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Data Recognition and Virtual JD

Zvěřina P., Mikulášek Z.

Department of Theoretical Physics and Astrophysics, Faculty of Science, Brno, The Czech Republic

Abstract. Chemically peculiar (CP) stars are the upper Main Sequence stars with an unusual chemical composition of the atmosphere. Magnetic chemically peculiar (mCP) stars, a meaningful group of CP stars, are variable in light, magnetism and both spectroscopically. Unfortunately, some important, mainly historical photometric or spectroscopic data exist only in the form of published phase diagrams. In this article we would like to present a new method of the analysis of these phase diagrams. This method is able to transform the phase from phase diagrams to a virtual JD, which can substitute the real (but unknown) JD.

Key words: CP stars – virtual JD – light curves of CP stars

1 Introduction

Magnetic chemically peculiar stars are light, magnetic and spectroscopic variable stars. The period of their variations is controlled by the rotation of the star. The shape of the light curve is determined by inhomogeneous distribution of chemical components on a stellar surface. There have been made a lot of photometric measurements. Based on these measurements, plenty of periods and light curves were determined. For a precise determination of a period or a shape of the light curve, many long–term measurements are required. Unfortunately, some original photometric (spectroscopic or magnetic) data do not exist in the original form. These data exist only as graphs of brightness dependence (intensity of magnetic field, equivalent width, etc.) on the phase. The original data are lost. But a method of converting the phase from a phase diagram to the format suitable for data processing does exist.

2 Virtual JD Method

In any case we are able to replace the original, but unknown, Julian date (JD) of observations by a virtual JD. The virtual JD is a time of observations, which isn't identical with the original time of measurement. However, the virtual JD can substitute the original JD for the purpose of the following process of data (period determination, finding a change of the period, correction of the shape of the light curve etc.) A precondition for an application of the virtual JD method is an existence of a diagram of dependence of the measured quantity on phase, which is constructed in a linear ephemeris. Then the phase is given by the following equation:

$$\varphi(t) = \mathrm{FRAC}\left[\frac{\mathrm{JD}(t) - M_{0D}}{P_D}\right]. \tag{1}$$

Here M_{0D} is a time of zero phase of the restored diagram, and P_D is the period. The index "D" means the values valid for the diagram. These entries (M_{0D}, P_D) have to be given in the body of the paper. The value of period P_D may be not accurate. If we know the interval of the observations of a star, and the variation of the stellar period is negligible at epoch E of the observations (and between the time of zero phase M_{0D} and time of observation), then we can use the virtual Julian date method. It means that the time of zero phase M_{0D} is replaced by a new time of zero phase M_0, which lies near the centre of observation.

$$M_0 = M_{0D} + n(E) \cdot P_D \tag{2}$$

n is the number of period between the time of zero phase M_{0D} and time of the centre of observation. Then the virtual JD is given by this equation:

$$\mathrm{JD_{vir}} = M_0 + P_D \cdot \varphi \tag{3}$$

The maximal error of the virtual JD method is given by this formula:

$$\delta_{\max} = \frac{\Delta t}{2P_D} \cdot \Delta P, \tag{4}$$

where Δt is the interval of observation and ΔP is a difference between the real period of the star and the estimated period used for the phase diagram.

The graphical illustration of the virtual JD method is given in Fig. 1. The original data are presented in the part A, the phase diagram is plotted in picture B, and the virtual Julian dates are laid out in part C.

3 Conversion of a Graphical Format to the ASCII Format

At the beginning we have to convert each point of the published phase diagram to the ASCII format, which is necessary for the further data processing. We have to solve a few problems at the format conversion:

1. The published phase diagrams are usually distorted or turned.
2. This phase diagrams often have poor quality. Usually they were made by hand.
3. Each point in the phase diagram can be marked by a different figure. Each figure corresponds to the time interval of observation.
4. The points in the phase diagram can be blended.

