Exoplanets and variable stars in K2 data. A Pro-Am collaboration

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Brief Abstract

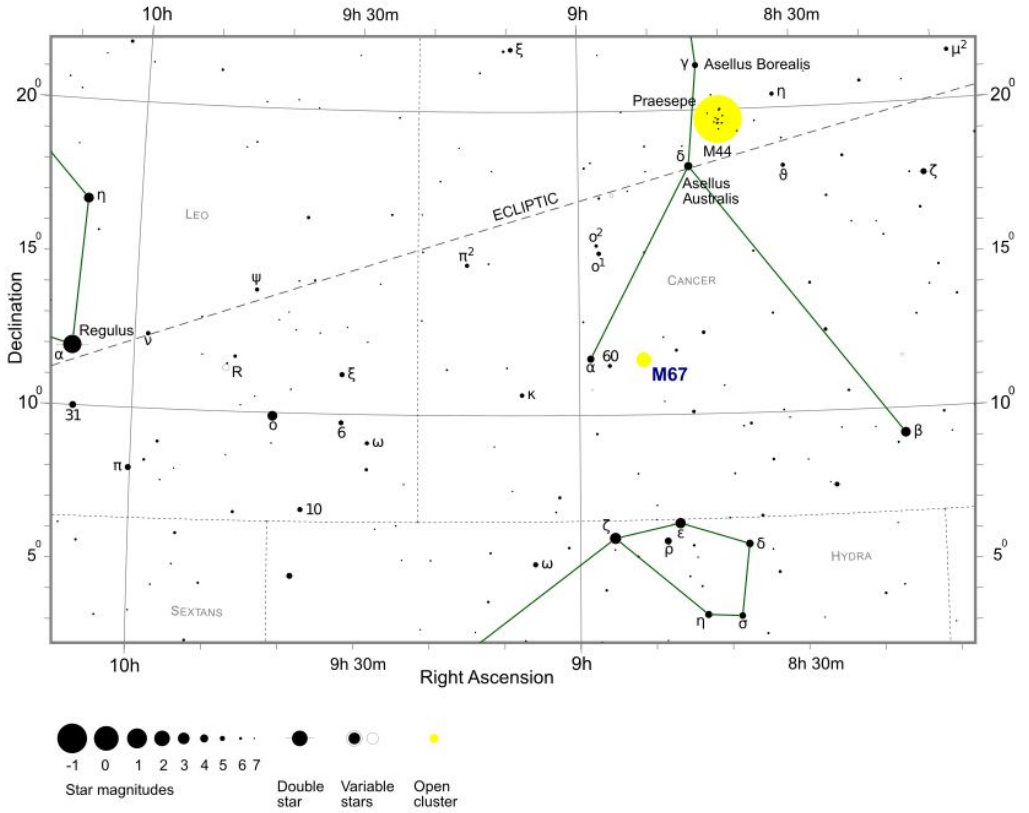
We explore the potential of Pro-Am collaborations inspecting one campaign of K2 in order to:

- Detect and characterize new exoplanet candidates.
- Recover previously published candidates and confirmed planets, whose parameters will be improved.
- Detect and characterize variable stars.
- Focus on targets belonging to M44 and M67 clusters.

Context

- K2 has monitored 19 ecliptic fields with the main scientific goal of discovering transiting exoplanets. Many campaigns overlap each other containing, among others, M44 and M67 clusters.

- Pro-Am collaborations have been proven to be a powerful tool to detect transits (e.g. Fischer et al. 2012, Zink et al. 2019), so although several confirmed exoplanets and candidates have been found (e.g. Livingston et al. 2018, Yu et al. 2018), visual inspection of light curves by trained amateur astronomers can result in the discovery of new planet candidates as well as hundreds of variable stars.



