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GH Lib: A MULTI-PERIODIC MIRA, NOT AN ECLIPSING BINARY

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GH Lib (≡BV 1623, $\alpha = 14^{\rm h}36^{\rm m}07\overset{\rm s}{.}82$, $\delta = -24^\circ 21' 50\overset{''}{.}9$ J2000) was discovered on sky patrol plates as a variable star and classified as an eclipsing binary of the Algol type by Carter (1975), who remarked that too few minima were observed to derive an orbital period. Based on Carter's report, Kukarkin et al. (1977) included GH Lib in the General Catalog of Variable stars and Malkov et al. (2006) in their compilation of eclipsing binaries, where no information appear in addition to what already given in the discovery paper.

Intrigued by the lack of suitable follow-up observations, we have obtained photometric and spectroscopic observations of GH Lib from 2012 to 2016. They show GH Lib to be an oxygen-rich Mira variable, of the multi-period type, and not an eclipsing variable. In spite the conclusion by Kharchenko (1985) that nearly all Miras with a peak magnitude brighter than 14 have already been discovered, here we have a brand new Mira variable peaking at V=11 mag.

V and $R_{\rm C}$ optical photometry of GH Lib has been obtained with two ANS Collaboration 0.30-m f/10 Meade LX200 telescopes located in Granarolo (Bologna, Italy) and Alfonsine (Ravenna, Italy). Aperture photometry was carried out at both telescopes against the same local photometric sequence extracted from the APASS survey (Henden et al. 2012). The photometry we collected on GH Lib during 50 independent nights, is given in Table 1 (provided as online data to the paper). Our V-band data are plotted in Figure 1 together with archive V-band data extracted from the ASAS database (Pojmanski 1997).

The light curve of GH Lib in Figure 1 is that of a Mira pulsating with more than one periodicity. A Fourier analysis using the code by Deeming (1975), shows the main period to be 157 days, with the following ephemeris providing times of maxima in the V band:

$$\mathrm{JD}^{V}_{\mathrm{max,primary}} = 2454299 + 157 \times E \qquad (1)$$

where E is the progressive cycle number. The corresponding phased light curve is given in Figure 2. The several branches which are clearly visible in Figure 2, the ∼1 mag spread similarly present at all phases, and the apparently regular up-and-downs in the peak brightness along the 157 day cycles in Figure 1, all points to the presence of a second periodicity. We have searched the *residuals* from the mean light curve in Figure 2 (the red continuous curve) and again performed a Fourier analysis that returned 1180 days as

– by large margin – the strongest peak. The following ephemeris provides the maxima for this secondary periodicity:

$$\mathrm{JD}^{V}_{\mathrm{max,secondary}} = 2454225 + 1180 \times E \tag{2}$$

The sinusoidal combination of these two pulsation periods is over-plotted to the data as the continuous line in Figure 1, with an amplitude of 3.5 mag for the 157 day and 1.0 mag for the 1180 day cycle. The total amplitude of variation of GH Lib is 4.5 mag in V. Secondary periods have been observed in several pulsating M giants, either of the Mira (Percy and Bagby 1999) or semi-regular types (Kiss et al. 1999). In the majority of cases, however, the cycle-to-cycle differences seems due to low-frequency stochastic variability (Eddington and Plakidis 1929, Percy and Colivas 1999, Templeton and Karovska 2009) and not to secondary periods.

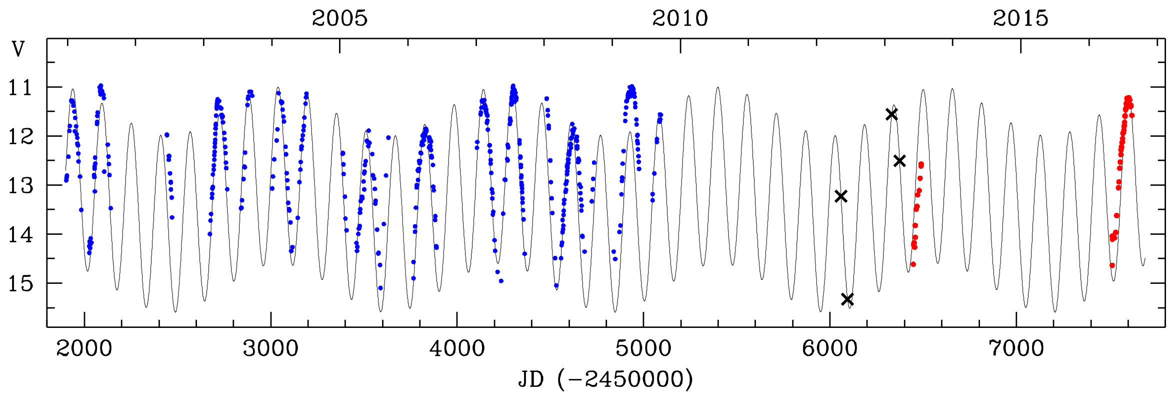

Figure 1. Long-term V-band light curve of GH Lib obtained by combining our observations (JD>2456400, in red) with ASAS archive data (JD<2455200, in blue). The bi-periodic curve is the sinusoid combination of ephemerides 1 and 2. The four crosses mark the time of the spectra in Figure 3.

