We observe an unexpected diversity of magnetic signatures in the first spectropolarimetric survey of classical Cepheids

Finding magnetic north: an extraordinary magnetic field detection in Polaris and first results of a magnetic survey of classical Cepheids[1]

James A. Barron[1,2], Gregg A. Wade[2], Nancy R. Evans[3], Colin P. Folsom[4], Hilding R. Neilson[5]

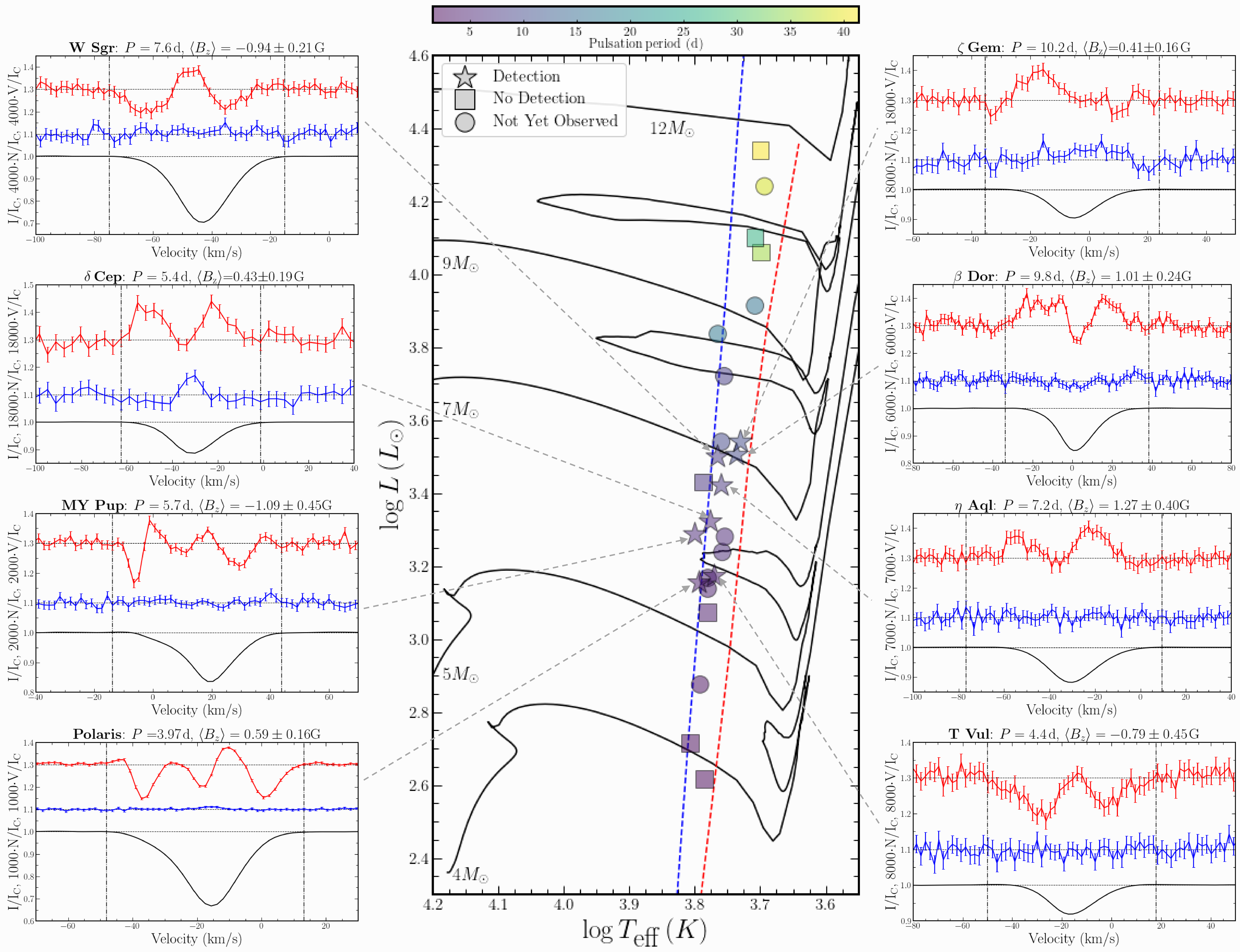
Background

- Classical Cepheids are essential tools for studying cosmology and stellar evolution due to their radial pulsations and period-luminosity relation (Leavitt Law).
- Little is known about the magnetic fields of Cepheids and their impact on Cepheid evolution and stellar properties.
- Previously η Aql was the only Cepheid to have a confirmed magnetic detection [2].

Survey

- We have identified a magnitude-limited sample (V<6) of **twenty-five** Cepheids to perform a **first systematic magnetic study**.
- **Fourteen** targets have been observed to date with ESPaDOnS at the Canada-France-Hawaii Telescope and HARPSpol at the ESO 3.6m Telescope.
- Polarimetric spectra are obtained at high S/N (~4000 at 500 nm) to detect weak magnetic signatures.

