The search for Dipper stars in the Orion A Molecular Cloud Complex from NGTS survey data

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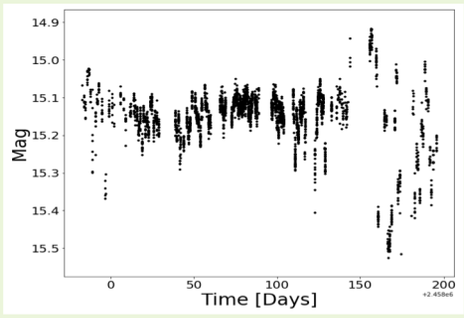
Dipper Stars

- Young, low-mass stellar variables which exhibit drops in flux by as much as 10 to 50 percent for hours to days
- Dipping connected to dust transits in the inner disk region (Bodman et al. 2016)
- Individual dippers studied in Orion via Morales-Calderon et al. 2011, Rice et al. 2015, but no population findings to date… that's where this research comes in!



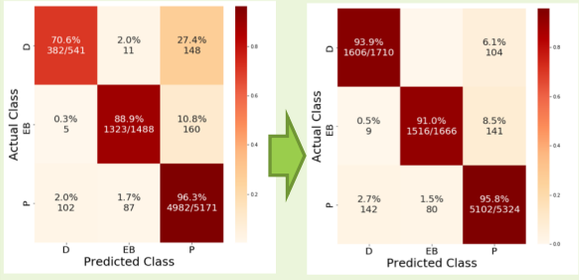
NGTS 12908 light curve, flagged as a dipper by Morales Calderon et al 2011

NGTS Data

- NGTS is a ground-based transit survey based in Paranal, Chile
- Centered on Orion A, may contain stars from Orion D
- 2017-2018 winter observing season
- photometric time-series data for 8,957 objects
- For further info on NGTS, please see Wheatley et al 2017

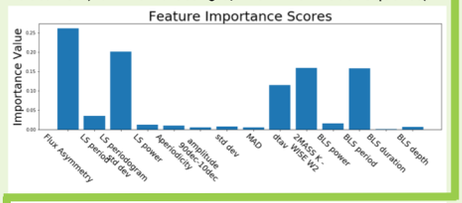
Searching for Dippers (and Disks) with Machine Learning

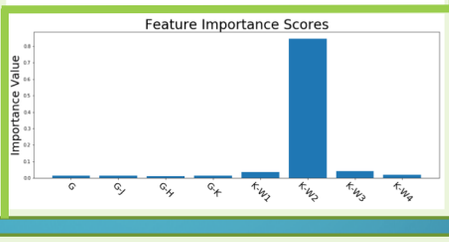
- We apply a two-step iterative random forest classifier to retrieve additional dippers in Orion from NGTS
- Features are built from statistical and numerical properties of the light curves, and the labelled training set of 9 dippers, 25 eclipsing binaries, and periodic variables in Orion is built from previous surveys
- Identify disk-bearing stars using NGTS, 2MASS, and WISE photometry as features for an RF classifier, building a labelled training set built from Yao et al 2018



Confusion matrices for round 1 and 2 of our classifier, using a train-test-split (TTS) of 80-20 and summing results over 300 iterations of random forest in each round. The improved dipper recovery between rounds is attributable to the 19 new dippers identified in round 1.

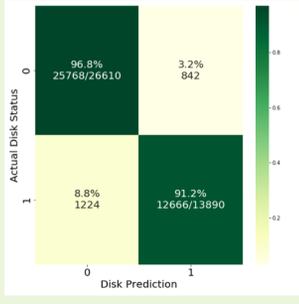
Key features used in our morphology classifier, with importance scores assigned by the second round classifier (LS = Lomb Scargle, BLS = Box Least Squares)



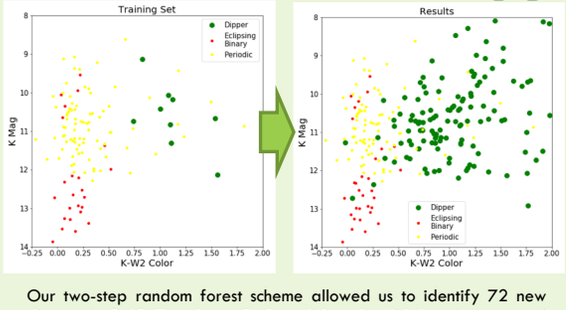


Key features used in our disk classifier, with importance scores assigned by the classifier itself. The IR Color excess K-W2 is most significant in disk classification. G mag is taken from NGTS; J, H, and K mags are from 2MASS; and W1, W2, W3, and W4 mags are from WISE.

Confusion matrix for disk classifier, using a TTS of 80-20 summed over 300 iterations. 0 refers to diskless stars, 1 to disk-bearing stars.



New Orion Dippers and the Orion Dipper Fraction



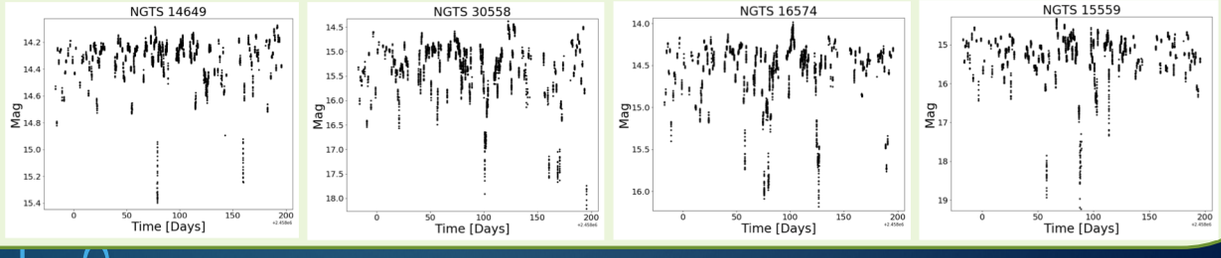
Our two-step random forest scheme allowed us to identify 72 new dippers in ONC. The above CMDs validate the disk-bearing status of dippers, as IR excess (K-W2 > 0.5) indicates the presence of a disk.

Cluster	Age (Myr)	Disk Fraction	Dipper Fraction*	Dipper Number
Rho Oph	0.505	40.2	20.1	22
NGC 2264	3	28	21.6	35
Upper Sco	10	26.7	21.8	42
Orion A	2	27.3	23.6	81

*The Dipper Fraction refers to the proportion of disk-bearing stars that are also dippers.

Relevant statistics for the four well-studied dipper populations: NGC 2264 (Cody et al. 2014), Upper Sco, Rho Oph (both Hedges et al. 2018), and ONC. The ONC dipper population is the largest one studied to date, and the ONC dipper fraction aligns with previous findings and supports the inclination effect hypothesis of McGinnis et al 2015.

New Dipper Light Curves:



Future Work

- Characterize the unique properties of Orion dppers to compare with previous moels (e.g. Bodman et al. 2016)
- Use Orion membership analysis of Kounkel et al. 2018 to study dipper evolution as a function of age

Acknowledgements

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