Four low resolution spectra of GH Lib have been obtained at different epochs with the 1.22m telescope + B&C spectrograph operated in Asiago by the Department of Physics and Astronomy of the University of Padova. The spectra cover the 3400-8000 Å range at a dispersion of 2.3 Å/pix, and have been treated in a standard fashion in IRAF, including correction for bias, dark and flat fields, subtraction of sky background, and wavelength calibration. Flux calibration has been achieved via spectrophotometric standard stars observed during the same nights as GH Lib itself. The spectra are shown in Figure 3, and their corresponding position in the pulsation light curve of GH Lib is marked with crosses in Figure 1. By lucky coincidence, two of the four spectra were obtained very close to the maximum and minimum along the 157-day cycle, and the remaining two at the same 0.20 phase. The continuum of the spectra at maximum and minimum are perfectly fitted by those of M2III and M7III spectral type standards, respectively, and by an M5III at 0.20 phase.

The primary period of 157 days places GH Lib close to the short term border in the period distribution for Miras. Among the 5202 Miras with a pulsation period listed in the General Catalog of Variable Stars (GCVS) at the time of writing, only 4% of the oxygen-rich type (M spectral type) have a period shorter than GH Lib. An amplitude of 4.5 magnitudes and a M2III-M7III spectral range are similar – according to the GCVS compilation – to those exhibited by other Miras of equivalent pulsation periods.

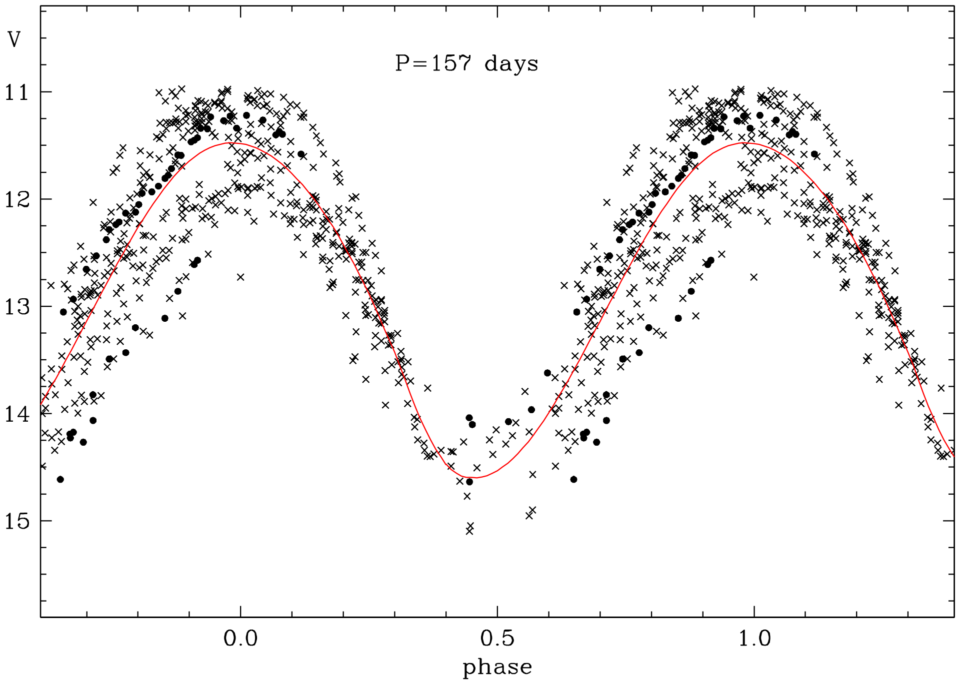

Figure 2. ASAS data (crosses) and our V-band observations (dots) of GH Lib folded with the main pulsation period of 157 days, following ephemeris 1. The continuous curve is a spline fit to the data.

