The largest modern analysis of chromospherically active stars towards the Galactic bulge

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OGLE

The Optical Gravitational Lensing Experiment (OGLE)


photo by Krzysztof Ulaczyk

- 1.3 m diameter telescope at Las Campanas Observatory dedicated for the OGLE project.
  - Two standard filters — *I* and *V* in the Johnson-Cousins system.
    - Continuous observation since 1992. Now in the 4th phase in operation (OGLE-IV) *(Udalski et al., 1992, 1993, 1997, 1998, 2013, 2015).*
      - **Over a bilion stars observed every night!** — the OGLE is one of the largest sky variability surveys worldwide, and a gold mine for the scientists.

Chromospherically active stars in the Milky Way

1

Up to 2011, about 500 spotted stars were observed with any kind of method *(Strassmeier, 2011).*

2

Previous analyses were based on several hundred stars *(Hall, 1991, 1994, 1998). The largest analysis consists of about 3000 stars from MACHO data (Drake, 2006).*

3

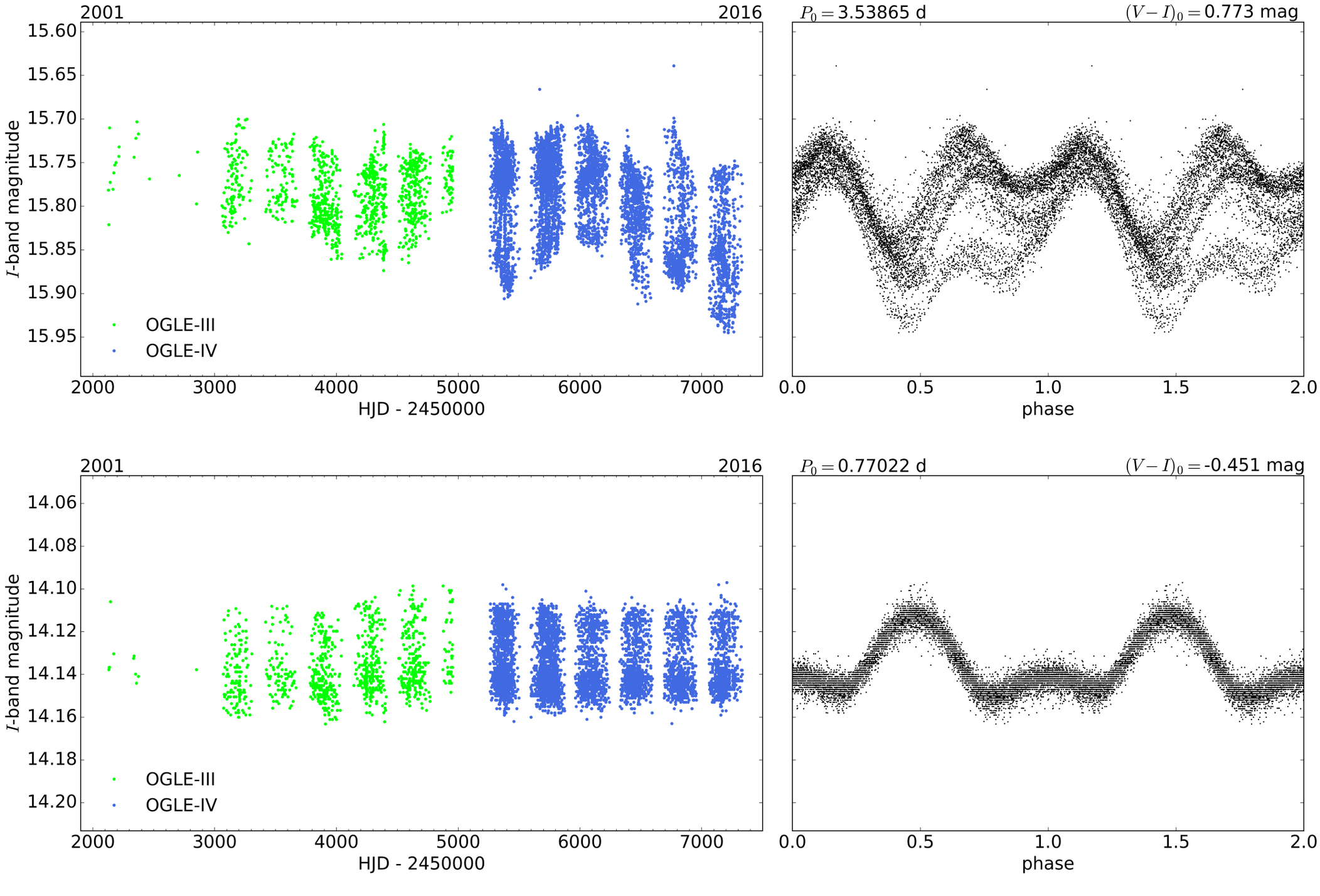
The most up-to-date catalogue is from 2008 and consists of 409 stars *(Eker et al., 2008).*

4

Up-to-date we have discovered almost 20 000 spotted stars and analysed over 13 000 of them!

Examples of spotted stars' light curves

Typical time span of light curves is 15 years and in some cases it is up to 25 years!



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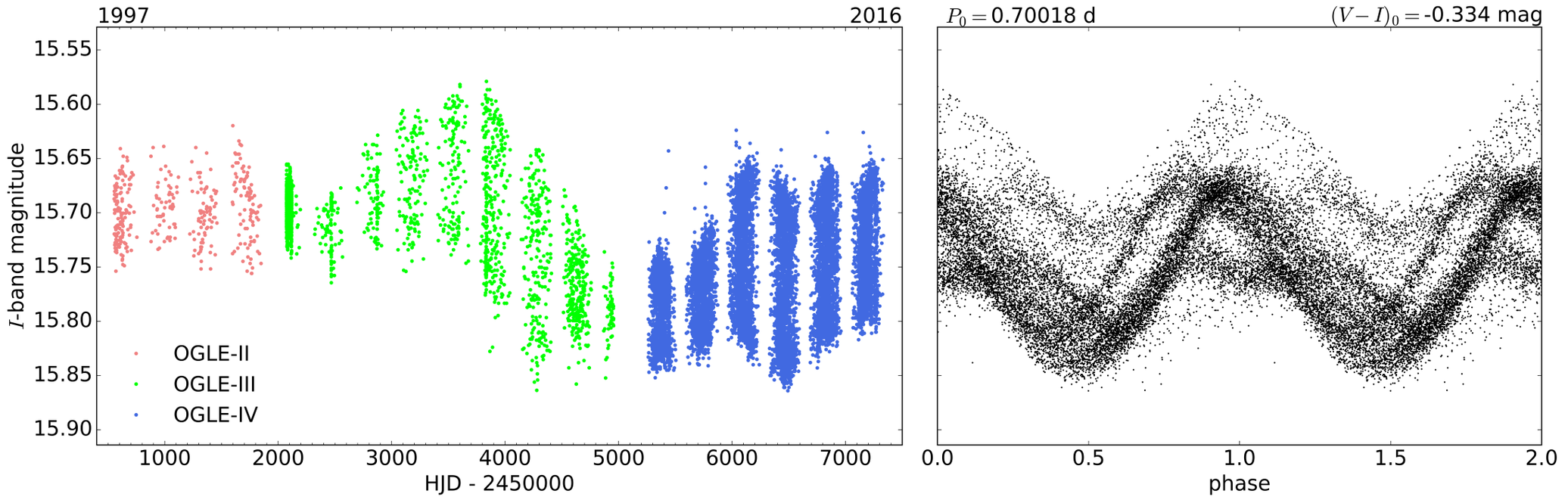

