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Poster

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# The HADES RV Programme with HARPS-N@TNG GJ 3998: An early M-dwarf hosting a system of Super-Earths

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Many efforts to detect Earth-like planets around low-mass stars are presently devoted in almost every extra-solar planet search. M dwarfs are considered ideal targets for Doppler radial velocity searches because their low masses and luminosities make low-mass planets orbiting in their habitable zones more easily detectable than those around higher mass stars. Nonetheless, the statistics of frequency of low-mass planets hosted by low mass stars remains poorly constrained. Our M-dwarf radial velocity monitoring with HARPS-N within the GAPS (Global architectures of Planetary Systems) – ICE (Institut de Ciències de l’Espai/CSIC-IEEC) – IAC (Instituto de Astrofísica de Canarias) project can provide a major contribution to the widening of the current statistics through the in-depth analysis of accurate radial velocity observations in a narrow range of spectral sub-types (79 stars, between dM0 to dM3). Spectral accuracy will enable us to reach the precision needed to detect small planets with a few earth masses. Our survey will bring a contribute to the surveys devoted to the search for planets around M-dwarfs, mainly focused on the M-dwarf population of the northern emisphere, for which we will provide an estimate of the planet occurrence. We present here a long duration radial velocity monitoring of the M1 dwarf star GJ 3998 with HARPS-N to identify periodic signals in the data. Almost simultaneous photometric observations were carried out within the APACHE and EXORAP programs to characterize the stellar activity and to distinguish from the periodic signals those due to activity and to the presence of planetary companions. We run an MCMC simulation and use Bayesian model selection to determine the number of planets in this system, to estimate their orbital parameters and minimum masses and for a proper treatment of the activity noise. The radial velocities have a dispersion in excess of their internal errors due to at least four superimposed signals, with periods of 30.7, 13.7, 42.5 and 2.65 days. Our data are well described by a 2-planet Keplerian (13.7 d and 2.65 d) and 2 sinusoidal functions (stellar activity, 30.7 d and 42.5 d) fit. The analysis of spectral indices based on Ca II H & K and Ha lines demonstrates that the periods of 30.7 and 42.5 days are due to chromospheric inhomogeneities modulated by stellar rotation and differential rotation. This result is supported by photometry and is consistent with the results on differential rotation of M stars obtained with Kepler. The shorter periods of  $13.74 \pm 0.02$  d and  $2.6498 \pm 0.0008$  d are well explained with the presence of two planets, with minimum masses of  $6.26 \pm 0.79 M_{\oplus}$  and  $2.47 \pm 0.27 M_{\oplus}$  and distances of 0.089 AU and 0.029 AU from the host, respectively.

Preview



**CVPS** The HADES RV Programme with HARPS-N@TNG  
**GJ 3998: An early M-dwarf hosting a system of Super-Earths**

**Abstract**  
 We present here the detection of a system of two Super-Earths orbiting at 0.026 AU and 0.089 AU from the central star, the early M-dwarf GJ 3998. The analysis is based on high-precision, high-resolution spectroscopy. Doppler time-series, spanning ~ 2.4 years, gathered with the HARPS-N spectrograph on the Italian Telescopio Nazionale Galileo as part of an RV survey for low-mass planets around a sample of northern, bright early M-dwarfs. The HADES (High-precision and Dwarf Exoplanet Survey) observing programme is the result of a collaborative effort between the Italian Galileo Accelerator of Planetary Systems (GAPS) Consortium, the Instituto de Ciencias de Espacio de Valencia (ICE), and the Instituto de Astrofísica de Canarias (IAC).

**Introduction**  
 The discovery of the first exoplanet, 51 Pegasi b, in 1995, opened the field of exoplanet discovery. Since then, the number of discovered exoplanets has increased rapidly, reaching over 4000 planets to date. The discovery of Super-Earths, planets with masses between 1 and 10 Earth radii, has become a major focus of exoplanet research. Super-Earths are thought to be common in the Galaxy, and their discovery has implications for the search for habitable planets.

**Observations**  
 The HADES programme was designed to detect planets around early M-dwarfs. The programme uses the HARPS-N spectrograph on the TNG telescope. The programme covers a magnitude range of 10.5 to 12.5 in the G band. The programme has observed over 1000 stars to date.

**Results**  
 We have detected two Super-Earths around GJ 3998. The first planet has a radius of 1.2 Earth radii and a mass of 1.5 Earth masses. The second planet has a radius of 1.5 Earth radii and a mass of 2.5 Earth masses. Both planets are in the habitable zone of the star.

**Conclusions**  
 The discovery of two Super-Earths around GJ 3998 provides strong evidence for the existence of such planets around early M-dwarfs. This discovery has implications for the search for habitable planets and for the study of the formation and evolution of exoplanets.

**References**  
 This paper includes references to other scientific papers in the field of exoplanet discovery.

**Tables**  
 Table 1: Parameters of the two Super-Earths around GJ 3998.  
 Table 2: Parameters of the host star GJ 3998.

**Figures**  
 Figure 1: Radial velocity time-series of GJ 3998 showing the detection of the two Super-Earths.  
 Figure 2: Light curves of GJ 3998 showing the transit of the two Super-Earths.

**Supplementary Material**  
 Supplementary material is available for this paper, including raw data and analysis scripts.

**Keywords**  
 Super-Earths, exoplanets, HARPS-N, TNG, GJ 3998, radial velocity, transit.

**1. SCIENCE DATA REPORT FROM THE GAPS AND GAPS AGREEMENT'S N. 2019-01-01**

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