- Adding photometry from latest campaigns and getting updated stellar parameters (Gaia collaboration et al. 2018, Hardegree-Ullman et al. 2020) is essential for a better characterization of confirmed planets, as well as for validating and improving the parameters for published candidates. This is of special interest for planets in clusters M44 and M67, key environments to check the planetary formation, evolution and migration theories.

Methods

- 11 (previously trained) amateur astronomers visually inspected the K2 Self Flat Fielding light curves (Vanderburg & Johnson, 2014) for the stars of one campaign, in batches of 1000 stars, selecting those with obvious variability and assigning a preliminar classification. Selected stars from each batch were also inspected by a different member of the team, to double check their variability and classification. All the *transiting planet* signals were also checked by professional astronomers.

- Among the variable stars, for those with periodic light curves (pulsating, rotating, eclipsing binaries) we obtained their periodograms with the GLS (Zechmeister & Kürster 2009) or BLS (Kovács et al. 2016) algorithms to obtain their periods and phase-folded light curves.

- The photometry for all the *bona fide* signals classified as *planet* was searched in previous overlapping campaigns, also verifying if they were already published. The data was analyzed with BLS algorithm to obtain transit parameters and to check for the presence of additional signals.

- Finally, all the stars of our initial sample were automatically analyzed using the BLS algorithm in order to recover possible undetected transit signals and to compare both methods (human vs automatic search).

211918855		Binaria	
211919004		Planeta	
211919173		Pulsante	RR Lyrae
211919528		Binaria	
211919680		Binaria	
211920311		Binaria	
211920604		Binaria	
211920612		Binaria	
211921220		Binaria	
211921308		Binaria	
211922225		Pulsante	Delta Scuti
211922849	M44	Binaria	
211923563		Binaria	
211924657		Planeta	
211606670		Rotante	
211925547		Pulsante	Delta Scuti
211926098		Binaria	
211926820		Pulsante	Delta Scuti
211927125		Binaria	
211928959		Binaria	
211929618		Binaria	
211929937		Binaria	
211930482		Binaria	

Results

- **20427** inspected stars.
- **1706** stars classified as variable (Fig 1).
- **190** of these 1706 stars belong to M44 (165) or M67 (25) clusters.
- **55** high quality transit signals detected in 44 stars. **13 signals are new**. **42** signals correspond to previously published candidates (**13**) and confirmed planets (**29**) detected in overlapping campaigns (Fig 2).

