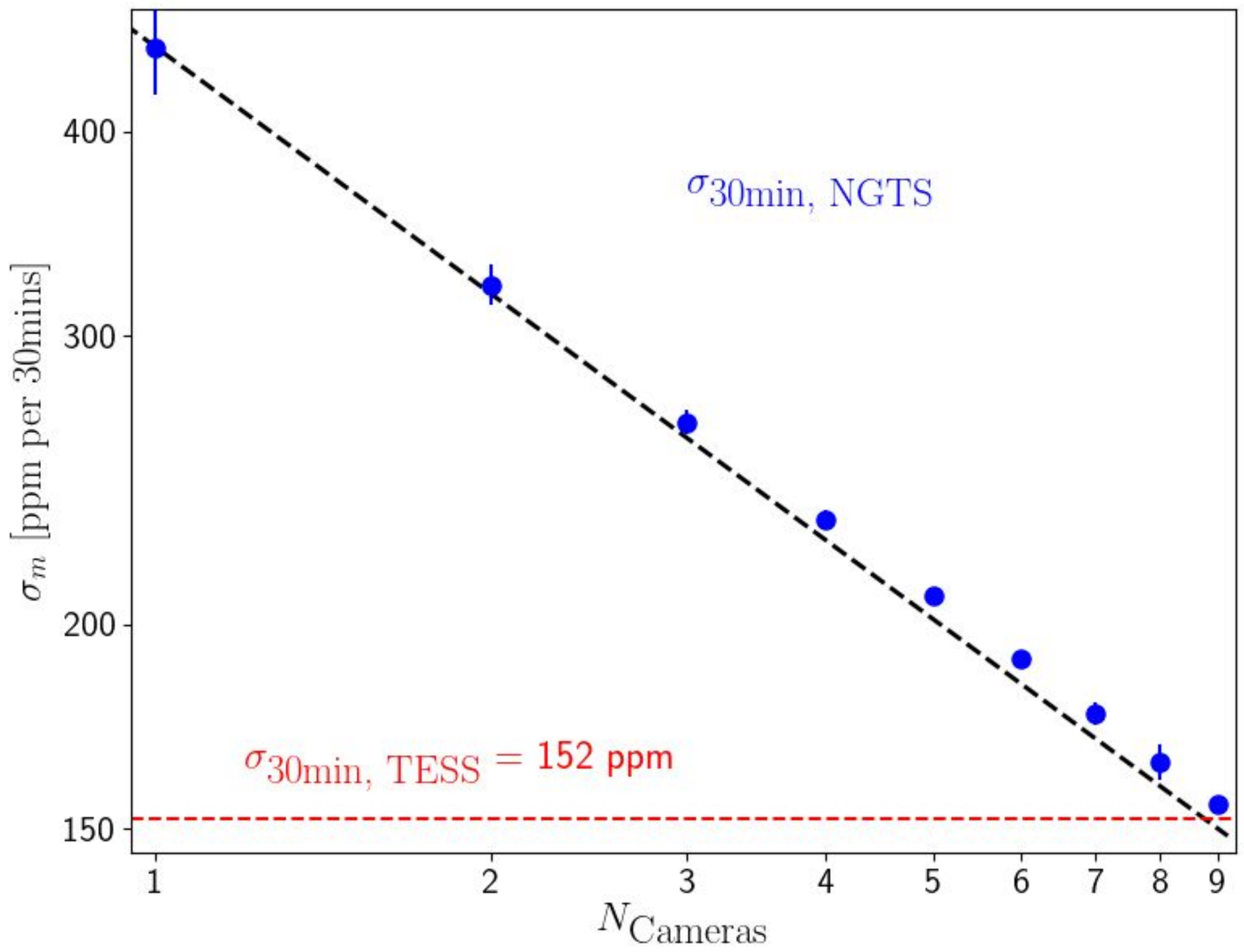

Figure 2: Improvement in photometric precision obtained with increasing number of telescopes used. The dashed lines give the best case theoretical improvement that would be obtained if the noise was 100% white noise (black) and the precision obtained by TESS for objects of similar magnitude (red)

3: WASP-166b

We performed a 9 telescope observation of a transit of the super-Neptune planet WASP-166b [3] on 25th February 2019. The 9 light curves were individually detrended and combined, and the final light curve is shown below. The photometric precision obtained is **152 ppm per half hour**. The observation was simultaneous with TESS observations of WASP-166, and the two light curves are of the **same quality**, and yield **consistent transit parameters**, with the **same uncertainties**.

