"Dipper" stars in the Upper Sco and ρ Oph star forming regions identified from the K2 mission

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Abstract. We report the discovery of 24 new "dippers" – young stars with disks that show 1-3 day long abrupt drops in their light curves. The search was based on the K2 Campaign 2 observations of the Upper Sco and ρ Oph star forming regions.

1 Introduction

Young stars are typically irregular variables, and they vary on different time scales, due to a number of mechanisms, such as rotational modulation by cold spots on the surface of the star or hot spots related to accretion and variations in the accretion rate from circumstellar disks.

The *Spitzer* YSOVAR (Young Stellar Objects VARiability) project ([4]) was the first to report "dippers" in the infrared: 41 objects in their sample showed "brief, sharp drops in their flux density with durations of one to a few days", superimposed on otherwise smooth or nearly flat light curves (LCs). Similar behaviour was seen earlier in the optical LCs of individual protostars and T Tau stars by [3].

Campaign 2 of the K2 mission utilized the *Kepler* spacecraft ([2]) to observe the Upper Scorpius and the ρ Ophiuchus star-forming regions. [1] announced 25 dippers. Here we report a thorough search aimed at finding more dippers in the same K2 campaign data.

2 Search and results

First, we filtered the normalized LCs of [5] through a high-pass filter with a cut-on frequency of $1\,\mathrm{day}^{-1}$, and estimated the standard deviation σ of each filtered LC using a biweight function. We considered as candidate dippers the objects with $\geq 3\sigma$ dipping event(s) on the filtered LCs. Dips with only one data point were discarded. This filtering removes periodic variations, because if the rotation-related variability is not removed, it can mask some of the dips.

Following [1], we parametrized dippers' behavior: (1) number of dips in the filtered LC N_{dip} – a lower limit to N_{dip} excludes spurious events; (2) average depth of the three deepest dips in normalized LC D_{dip} – it characterizes the dips' strength, as a sample; (3) the ratio R_{dip} of the average depth of the three deepest dips D_{dip} to σ – it measures the significance of the dips, again as a sample.

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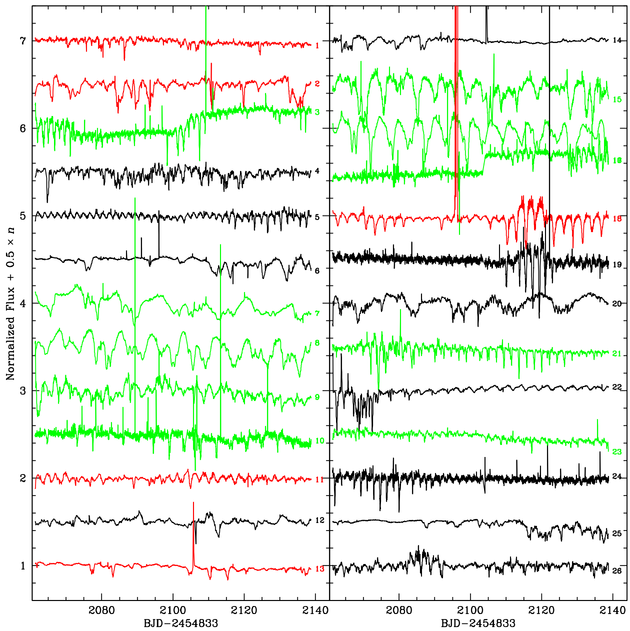

Figure 1. Light curves of a subset of the selected dippers: newly identified objects from this work are plotted in black; objects previously reported in [1] are plotted in red and green, depending on whether they are listed in their Tables 1 or 5, respectively.

In our survey we set the limits as follows: $N_{dip} > 3$, $D_{dip} > 0.07$ and $R_{dip} > 5$, somewhat more relaxed than the values adopted by [1]. These numbers were selected after inspecting the LCs, and the distributions of the parameters for the entire Campaign 2. We found no significant correlations between any of these three parameters, because they appear to constrain different aspects of the objects. The automatic identification yielded 475 dipper candidates. Next, we conservatively ignored some LCs that show extremely unreasonable artifacts, most likely due to failure of the de-trending. We removed sources with periodic dips, probably related to stellar spots, and objects that suffer contamination from nearby sources.

Our approach works well – we recovered all dippers listed by [1] and 24 new ones (Fig. 1). Further details are available in a forthcoming paper (Zhang & Ivanov, in preparation).

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