Fig 1

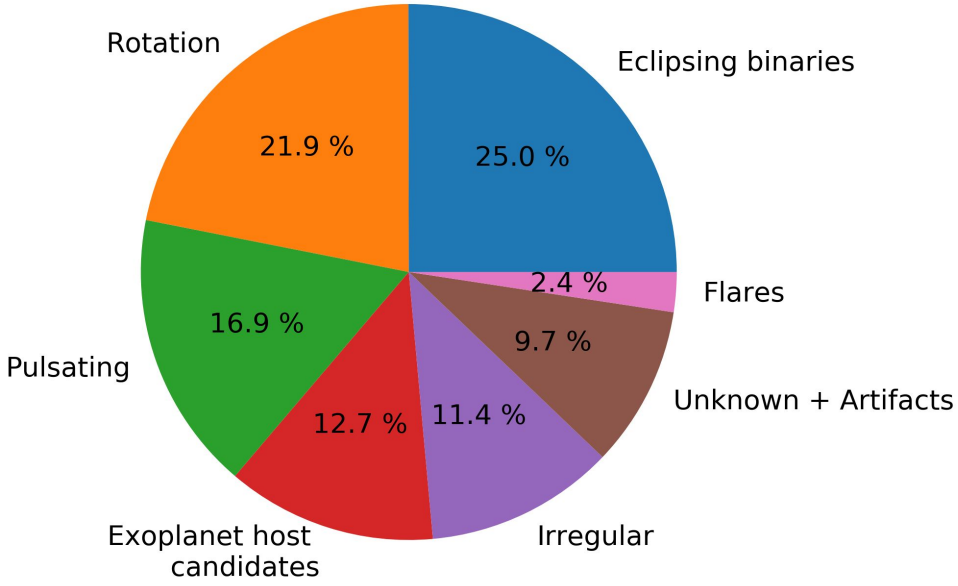
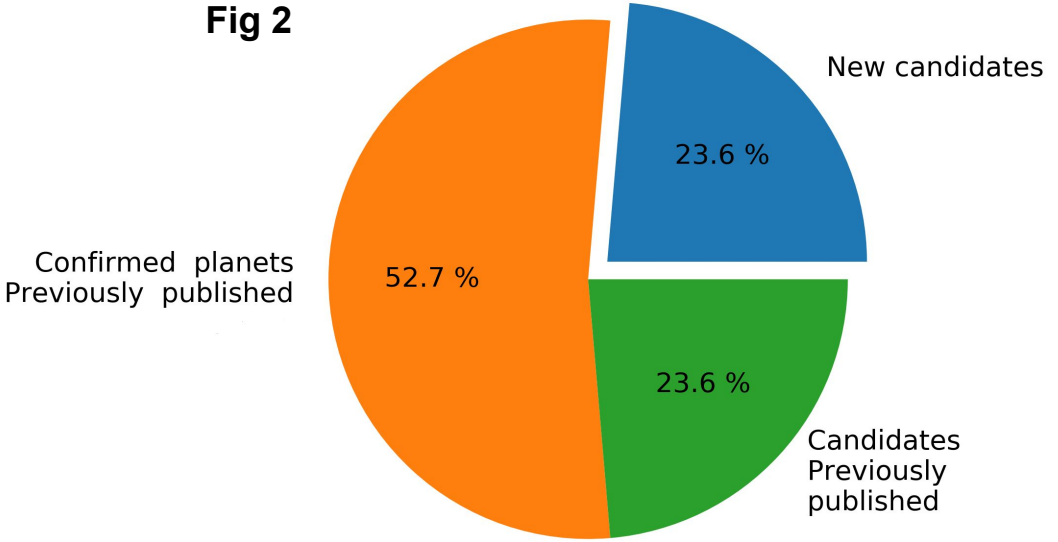