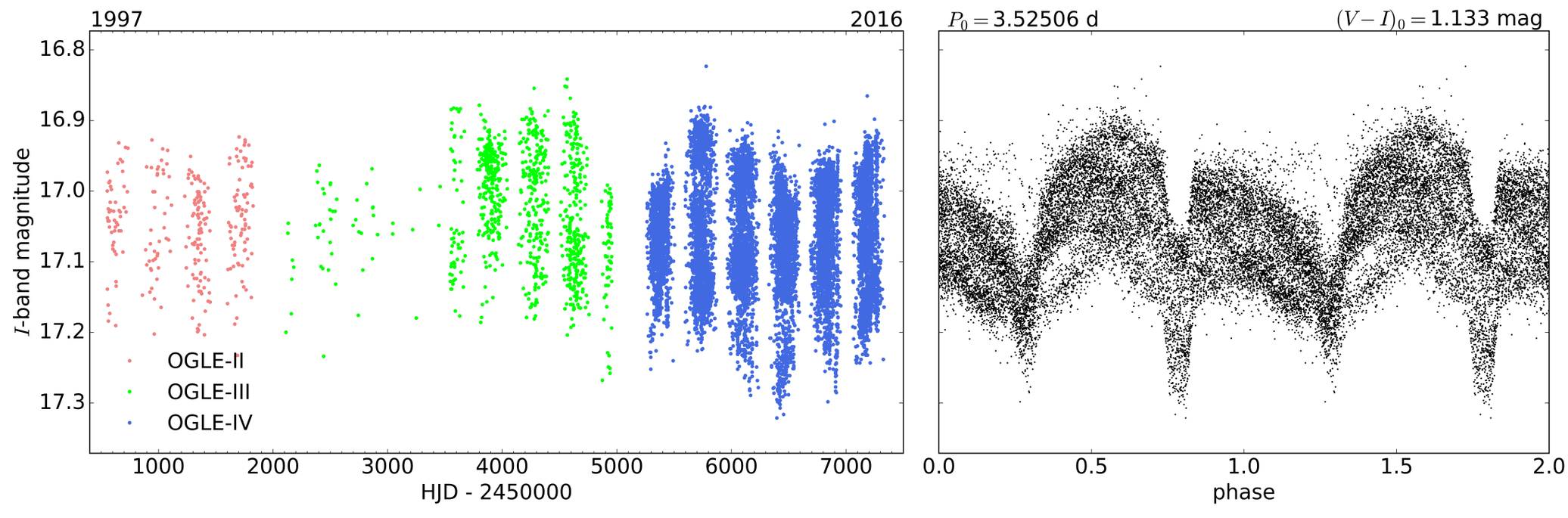

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