Diversity of Stokes V Magnetic Signatures

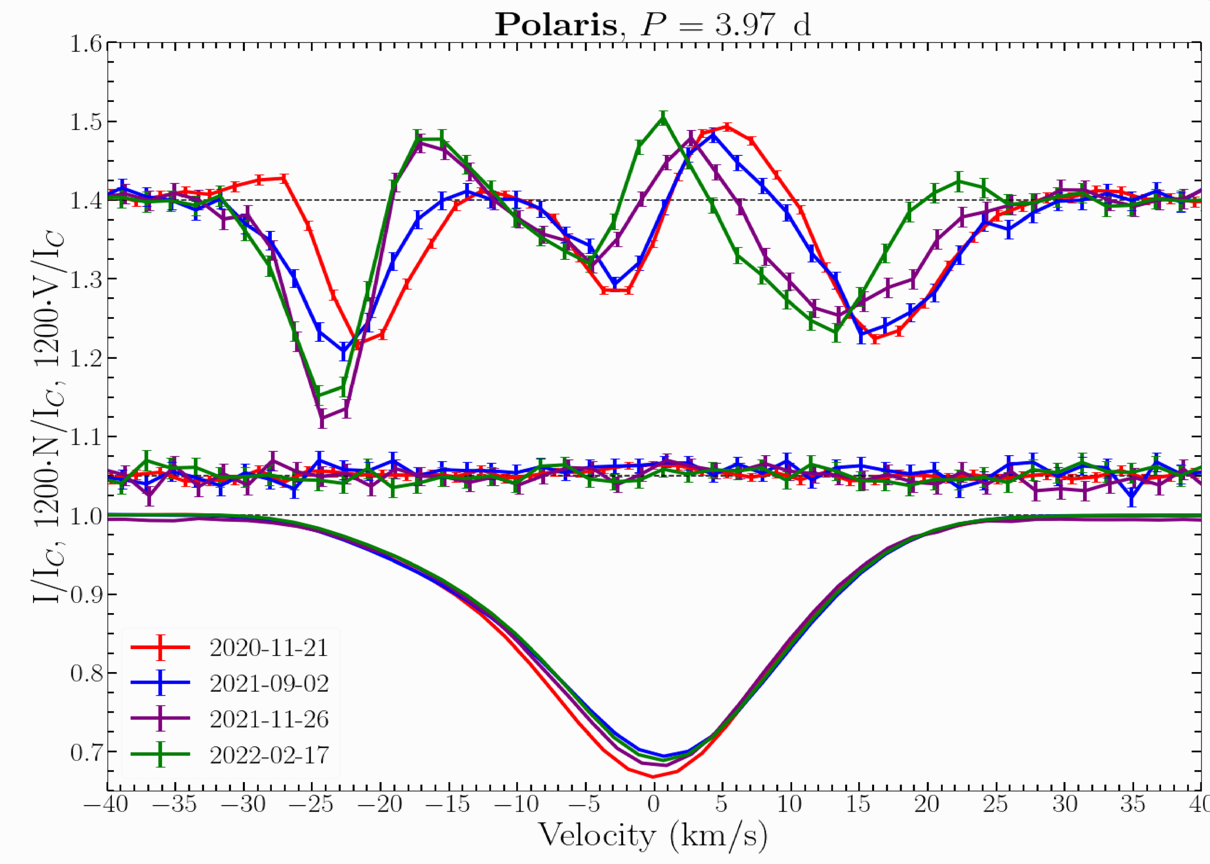


LSD Stokes I (black), V (red) and diagnostic null (blue) profiles for the Cepheid magnetic detections we have obtained to date. The Hertzprung-Russell diagram illustrates that the sample is representative of a wide range of stellar parameters across the instability strip [3, 4, 5, 6].

Discussion

- We detect LSD Stokes V signatures in eight Cepheids, demonstrating that magnetic fields are frequently detectable in this class of stars when observed with sufficient precision.
- Many targets show **peculiar unipolar positive or negative Stokes V lobes,** which are not predicted by standard Zeeman theory. We hypothesize that these features are due to the Zeeman effect modified by atmospheric velocity/magnetic field gradients and shocks [7, 8].
- These Stokes V profiles show **similarities** to those **detected in some Am stars** (e.g. Sirius A) [9]. Preliminary modelling that incorporates gradients can reproduce these signatures [10].
- In contrast, the LSD Stokes V profiles of Polaris and MY Pup appear similar to those observed in cool non-pulsating supergiants [1]. We attribute this to their **low amplitude pulsations**.
- Polarized radiative transfer modelling of Cepheid Stokes V signatures could provide a new and unique probe of Cepheid atmospheric dynamics.