Fig 2



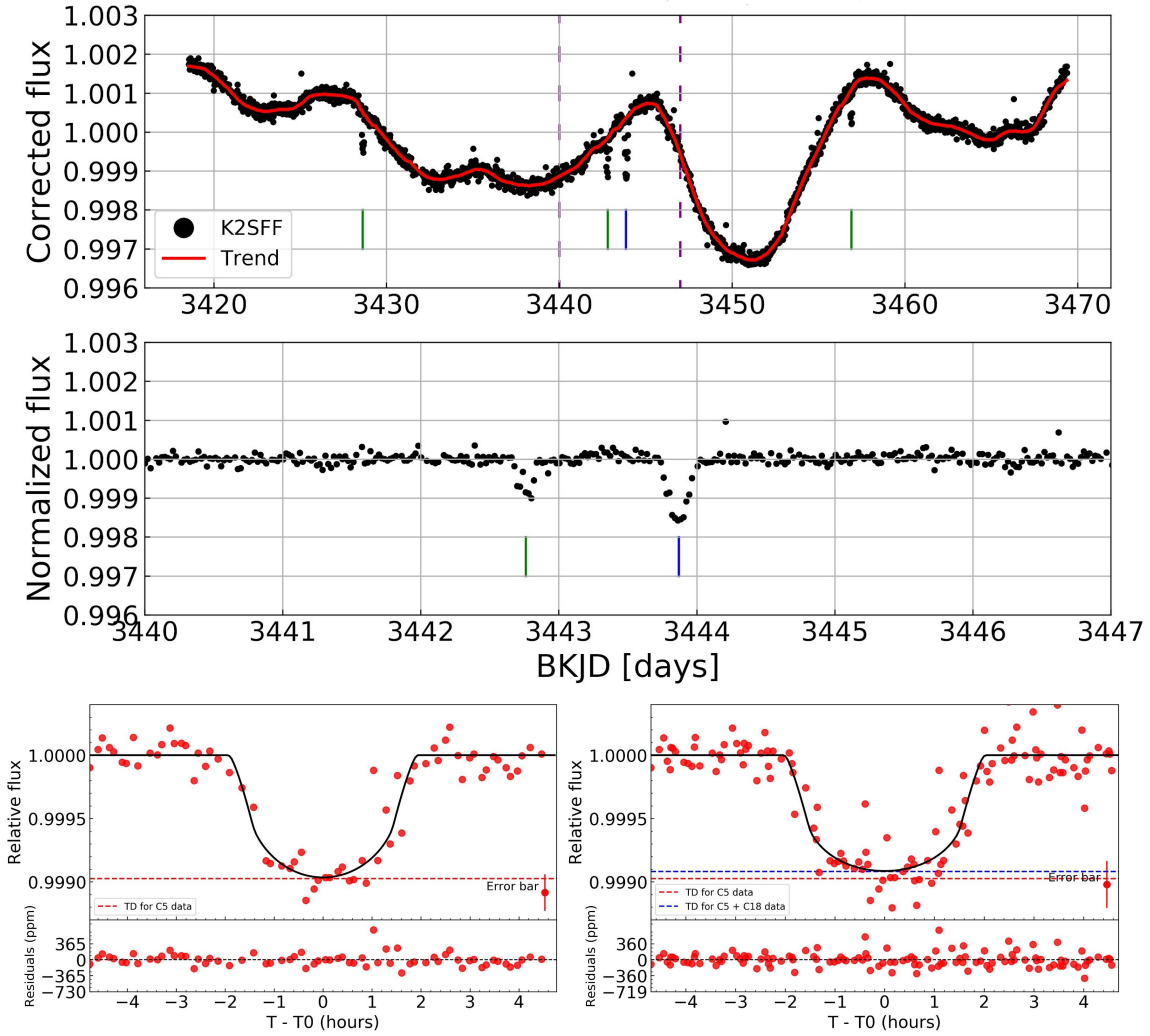


Fig 3. K2-274b (Livingston et al. 2018) recovered in this work (green lines). MCMC fit combining archival and recent photometric data and considering spectroscopic parameters (Hardegree-Ullmann 2020) updates the published radius R = 2.2 ± 0.1 *Re* to 2.1 ± 0.1 *Re*. **An additional transit-like event** has been detected in this work (blue line), which would correspond to a ~3.3 *Re* mini-Neptune.