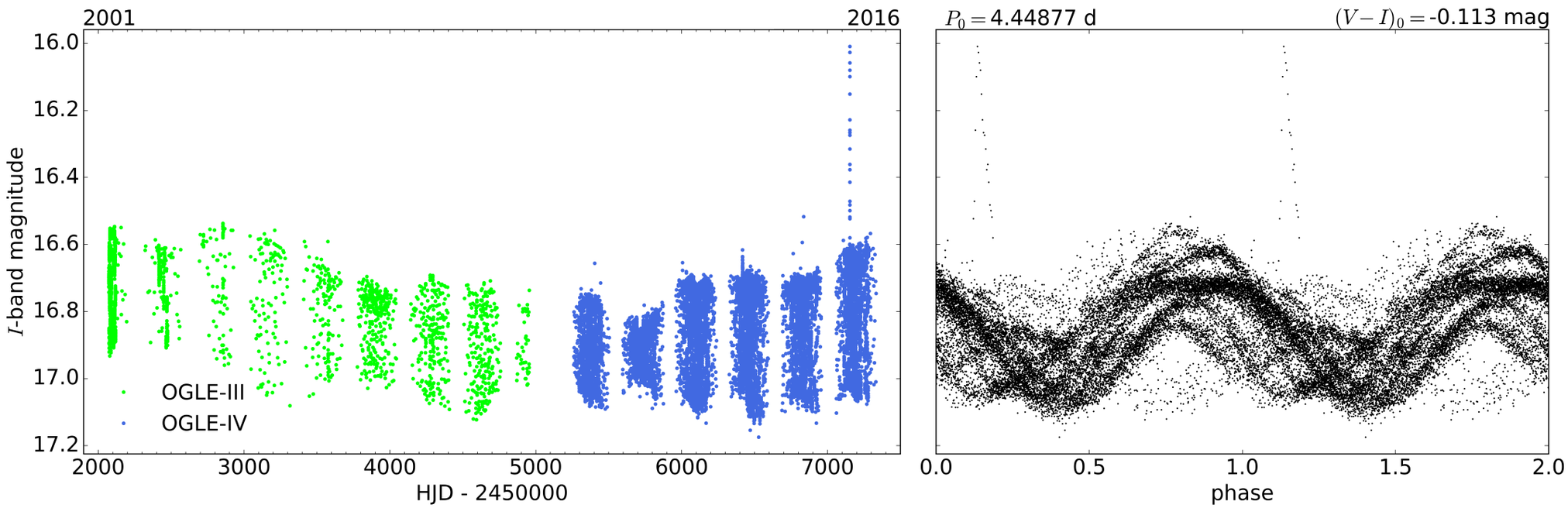
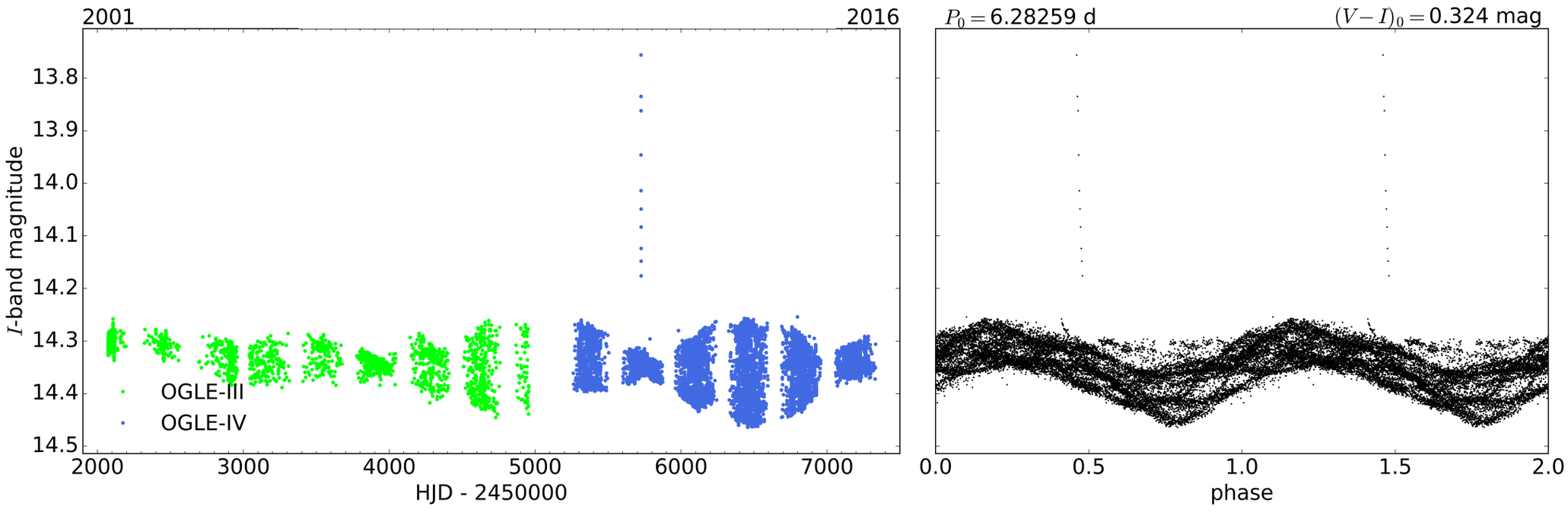
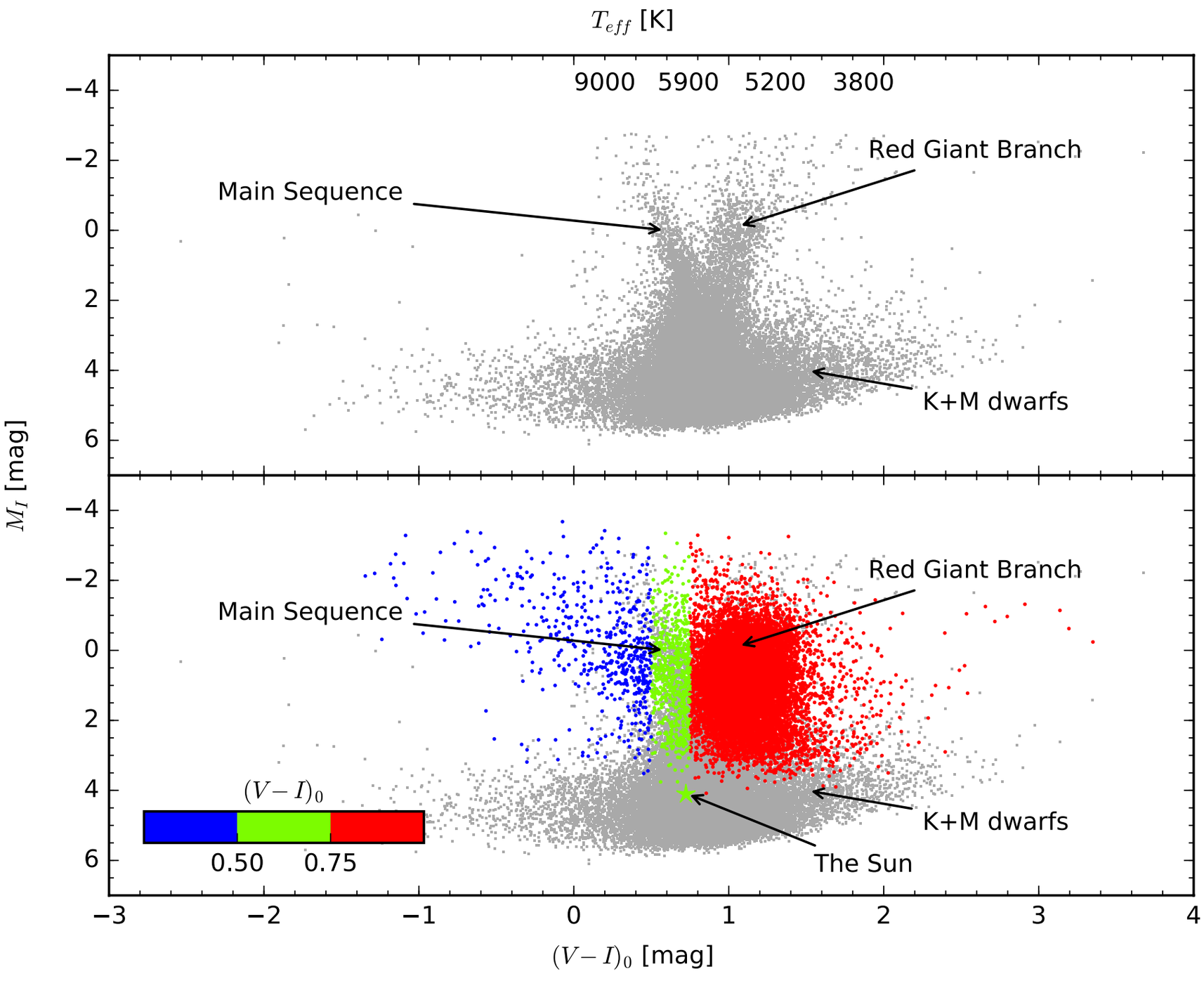


