EXPLORE/OC: A Search for Planetary Transits in the Field of NGC 2660

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Abstract/Introduction

As part of the EXPLORE Project, we have recently begun a survey of southern open clusters with the aim of detecting planetary transits (EXPLORE/OC). Probing cluster populations provides a complement to our ongoing deep monitoring studies of rich Galactic fields.

Open cluster monitoring provides the following advantages and incentives:

1. in general, metallicity, age, distance, and foreground reddening are either known or may be determined for cluster members (more easily than for random field stars). Thus, planets detected around cluster stars will immediately represent data points for any statistic correlating planet frequency with age or metallicity of the parent star.
2. the planet-formation processes, and hence planet frequencies, may differ between the open cluster and Galactic field populations. This study allows the EXPLORE Project to compare these two different environments.
3. specific masses and radii for cluster stars may be targeted in the search by the choice of cluster and by adjusting exposure times for the target. In general, smaller stars offer better chances to detect the low-amplitude transit signal.

The difficulties and challenges involving open cluster surveys are:

1. the number of monitored stars is typically lower than in rich Galactic fields, reducing the statistical chance of detecting planets.
2. determining cluster membership of stars in the open cluster fields without spectroscopic data is difficult due to the contamination by Galactic field stars. Since the clusters are typically concentrated toward the Galactic disk, this contamination may be significant.
3. differential reddening across the cluster field and along the line of sight can make isochrone fitting (and subsequent determination of age, distance, and metallicity) difficult.

In this presentation, we illustrate some of the points mentioned above, describe our observing and data-reduction strategies, and show some of our preliminary results of our study of **NGC 2660** using the Carnegie Institution's Swope 1m Telescope at **Las Campanas Observatory** in Chile.

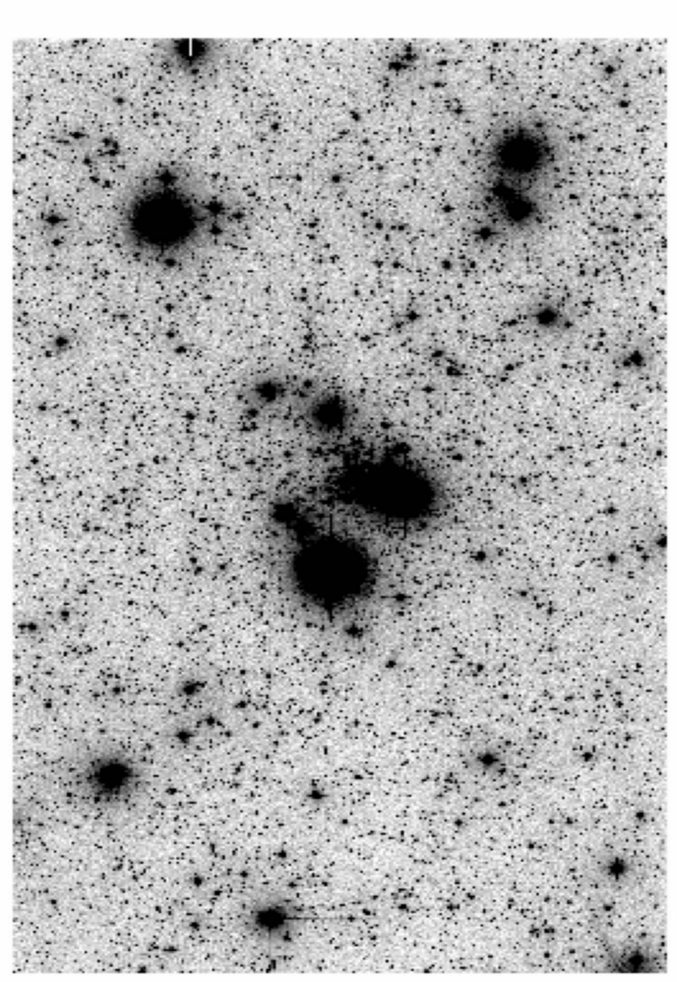

Fig 2: The field of the open cluster **NGC 2660**. N is toward the top, E to the left; (l,b) = (266,-3). The field size is around 23 arcmin by 15 arcmin. The total number of stars we are monitoring in the field is around 31000.