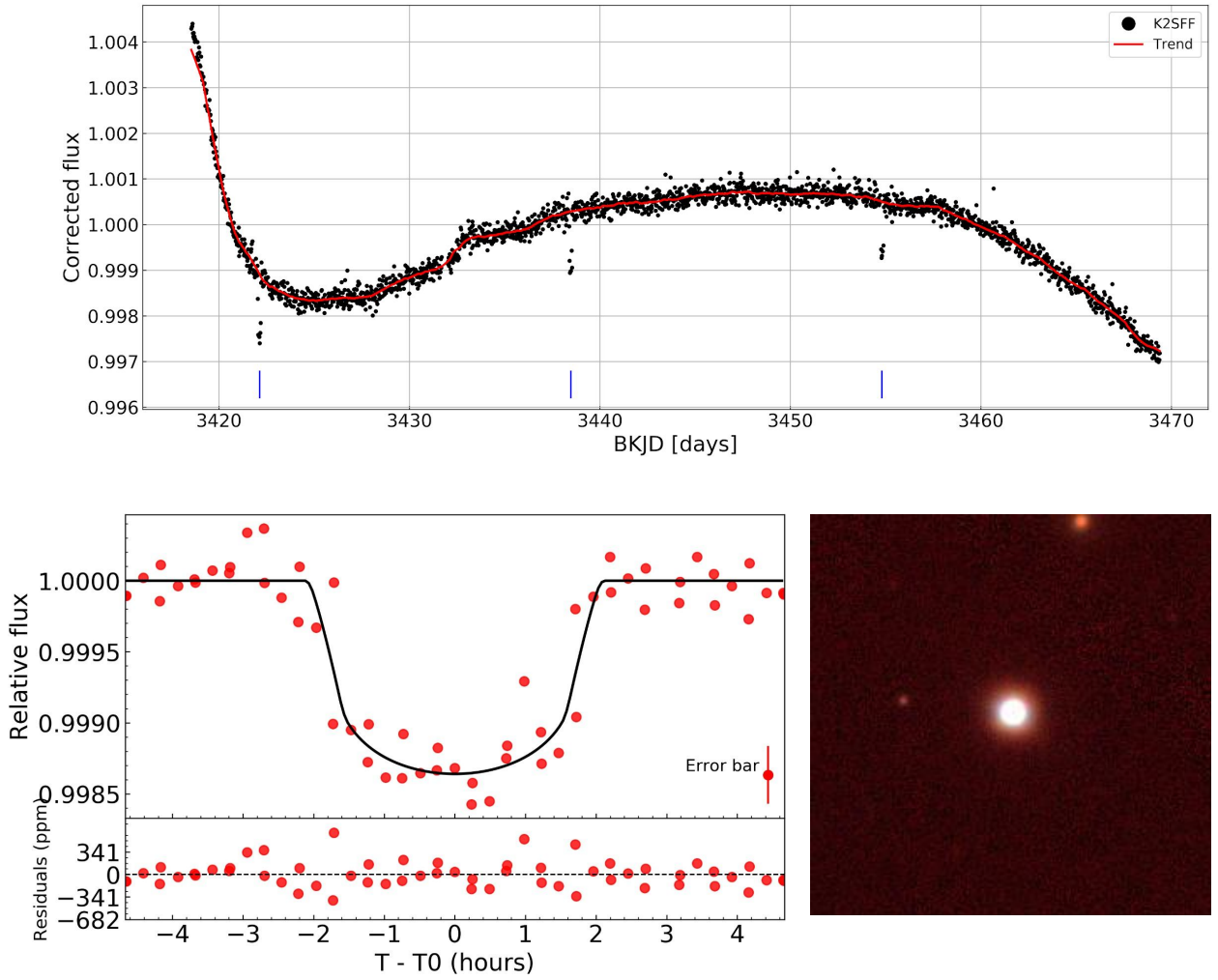


Fig 4. A **new transiting exoplanet candidate** found in this work. Top: corrected light curve. Blue lines show transit events. Bottom left: phase-folded light curve. Bottom right: 1' x 1' Pan-STARRS1 image shows no close contaminant stars. VESPA analysis results in FPP = 0.0003, being thus a validated planet. The MCMC fit results in a R = 3.6 ± 0.2 *Re* mini-Neptune with an orbital period Porb = 16.335 ± 0.001 *d* and equilibrium temperature Teq = 715 ± 40 *K*.

Future & Impact

- Perform false positive analysis and obtain accurate stellar and planetary parameters for new discovered candidates.
- Perform false positive analysis for previous published candidates.
- Update the parameters of previous published candidates and confirmed planets, adding photometry data and updated stellar parameters.
- Build a complete variable star catalogue adding recent data to previous data from overlapping campaigns.
- Detailed study of targets belonging to M44 and M67.
- Measure the efficiency of visual inspection, comparing with automatic detection methods.
- Extend the collaboration to poor studied campaigns of K2 and additional photometric surveys as TESS, increasing also the number of participants.
- **Blurring frontiers through Pro-Am collaborations.**

"The whole is more than the sum of its parts"

Aristotle