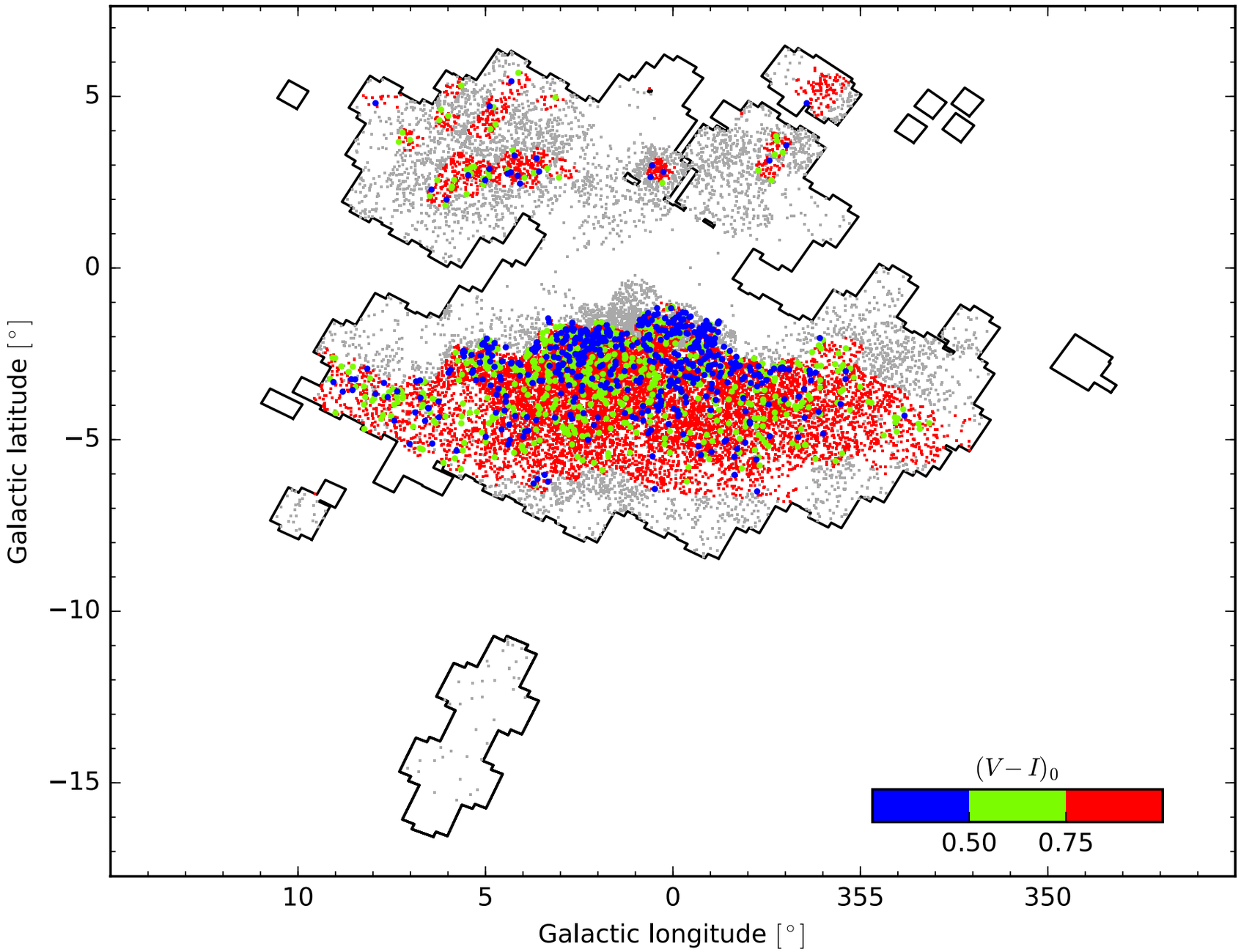


Our stars on the Hertzsprung-Russell diagram



- We have analysed over 13 000 stars from the OGLE-III data for which interstellar extinction maps *(Nataf et al., 2013)* are available.
- Distance to the Galactic bulge — 8.27 kpc *(Pietrukowicz et al., 2015).*

Location of our stars in the Milky Way



- The Galactic bulge is dominated by red, cold, old stars which formed before spiral arms of the Galaxy.

Analysis of chromospherically active stars found in the **OGLE** data

Correlations found by Drake *(2006):*

1 [CONFIRMED]

Average rotational periods of these stars decrease with their distance from the Galactic plane.

2 [CONFIRMED]

Average rotational periods increase with colour indices for stars with rotational periods shorter than 30 days.

3 [CONFIRMED]

Fainter stars exhibit larger variations in their mean brightness.

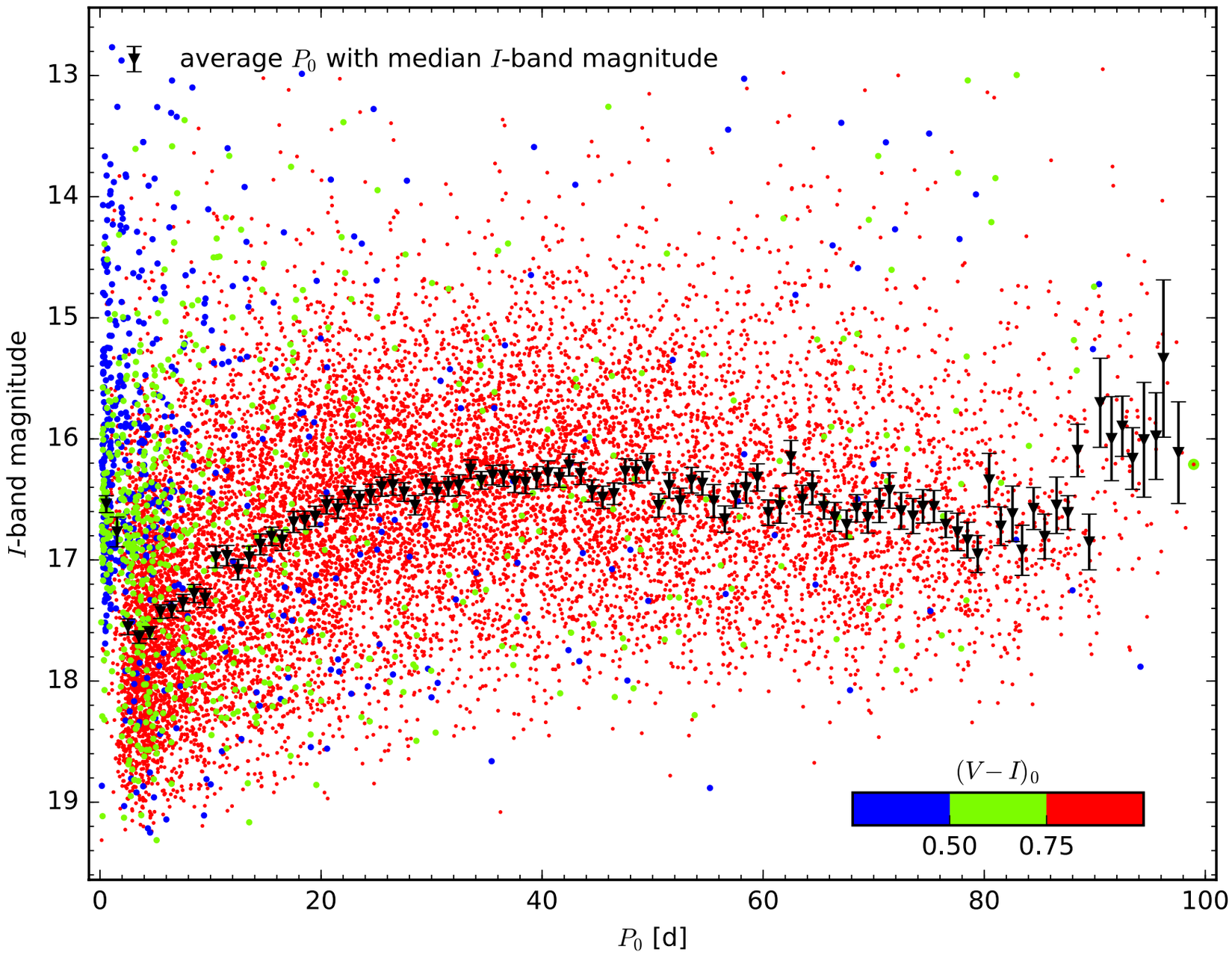
4

No evidence for a relationship between brightness of chromospherically active stars and their periods.