A typical phase diagram is presented in Fig. 2. For the data conversion we developed the FCON code in the MATLAB language. This code is available at the following link:

http://www.physics.muni.cz/~pavel/virtjd.html

The first step in the conversion of a picture to the text format is a definition of eight points on the axes that will define the axis system in the picture. Four points define the axis for phase, and four points define the axis for the dependent quantity (brightness, magnetic field intensity, etc.). These points are displayed in Fig. 2.

The second step consists in defining a position of each point in the phase diagram. Since the points in the phase diagram can be blended or cramped, we are not able to recognize the position automatically. Each point has to be by hand associated with a number, which indicates the shape of the point. The position of each point on the reference grid is determined by a linear interpolation. The linear interpolation gives accurate outcomes in case of a turned or skewed figure, but it is unable to render the right outcomes in the case of a more complicated distortion of the phase diagram (extension of a corner of the diagram, etc.). The error of this method depends on the quality of the phase diagram. In most cases the relative error of conversion to an ASCII format is less than five percent. (Zvěřina 2006)

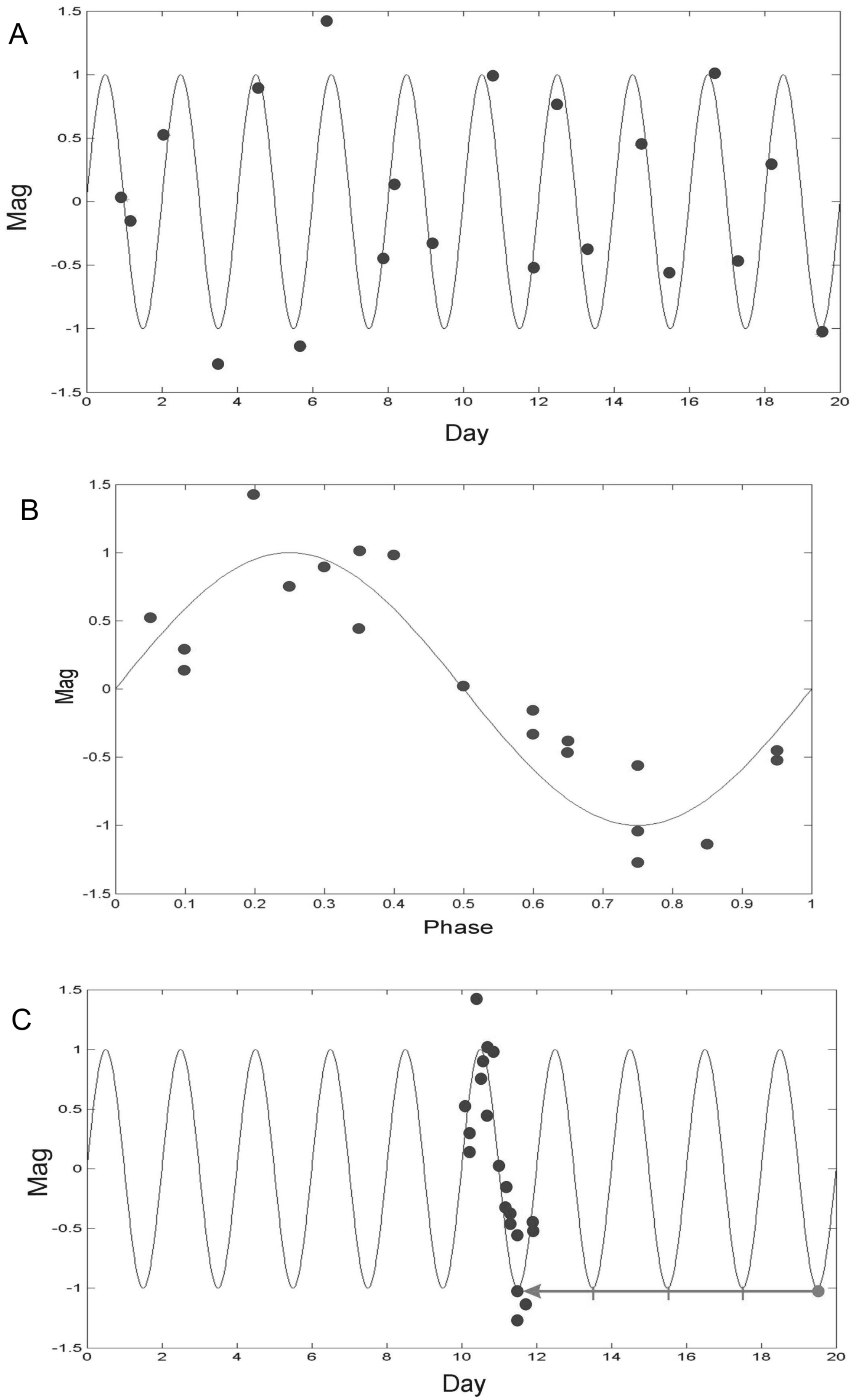

Figure 1: Graphical illustration of the virtual JD method: A — original data, B — phase diagram, C — virtual JD

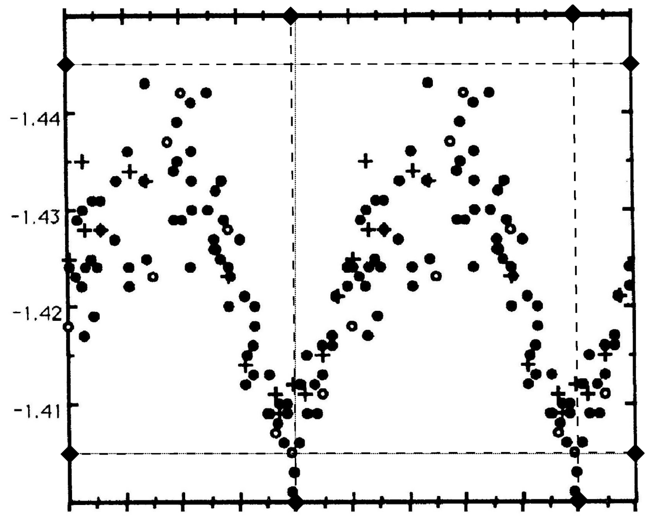

Figure 2: A typical phase diagram published in the papers (from Adelman, 1992). The dashed line is a reference grid defined by eight points on the axis (the black rhombs). The dotted line shows a vertical direction.