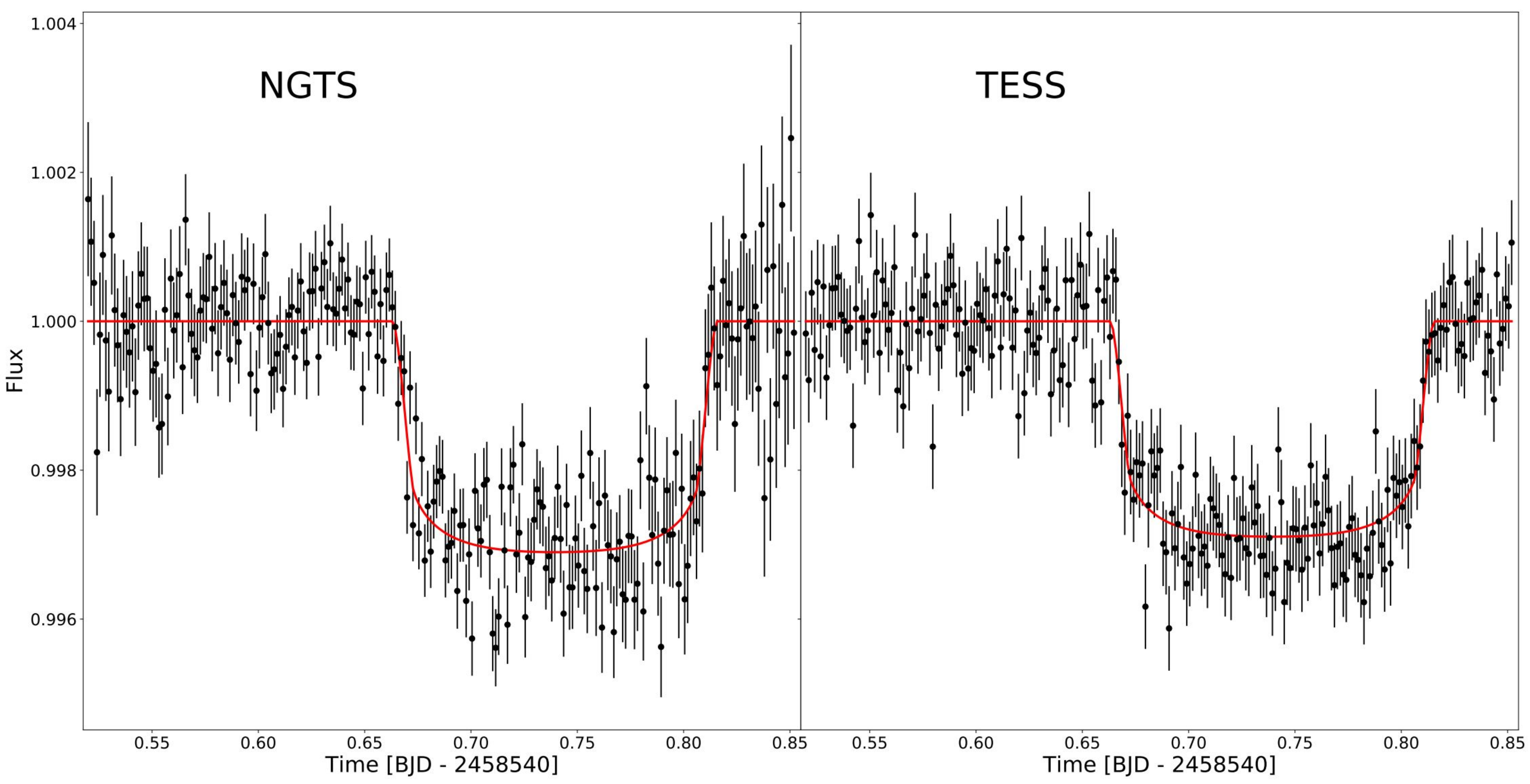

Figure 3: Final NGTS light curve for the 9 telescope observation of WASP-166, compared with the TESS light curve for the same event. The NGTS data is binned to 2 minutes to match the 2 minute TESS cadence.

4: Conclusions and Future

- NGTS bright star light curves are **free from correlated noise**
- Through **simultaneous observations** with multiple telescopes, we **drastically improve the precision**
- We can reach the **same precision as TESS** for V=9 mag stars (eg. WASP-166)
- We also measure the **same transit parameters** as TESS

Through this program, we have already contributed high precision light curves to the TESS discoveries of:

TOI-849 b
TOI-129 b
LTT-9779 b

We will continue this observing program over the coming years, contributing to many more exciting discoveries!

If you have interesting, bright targets and would like a high precision light curve, please get in touch! We are always happy to collaborate!

References

[1] Wheatley, P. J. et al., 2018, *The Next Generation Transit Survey (NGTS)*, MNRAS, 475, 4476

[2] Ricker, G. R. et al., 2014, *Transiting Exoplanet Survey Satellite (TESS)*,

[3] Hellier, C. et al., 2019, *WASP-166b: a bloated super-Neptune transiting a V = 9 star*, MNRAS, 488, 3067

[4] Bryant, E. M. et al., 2020, *Simultaneous TESS and NGTS transit observations of WASP-166 b*, MNRAS, 494, 5873