5

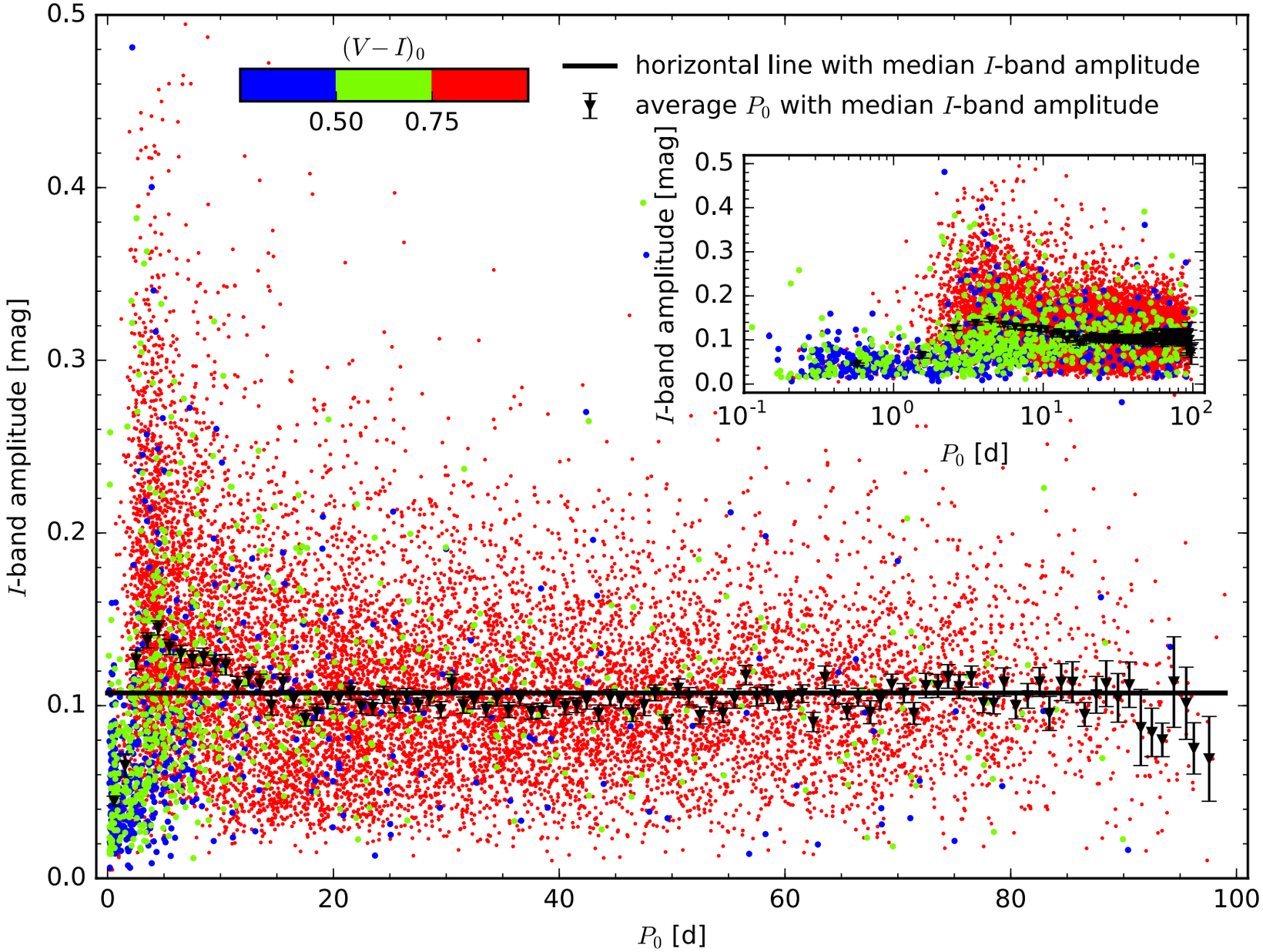
If spot cycles like in the Sun exist, then the cycle period must be longer than 10 years.

Correlation between brightness and rotational period



- Two groups of chromospherically active stars. Separation of these two groups at P_0 ~ 2.5 d.
- Both groups have opposite correlations.
- Strong evidence for a relationship between brightness and rotational periods!

Correlation between brightness amplitude and rotational period



- Contrary to popular belief, the fastest rotating stars are less active!
- Again we have two groups of chromospherically active stars.
- The largest brightness amplitude for stars with P_0 ~ 5 d.
- There is a strong correlation for stars with rotational periods smaller than 20 days.

Activity cycles analysis

1

Very rarely discussed topic. Not enough long and accurate observations for many stars.

2

Activity cycles measured for several objects *(e.g. Henry et al., 1995, Messina & Guinan, 2002, Wargelin et al., 2017, Olah et al., 2017).*

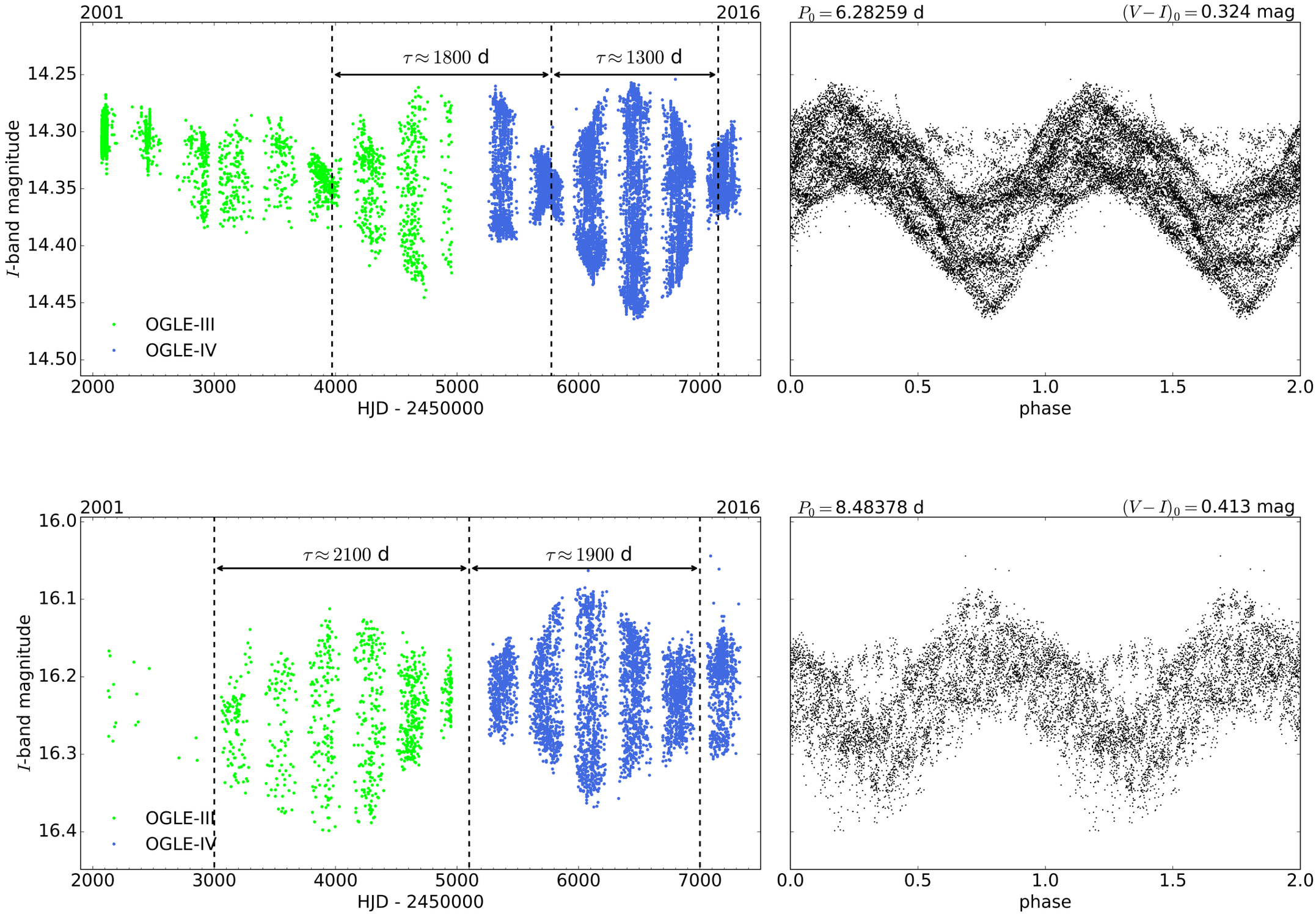
3

Long-term massive OGLE photometry allowed us to find and measure activity cycles in almost all analysed stars.

