PHOTOMETRY OF HIPPARCOS VARIABLE STARS

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Abstract

Among the discoveries reported by the Hipparcos team was the detection of short-term photometric fluctuations in several long period, or Mira, variables (de Laverny *et al.* 1998). Nearly 15 percent of the 250 Miras surveyed in the broadband 380 to 800 nm filter showed variation of 0.2 to 1.1 magnitudes on timescales of 2 to 100 hours, preferentially around minimum light phases. We have begun an observational effort to confirm these variations. We seek to correlate the behavior with ancillary information, such as optical and infrared spectra plus maser data, to determine whether the fluctuations can be understood as thermal instabilities or so-called molecular catastrophe (cf. Muchmore *et al.* 1987; Stencel *et al.* 1990). A progress report and call for observation coordination are given.

1. Introduction and background

Variable stars are stars that change in brightness/magnitude. Depending on the type of variable star, these brightness changes can range from a few hundredths to as much as twenty magnitudes over periods of a fraction of a second to years. It is reported in the *General Catalogue of Variable Stars* (Kholopov *et al.* 1985) and subsequent Name Lists (Kholopov *et al.* 1985, 1987, 1989; Kazarovets and Samus 1990, 1995, 1997; Kazarovets *et al.* 1993) that there are now over 31,500 stars known to be variable and over 14,000 more that are suspected to be changing in brightness in our own galaxy.

There are many types of variable stars, ranging from pulsating, eruptive, and eclipsing to rotating variables. Research on variable stars is important because it can provide much information about stellar properties, such as mass, radius, luminosity, temperature, internal and external structure, composition, and age.

In the category of pulsating variables there are long period Mira-type variables. These variable stars are very cool red giants with temperatures around 3000 K; they are very large, ranging 200 to 300 times the radius of the sun, and very luminous, 3000 to 4000 times the luminosity of the sun. They are post-main sequence, pulsating long-period variables, with periods ranging from 150 to 1000 days. They are known to have large amplitudes of light variation of more than 2.5 magnitudes in the visual and more than 1magnitude in the infrared wavelengths (Mattei 1997).

These are the types of stars of interest for this study. The main goal of this student project is to select a few of these particular stars and observe them over a period of time using CCD technology. These images will be analyzed using aperture photometry and the results will be compared to known findings. The results of this study will determine if we can match the variability (magnitude fluctuations) of the stars as seen in previous studies.

2. The Hipparcos variables

The majority of the stars selected for observation came from the HIgh Precision and

PARallax COllecting Satellite (Hipparcos) mission (ESA 1997), identified as unique by de Laverny *et al.* (1998). Part of this mission was to make position measurements (astrometry) and record brightness measurements (photometry) of all its 118,000 target stars. The satellite was named after the Greek astronomer Hipparchus, who in 129 BC completed a catalogue of a thousand stars. By noting their directions in the sky and their relative brightness, he founded the science of astrometry, or star position measurement.

The stars in this study include RT Boo, SV And, CE Lyr, etc. The Mira variable R Leo (in the Hipparcos program but not in the list of stars given in de Laverny *et al.*) was CCD-imaged and analyzed in order to get a baseline reading when using the software MIRA for determining magnitudes. Basic information for R Leo includes R.A. $09^h 47^m 33^s.44$, Decl. +11° 25′ 45″.8 (2000); spectral type M6–M8–M9.5; period 309.95 days; mean magnitude at maximum v = 5.8.

Table 1 represents a number of Mira-type variable stars that were used in a study conducted by de Laverny *et al.* (1998). This special class of variable stars was found by them to have rapid variations in amplitude ranging from 0.23 magnitude up to 1.11 magnitude with timescales extending from 2 hours up to almost 6 days (albeit with limited sampling). All of the stars in the de Laverny *et al.* list are oxygen-rich Miras. De Laverny *et al.* suggest that such variations might be related to molecular opacity changes and to variations in the physical conditions of the stars, inducing instabilities. However, they also suggest that other mechanisms might be involved, such as hydrodynamic effects.

3. Observations and analysis

Data are being gathered using the "Roboscope" (a semi-automated 8-inch Schmidt-Cassegrain telescope) at the Chamberlin Observatory, Denver, Colorado. An SBIG ST5

Table 1. Selected Hipparcos long period variables under study (from de Laverny *et al.* 1998).