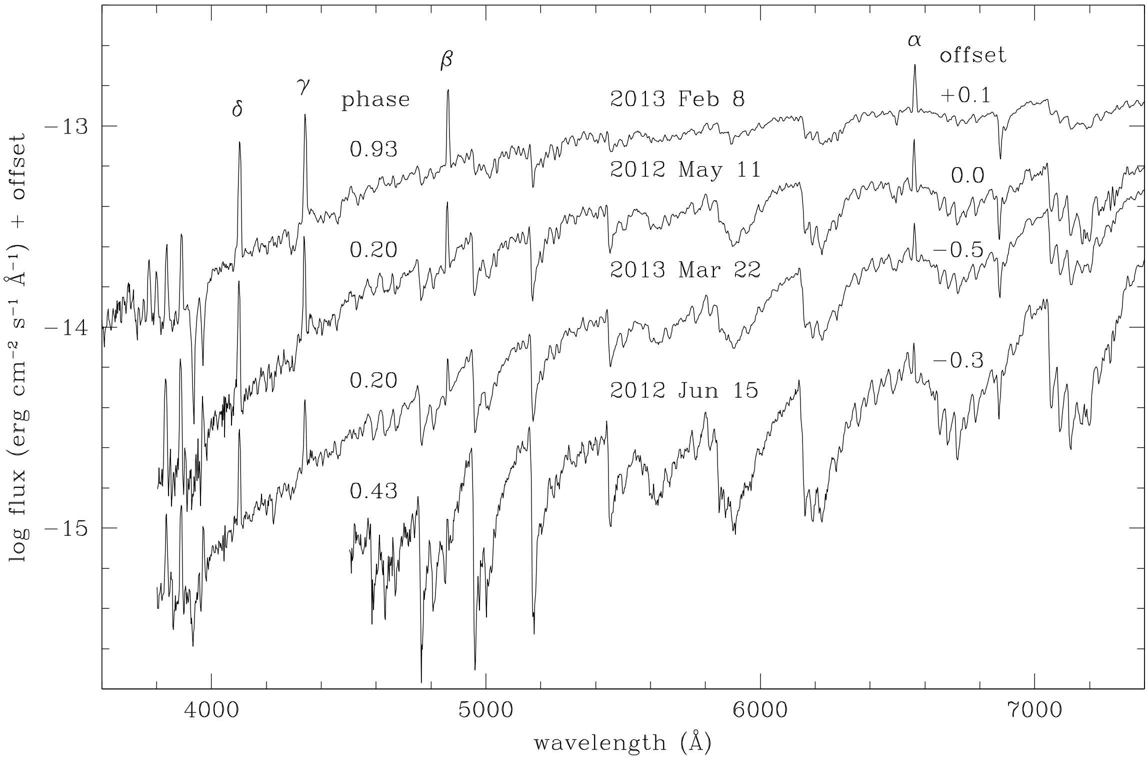

Figure 3. Spectra of GH Lib at four distinct epochs. To enhance visibility, an offset in ordinates is applied as indicated. The phase is relative to the main pulsation period of 157 days, following ephemeris 1.

What is not typical is the large intensity of the Hα and Hβ emission lines visible in the spectra of GH Lib in Figure 3. Lower Balmer lines do not generally stand in prominent emission in low resolution spectra of Mira variables, the strongest observed emission being that of Hδ (Joy 1926). The reason for such an anomalous ratio in the intensity of Balmer emission lines is due to the overlapping absorption by TiO bands (Scott 1945). Shortwards of 4300 Å there is essentially no absorption band from TiO, and therefore Hδ (4100 Å), H8 (3889 Å) and H9 (3835 Å) can emerge unabsorbed through the stellar atmosphere (Merrill et al. 1962). On the contrary, at the redder wavelengths of Hα and Hβ the absorption from many strong and overlapping TiO bands effectively blocks the emergence of radiation from internal atmospheric layers.

In Miras, the ionization of hydrogen responsible for the observed emission lines occurs in a shock region in the atmosphere (Joy 1947, Merrill 1955), where infalling material from the previous pulsation cycle collides with that moving outward from the following cycle (Fox et al. 1984, Gillet et al. 1985). This shock region is usually located deep in the atmosphere, well below the region from where TiO absorption originates (de Laverny and Magnan 1995). In GH Lib, the Hδ/Hγ/Hβ/Hα intensity ratio is 1.00/1.34/1.44/1.48, 1.00/1.51/1.88/4.84, and 1.00/1.17/1.51/3.25 for the 2013 Feb 8, 2012 May 11, and 2013 Mar 22 spectra in Figure 3, respectively. For comparison, this same ratio measured on some spectra of *o* Cet (obtained with the same instrumentation as for GH Lib) is 1.00/0.40/0.05/0.62 (similar numbers are tabulated by Crowe and Garrison (1988) for a large sample of southern Miras). We conclude that the region of Balmer line formation in GH Lib seems located at a larger radius (more external atmospheric layers) than in typical Miras, as if mixed with and not deeply below the region where absorption by TiO molecules occurs, which poses the interesting question of how TiO can survive in the same place where hydrogen is collisionally ionized (comparing the 6.8 eV ionization potential for TiO with that of hydrogen, 13.6 eV). The relative location within the atmosphere of GH Lib of the regions where Balmer emission lines and TiO absorption bands form should be investigated via radial velocities from high-resolution spectra.

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