For additional information, you may visit the following EXPLORE Project websites:

http://www.ciw.edu/seager/EXPLORE/explore.htm (global project website)

http://www.ciw.edu/seager/EXPLORE/open_clusters_survey.htm (EXPLORE/OC)

The publication describing the EXPLORE Project is:

Mallén-Ornelas et al. 2003 , The Astrophysical Journal, Volume 582, pp. 1123-1140.

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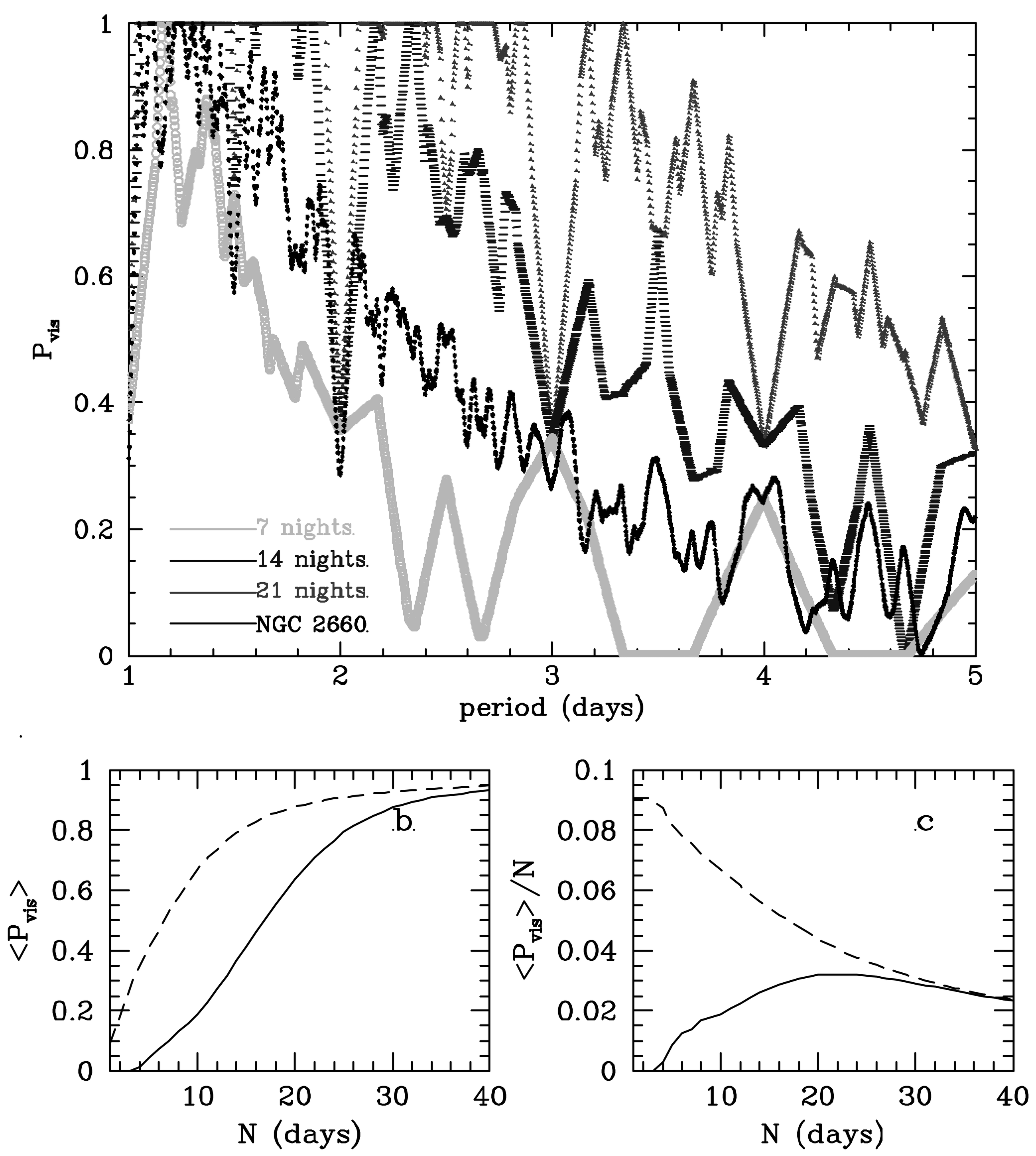