Star Name	Right Ascension (2000)	Declination (2000)	Spectral Type	Period (Days)	Magnitude (Hp)	Delta Mag	Timescale (Hours)
SV And	00 04 20.03	+40 06 35.5	M5.0–M7.0	316.2	11.56	0.65	10.66
R Cet	02 26 02.20	–00 01 42.3	M4.0–M9.0	166.2	11.27	0.26	4.27
T Eri	03 55 13.8	–24 01 58	M3.0–M5.0	252.3	11.09	0.31	23.47
V Mon	06 22 42.84	–02 11 48.7	M5.0–M8.0	340.5	11.26	0.32	4.61
RX Mon	07 29 21	–04 00 17.0	M6.0–M9.0	345.7	12.20	0.42	15.28
T Hya	08 55 39.75	–09 08 29.2	M3.0–M9.0	298.7	10.86	0.34	11.01
X Hya	09 35 30.3	–14 41 29	M7.0–M8.5	301.1	10.58	0.26	28.08
RR Boo	14 47 05.69	+39 19 00.5	M2.0–M6.0	194.7	11.54	0.25	4.27
RT Boo	15 17 14	+36 00 21.6	M6.0–M8.0	273.9	11.58	0.34	10.67
S Ser	15 21 39.49	+14 18 52.5	M5.0–M6.0	371.8	8.35	0.32	93.86
X CrB	15 48 53.4	+36 14 52.8	M5.0–M7.0	241.2	12.42	0.23	2.48
AH Ser	15 59 20	+19 00 47.7	M2.0–?	283.5	10.96	0.34	96.00
RU Her	16 10 14.5	+25 04 13	M6.0–M9.0	484.8	11.67	0.55	25.94
SS Her	16 32 55	+06 00 51.5	M0.0–M5.0	107.4	11.88	0.69	110.93
XZ Her	18 10 03.87	+18 06 15.2	M0.0–?	171.7	11.44	0.34	6.40
CE Lyr	18 36 52	+28 00 04.4	——	318.0	11.64	0.44	6.74
HO Lyr	19 20 09	+41 00 40.9	M2.0–?	100.4	12.52	0.27	2.48
AM Cyg	20 48 58	+31 00 50.9	M6.0–?	370.6	12.96	0.56	138.67

The Hipparcos magnitude, denoted by Hp, *is at the precise epoch of observation. The last two rows,* Delta Mag *and* Timescale, *indicate the change in magnitude, and timescale for the change.*

CCD camera is used to take the pictures. This camera has a dynamic range of 0 to 2^{14} numerical capacity, and it is able to display 16,384 shades of gray (14 bits). SKY PRO software (Software Bisque), is used to obtain the digital pictures taken with the camera. Aperture photometry (measuring the instrumental magnitude of the star) is then performed using the software program MIRA. This method measures the total brightness of one or more objects using an automated background subtraction method. This method involves summing the values of all pixels within a defined boundary (circular) centered on the star, then subtracting the contribution from the diffuse sky background, usually by sampling an annulus of pixels around the star. Data will also be collected from the University of Denver's Mt. Evans Meyer-Womble Observatory.

4. Results and discussion of accuracy

Observations are underway. To date, multiple images have been obtained of R Leo and several stars in Table 1. The software program MIRA and its Aperture Photometry routines were used to evaluate magnitudes differentially from the CCD frames.

Many images of R Leo were taken between April 29, 1998, and May 26, 1998. Exposure times ranged from 0.75 to 2.0 seconds. The instrumental magnitude of R Leo ranged from -14.032 to -14.678, and the instrumental magnitudes of the comparison stars, Star 2 and Star 3, ranged from -10.243 to -10.526 and -9.243 to -9.560, respectively. These negative instrumental magnitudes have not yet been calibrated. Note that due to software conversions comparison Star 2 was unobtainable in some of the images.

Also analyzed were the differences found for a given star taken from consecutive images on the same night. These differences ranged from -0.003 to 0.302. We are therefore not getting a perfectly constant reading from the images, which can be

Table 2. Results of differential photometry for R Leo (difference between normalized exposures taken on the same night).

Frame	*R Leo – Star 2*	*R Leo – Star 3*	*Star 2 – Star 3*
RLeo429A	-4.321	-5.172	-0.851
RLeo429B	-4.261	-5.283	-1.022
RLeo429C	-4.321	-5.307	-0.986
RLeo510A	—	-4.753	—
RLeo510B	—	-4.624	—
RLeo513A	-4.028	-4.775	-0.747
RLeo513B	-3.932	-5.142	-1.210
RLeoS13C	-4.662	-5.628	0.034
RLeo519A	—	-4.952	—
RLeo519B	—	-5.144	—
RLeo519C	—	-4.896	—
RLeo519D	-3.932	-5.083	-1.151
RLeo519E	-4.182	-5.035	-0.853
RLeo526A	-4.244	-5.095	-0.851
RLeo526B	-4.261	-5.283	-1.022
RLeo526C	-4.321	-5.172	-0.851
Mean Difference	-4.224	-5.084	0.864
Standard Deviation	0.208	0.248	0.330
Standard Dev. Squared	0.043	0.061	0.109

explained by various factors, such as camera temperature, software calculations, etc.

Table 2 compares the magnitudes among the three stars within the same exposure. As we can see from the table, the mean difference in magnitude found between R Leo and comparison star 2 was approximately –4.224 ±0.208 (s). The difference between R Leo and comparison star 3 was approximately –5.084 ±0.248 (s), and the difference between star 2 and star 3 was 0.864 ±0.330 (s).

5. Conclusion

From the data collected so far, we find that it is possible to get relatively stable readings from image to image on the same night using CCD technology to approximately 10% (0.1 magnitude). When observing R Leo over a time span of a month, we find that the two comparison stars were nearly stable, while there was some variation in R Leo, which is to be expected. Currently an observational study of the Hipparcos variables is underway.

To date, this effort has proven to be full of promise, and we urge others to take part in the observing of the Hipparcos variable stars. Suggestions and comments would be greatly appreciated, and should be sent via e-mail to tao@phoenix.phys.du.edu.

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