Table 1: The comparison of periods estimated on data determined by the virtual JD method and the published periods

Star Number	New Period	Virtual Data [%]	Published Period	Reference
HD 83368	2.8519424(57)	33	2.851982(5)	Kurtz et al. (1992)
HD 125248	9.295468(39)	37	9.295450(30)	Mikulášek et al. (2004)
HD 137909	18.48476(47)	46	18.4868	Catalano & Renson (1997)
HD 22470	1.9288956(13)	20	1.928890(50)	Adelman (2000)
HD 71866	6.800413(80)	17	6.80054	Catalano & Renson (1997)
			6.80022(6)	Bagnulo et al. (1995)

4 Conclusion

The virtual JD method was verified on a sample of five mCP stars. The periods (new period) were estimated based on all photometric data available (including the data estimated in the virtual JD method) on these stars and compared with the published period. This comparison is presented in Table 1 (Zvěřina, 2006). The periods of the stars estimated based on the virtual data and the published periods match.

If we know the ephemerids of the phase diagram and the interval of observation, we are able to substitute the real JD by the virtual JD. The error of the virtual JD method depends on the length of the observation period, on the variation period of the star and its error. This method is able to more precisely measure the period and the shape of the light curve in the case of hardly periodic stars (mCP stars).

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References

Adelman S. J., 1992, AJ, 104, 314A
Adelman S. J., 2000, A&AS, 146, 13
Bagnulo S., Landi Degl'Innocenti E., Landolfi M., Leroy J. L., 1995, A&A, 295 , 459
Catalano F. A., Renson P., 1997, A&AS, 121, 57
Kurtz D. W., Kanaan A., Martinez P., Tripe P., 1992, MNRAS, 255, 289
Mikulášek Z., Zverko J., Žižňovský J., Janík J., 2004, IAUS, 224, 657
Zvěřina P., 2006, "Analýza světelných křivek magnetických chemicky pekuliárních hvězd", Diploma thesis, Masaryk University, Brno