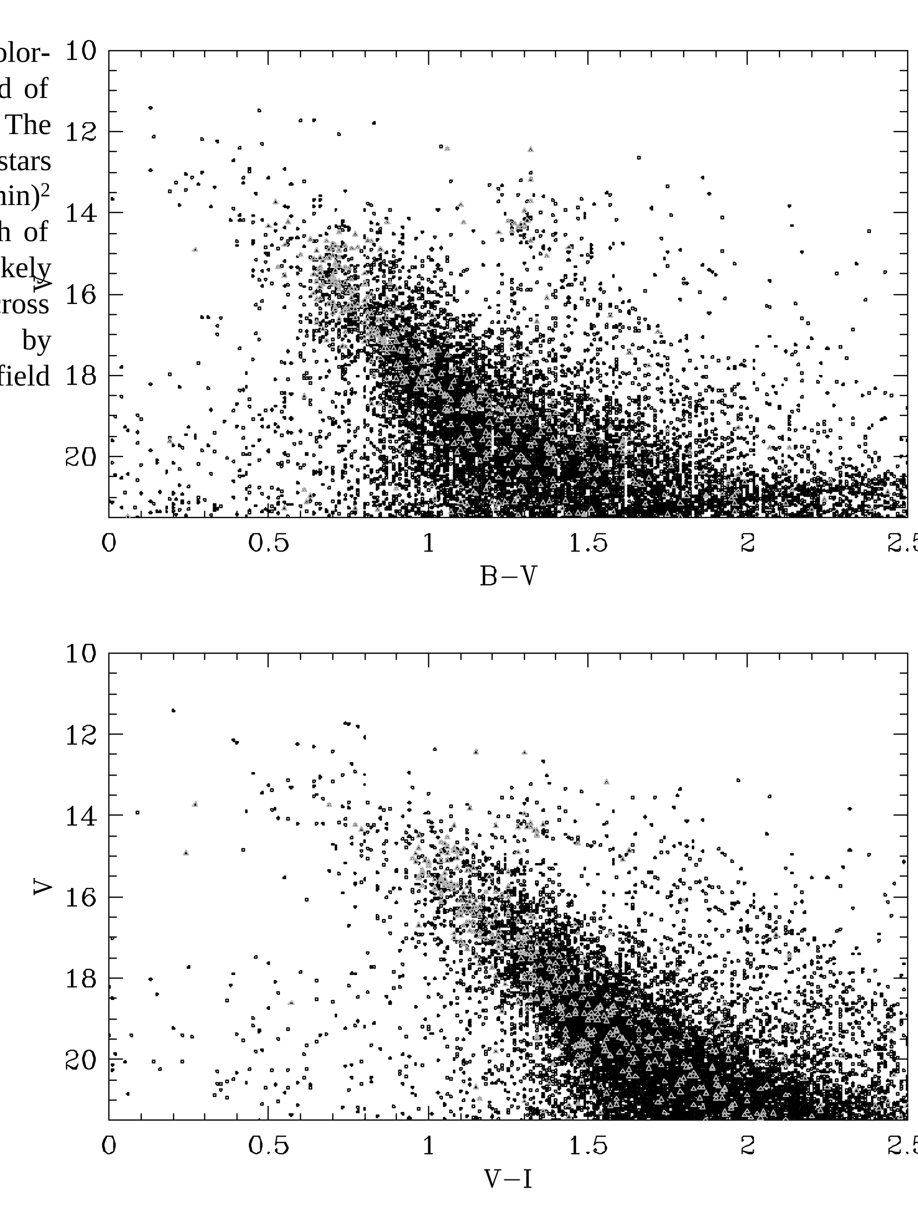
Fig. 1: Probability P_{vis} of detecting existing transiting planets with different orbital periods. P_{vis} is calculated with the requirement that two transits must be observed.

Panel a: P_{vis} of detecting 2 transits of an existing transiting planet with 2-5 days periods after 21 (**red triangles**), 14 (**blue bars**) and 7 (**green circles**) consecutive, uninterrupted nights of observing (10.8 hours per night). The difficulty of detecting some phase angles is shown by the dips in the curves (for instance, orbital periods of an integer number of days may always feature their transits during the day and are therefore statistically harder to detect). All phases are considered for each period. The **black triangles** curve shows the real P_{vis} for our monitoring study of **NGC 2660** (19 nights of 7-8 hours per night, with interruptions due to weather and telescope scheduling; see **Fig. 5**).