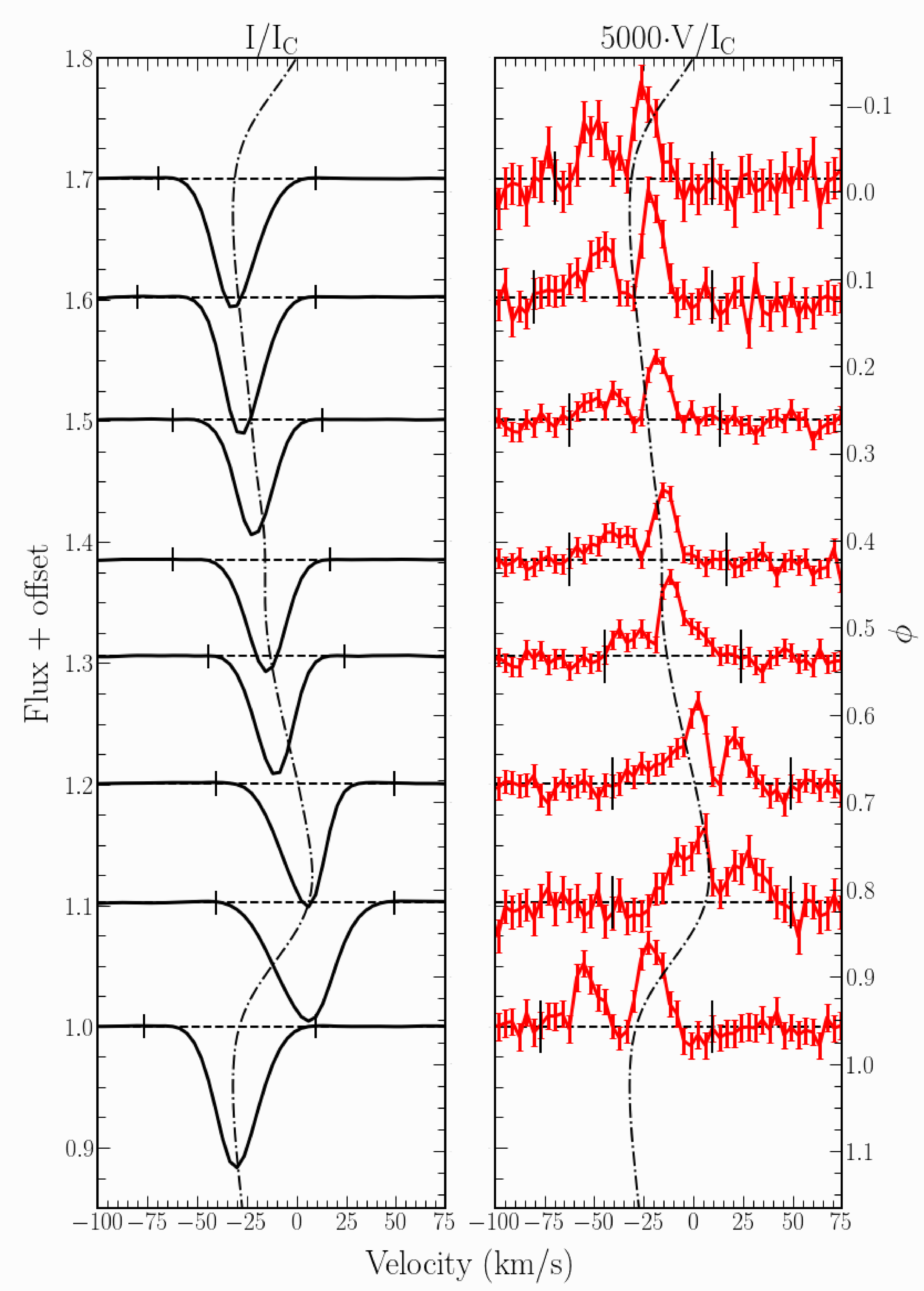
Polaris



Representative Stokes V (top), null (middle) and Stokes I (bottom) profiles for Polaris obtained over five ESPaDOnS runs (centered on 0 km/s).

The Stokes V signatures of Polaris are detected at high S/N and indicate a **complex topology**. We have initiated a monitoring campaign of Polaris to identify its rotational period and **map its magnetic field** using Zeeman-Doppler Imaging.

Impact of Pulsation: η Aql



LSD Stokes I (left) and V (right) profiles of η Aql as a function of pulsation phase. Observations were obtained nightly over the 7.2 d pulsation period.

The Stokes V profile morphology remains relatively stable during pulsation with some variation in the relative height of the blue and red lobes. We will attempt to model these Stokes V profiles accounting for velocity gradients and shocks.

Affiliations:

1. Queen's University, Kingston, ON, Canada
2. Royal Military College of Canada, Kingston, ON, Canada
3. Smithsonian Astrophysical Observatory, Cambridge, MA, USA
4. Tartu Observatory, University of Tartu, Tõravere, Tartumaa, Estonia
5. University of Toronto, Toronto, ON, Canada

References:

1. Barron, J.A., et al. (2022), MNRAS, 512, 4021-4030
2. Grunhut, J. H., et al. (2010), MNRAS, 408, 2290-2297
3. Turner, D. G. (2010), Ap&SS, 326, 219-231
4. Luck, R. E. (2018), AJ, 156, 171
5. Georgy, C., et al. (2013), A&A, 553, A24
6. Anderson, R. I., et al. (2016), A&A, 591, A8
7. Nardetto, N., et al. (2006), A&A, 453, 309-319
8. Hocdé, V., et al. (2020), A&A, 641, A74
9. Petit, P., et al. (2011), A&A, 532, L13
10. Folsom, C. P. (2018), CoSka, 48, 53-57

2022MNRAS.512.4021B

SCAN ME

Queen's UNIVERSITY