4

We have confirmed the existence of activity cycles in stars of various types.

Activity cycles in light curves



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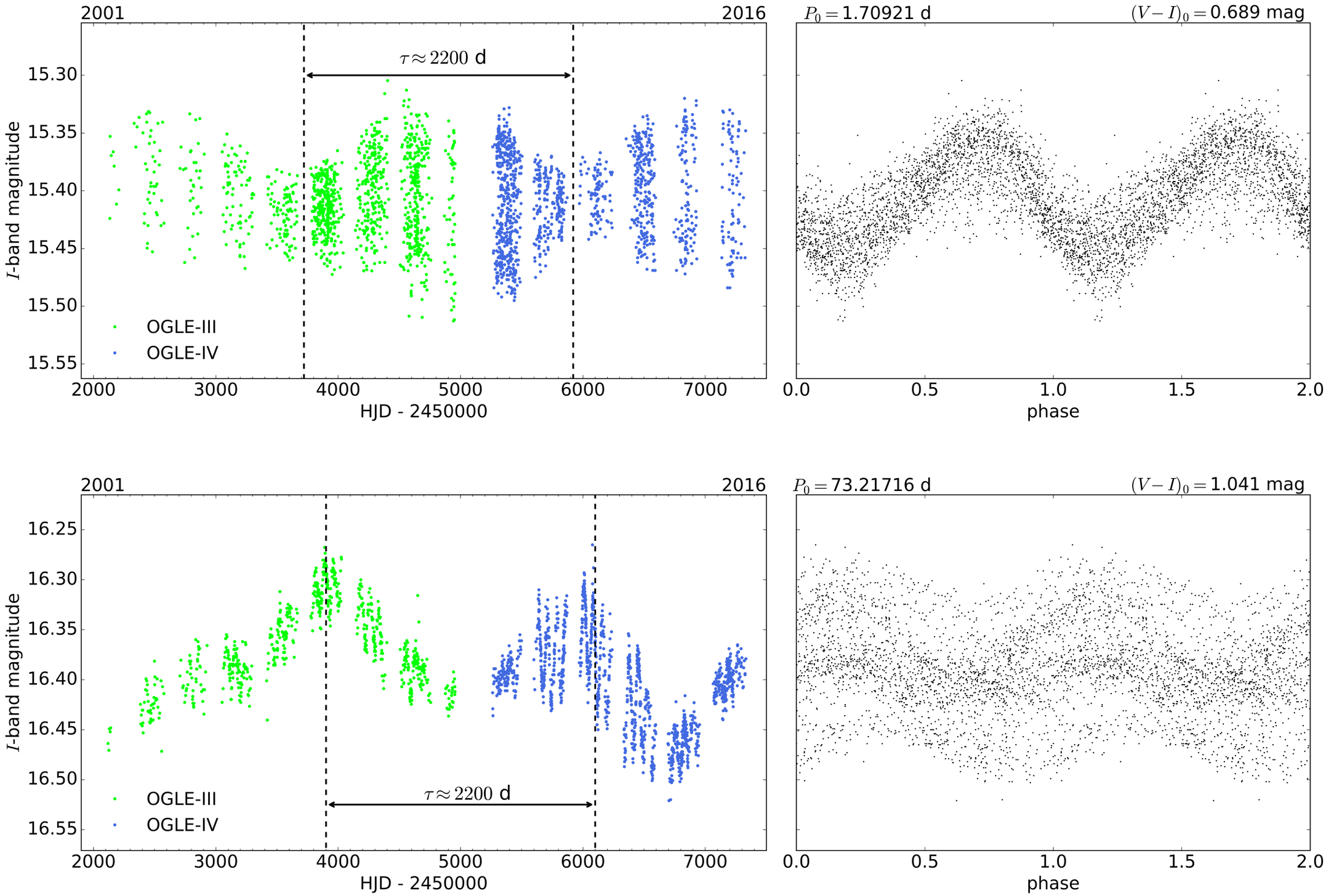
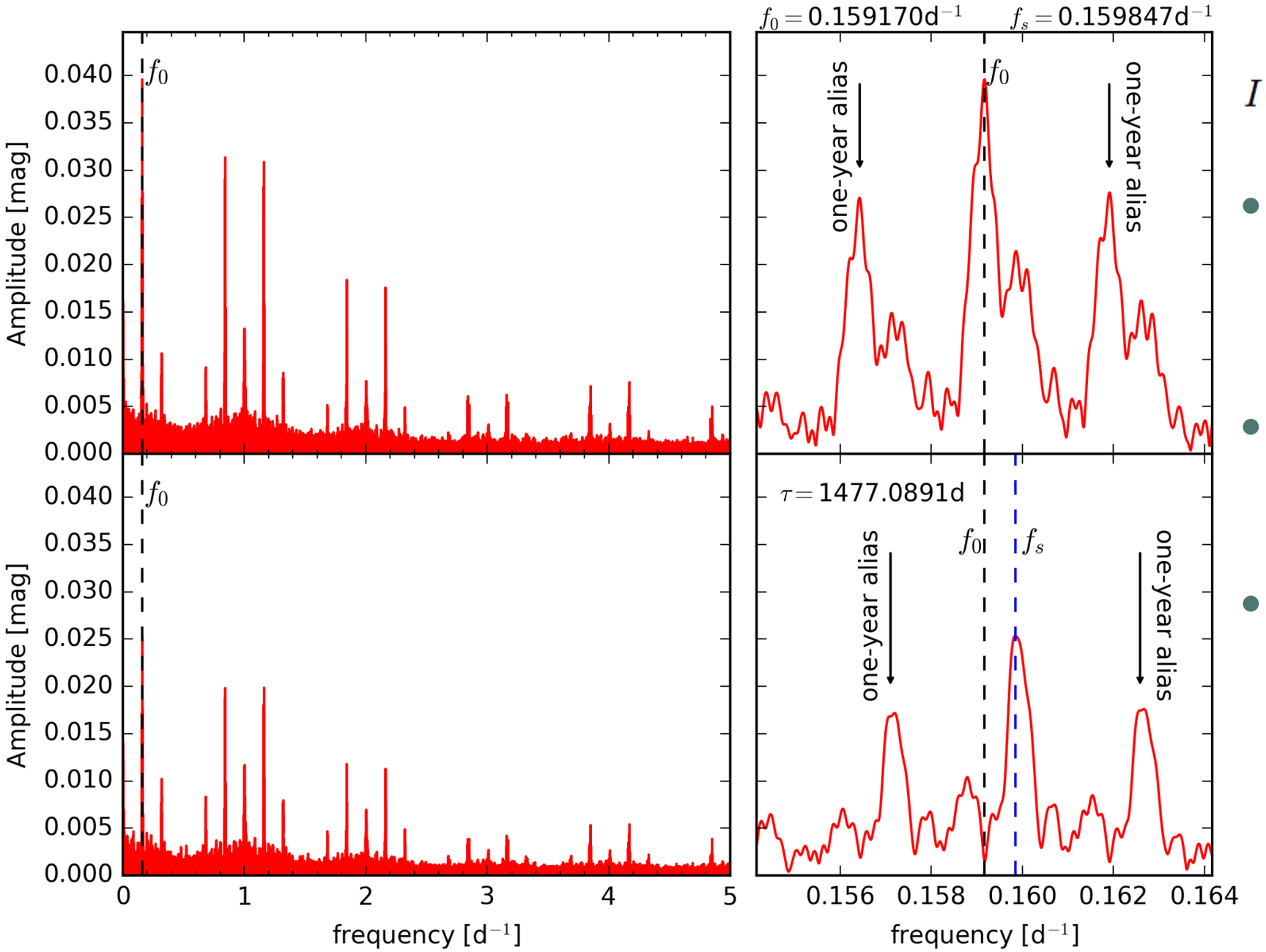