Panel b: The mean $<P_{vis}>$ as a function of number of consecutive nights in an observing run (10.8 hour nights). The solid line is for the requirement to detect two transits and the dashed line for one transit. This figure indicates how much higher the likelihood of finding existing transits becomes with an increasing number of nights in an observing run.

Panel c: The efficiency of $<P_{vis}>$ per night. For the two transits requirement (solid line) and 10.8 hour long nights, an observing run of 21 nights is most efficient. For the single transit requirement, the efficiency decreases monotonically with the number of nights since additional nights will add less and less probability of detecting "new" transits.

Fig 3: V/B-V and V/V-I color-magnitude diagrams of the field of the open cluster **NGC 2660**. The **green triangles** represent stars located within the inner (3 arcmin)^2 of the cluster center. The width of the main sequence is most likely due to differential reddening across the field of view and by contamination due to Galactic field stars.



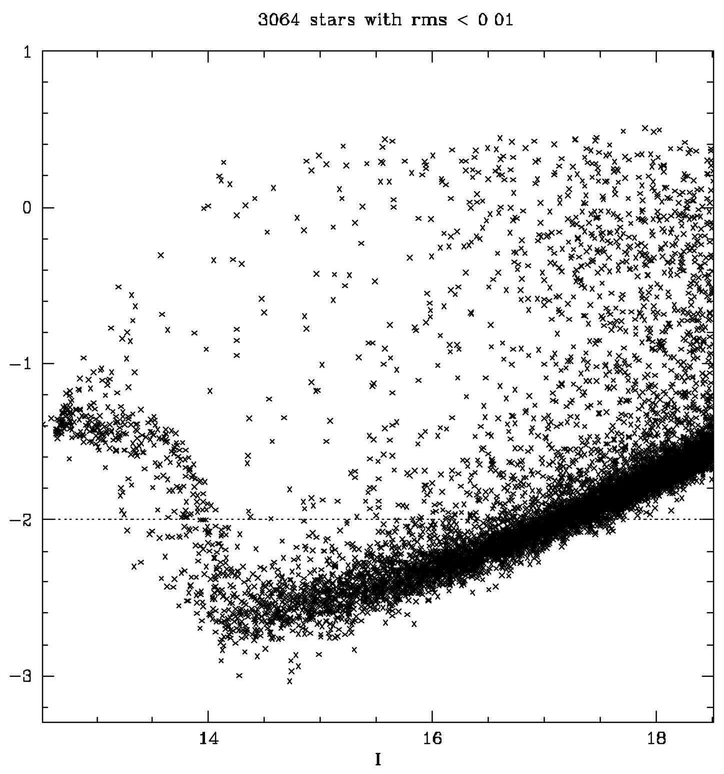


Fig 4: Photometric precision of night 1 of our monitoring run of **NGC 2660**. Of the roughly 21000 stars shown in this diagram, slightly more than 3000 have photometry of precision 1% or better. This rms is measured as the scatter around the mean magnitude of the star under investigation. The 1% photometry stars cover a magnitude range of slightly above 2.5 mags. By adjusting the exposure time, one can therefore target OC member stars of a range of certain spectral types to maximize the likelihood of detecting a transit (taking into account distance to the cluster and foreground reddening).

NGC 2660 Properties

- RA / Dec (2000) = 8:42:38 / - 47:12:02
- l / b = 265.9 / - 3.01
- distance = 2.8 kpc
- E(B-V) = 0.313
- age = 1.1 Gyr
- [Fe/H] = - 0.18