Activity cycles in the Fourier's spectrum

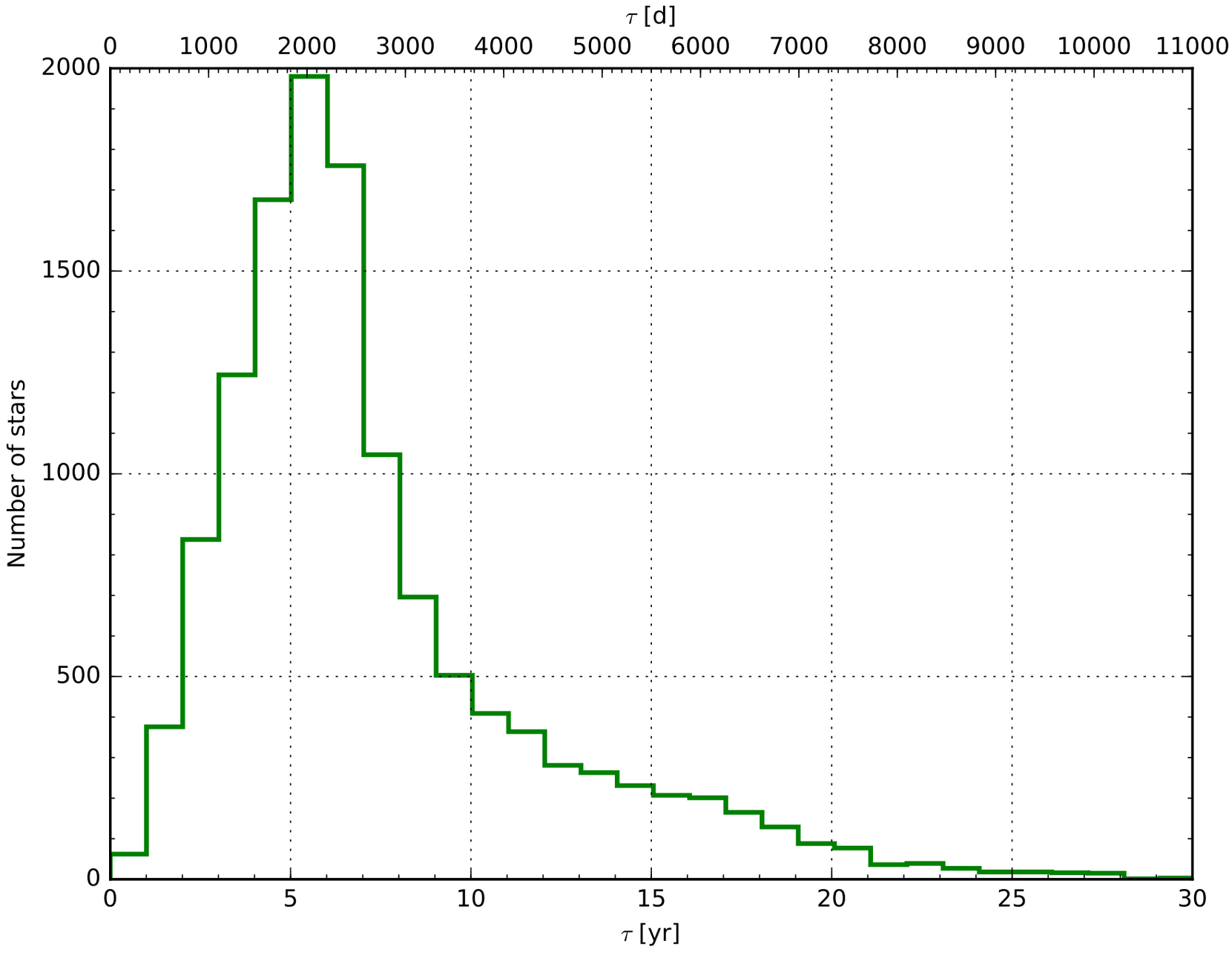


$$I(t) = A_0 + \sum_{k=1}^{N} A_k \cos(2\pi kft + \phi_k)$$

- After subtracting main frequency f_0 from data we were looking for very close to f_0 peak with frequency f_s.
- f_s is long-period modulation imposed on the rotation period of the star.
- We measure the time span of the activity cycles as:

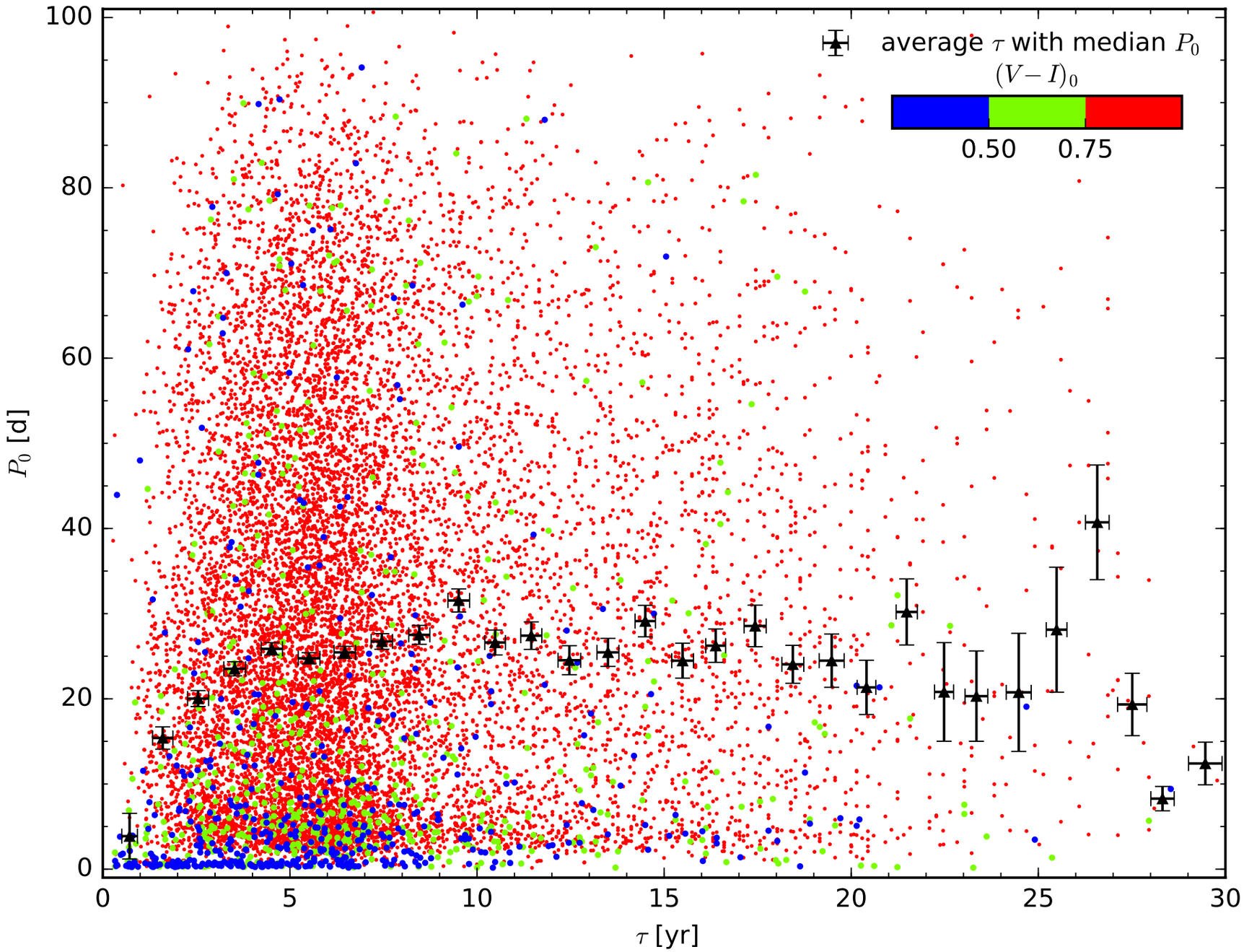
$$(|f_0 - f_s|)^{-1} = \tau$$

Time span of activity cycles



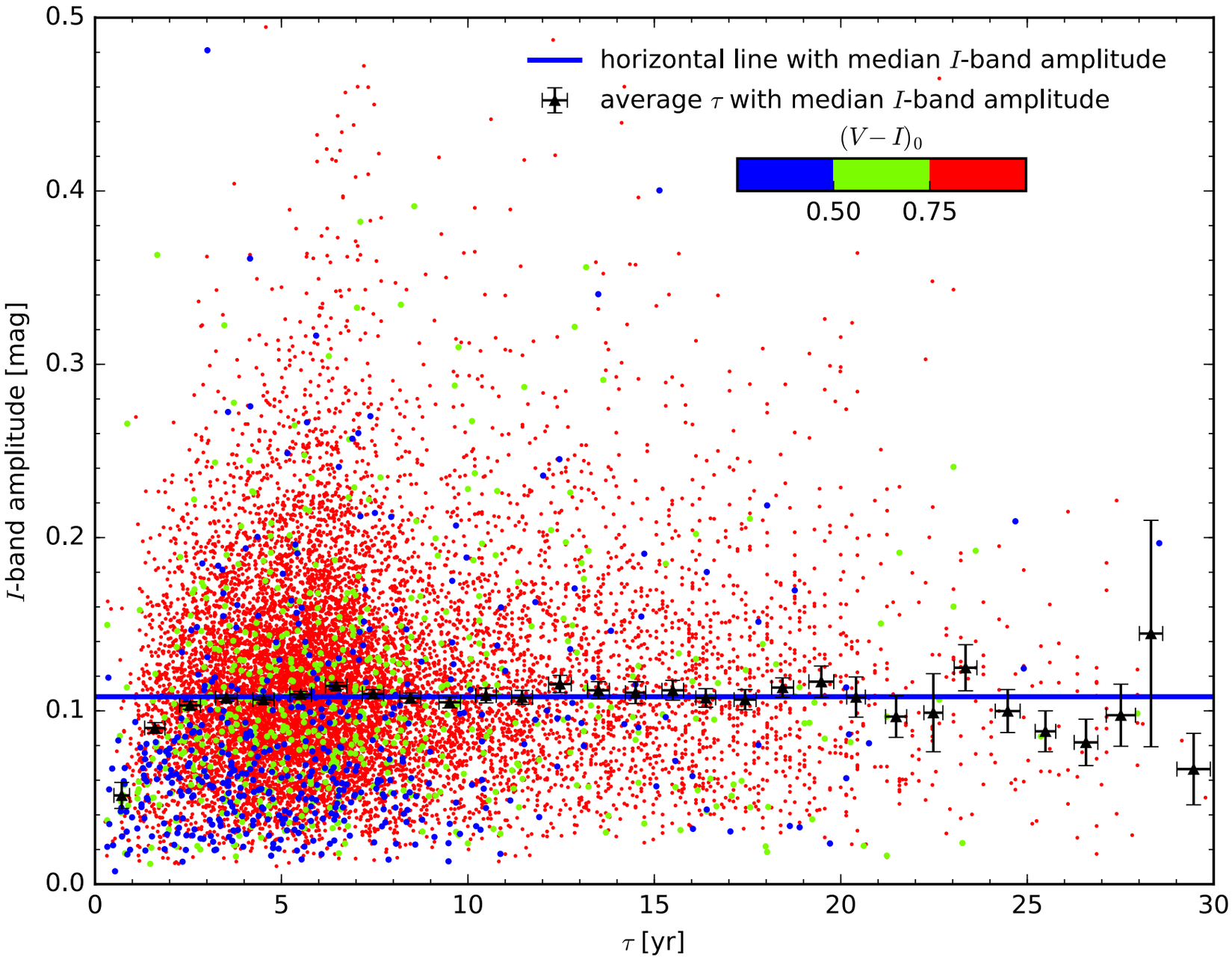
- **Over 90% of discovered stars have activity cycles shorter than 15 years!**
- Longer cycles are unreliable, because they exceed the time span of the OGLE observations.
- Most of our stars show activity cycles **from 4 to 8 years with most common value at 5-6 years.**

Correlation between activity cycles' time span and rotational period



- This correlation exists for stars with activity cycles shorter than 10 years. For longer activity cycles we do not have enough sample data.
- Slower rotating stars have on average longer activity cycles!
- The life time of stellar spots, their migration and evolution time could depend on the rotational period.

Correlation between activity cycles' time span and brightness amplitude



- Correlation exists for stars with activity cycles shorter than 7 years.
- By combining all discovered and proven correlations, it can be stated that for stars with rotation periods lower than 25 days, **the average brightness amplitudes are greater and activity cycles are longer if stars rotate slower.**

Conclusions

1

We have confirmed three out of five correlations found by *Drake (2006).*

2

We have discovered a few up-to-date unknown correlations.

3

We have confirmed the existence and measured the time span of activity cycles in various types of stars. The 11-years cycle like in the Sun does not seem to be common.

4

Future plans:
- finding chromospherically active stars in the Magellanic Clouds;
- publishing all the results;
- publishing the largest catalogue of chromospherically active stars **in the history of astronomy.**

Thank you for your attention!

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