source: WEBDA Database

http://obswww.unige.ch/webda/webda.html

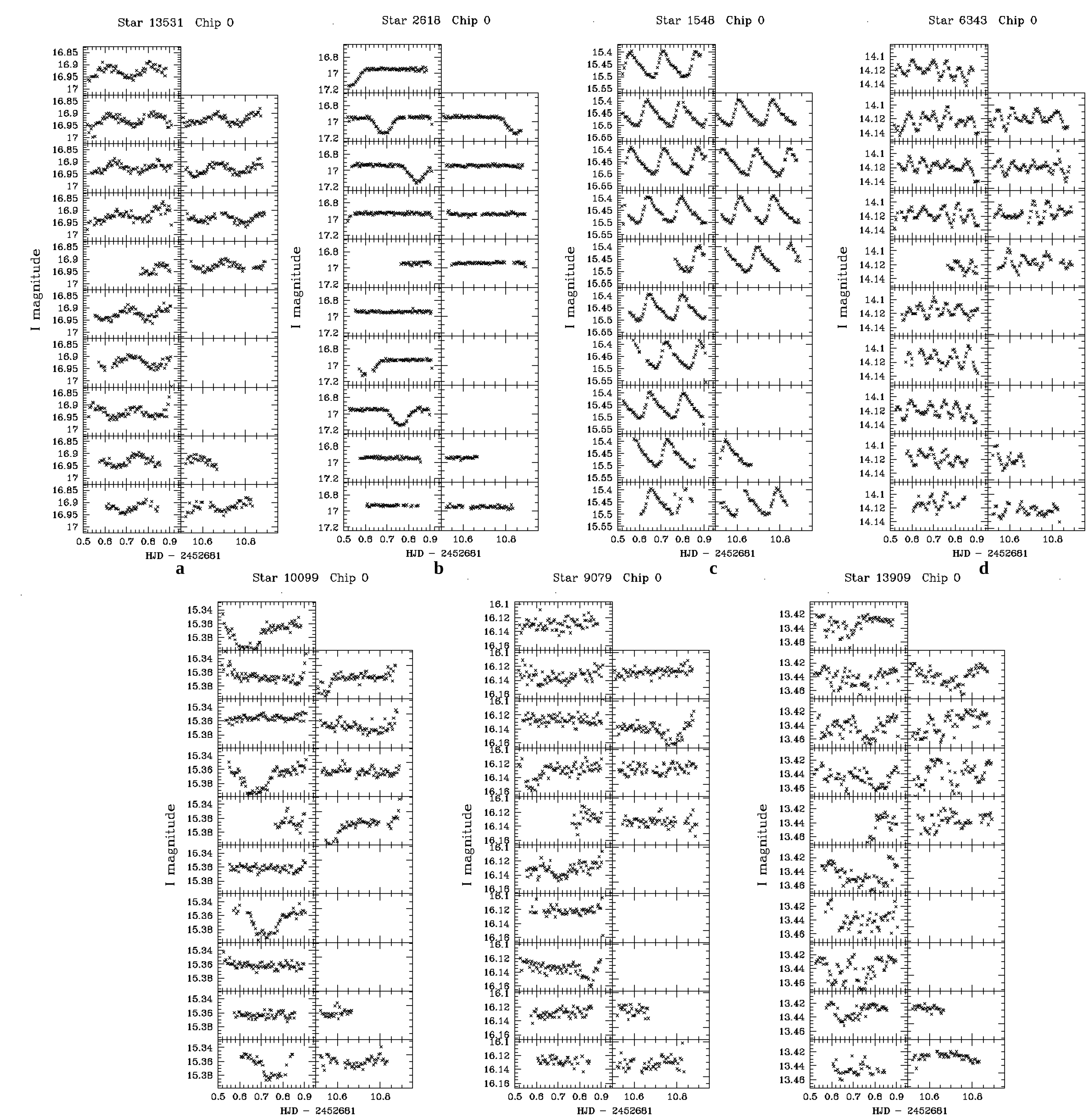


Fig 5: Examples of real-time (unphased) lightcurves from our monitoring run of **NGC 2660**. Every panel represents data taken during one night, starting on the bottom left with night 1. Night 2's data are directly above it, night 3 above that and so on. We did not obtain any data during nights 13-15. Note that the magnitude scale is different for every example shown. All these lightcurves were obtained in quasi-real-time at the telescope to implement a dynamic observing strategy to maximize observing/P_{vis} efficiency for a given number of nights.

The top four panels (**a – d**) show a number of variable stars we typically detect in the open cluster fields. The bottom three panels (**e – g**) display the kind of low-amplitude signal that we are looking for in the search for planetary transits.