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On Infrared Excess Emission from HZ Herculis

by

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ABSTRACT

In an attempt to confirm the recently observed 1.6 μm excess emission from HZ Her (Gnedin *et al.* 1986), we report negative result from observations made at identical binary phase. Implications of these measurements have been discussed in the light of 35 day cycles of Her X-1.

1. Introduction

HZ Herculis is an optically variable star (A/F spectral type) in a binary system, the other star being a neutron star. Binary orbital period is 1.7 days. The neutron star spin period is 1.24 sec as observed in X-ray pulsations. The X-ray pulsar has a 35 day activity cycle during which X-ray emission gets turned on (and off) twice, so-called "main-on" and "short-on"..

Recently Gnedin *et al.* (1986) (hereafter, GKKPT) have reported near infrared (1-2 μm) observations of HZ Her, discovering a large excess emission in H (1.6 μm) band at an orbital phase $\phi_{1.7}=0.91$, just before the X-ray eclipse ($\equiv \phi_{1.7} = 0.0/1.0$). Interestingly enough, this excess emission did not show up in the neighbouring J (1.2 μm) and K (2.2 μm) bands.

In an attempt to confirm the H-band excess emission from HZ Her, we have made observations at H band through the binary orbital phase, $\phi_{1.7}=0.88$-0.94 (using the ephemeris used by GKKPT) covering the entire phase range of H band excess emission reported by GKKPT.

2. Observations and Results

A near infrared photometer incorporating a liquid nitrogen cooled InSb detector, has been used on the 1-m telescope of Uttar Pradesh State Observatory, Nainital. The radiation is chopped at 20 Hz by a vibrating tertiary mirror near the Cassegrain focal plane of the telescope for sky background subtraction. A cooled filter-wheel with J, H, K, L and M band filters was used to select the passband.

HZ Her was observed on April 6, 1987 during 19:55 UT to 22:07 UT. HZ Her was acquired by the telescope via the SAO star # 065670 ($m_{pg}=9.4$, $m_v = 7.8$) in the offset mode (by using a Star Changing Device). In order to check this offset motion of the telescope, the SAO star was reacquired twice during the observations, and it gave strong J/H band signals in our photometer. The photometer was calibrated by repeated observations of the standard stars: α CMi, α Leo and β Oph.

We failed to detect any measurable H band signal throughout the phase range of observations $\phi_{1.7}=0.88$-0.94. Our 5σ upper limit on H band flux for HZ Her is 8.5×10^{-17} W cm^{-2} µm^{-1} which very firmly rules out excess emission of the magnitude reported by GKKPT, during our observations. Fig. 1 shows our limits superposed on GKKPT's measurements of F_λ, at 1.6 µm, as a function of binary phase $\varphi_{1.7}$.

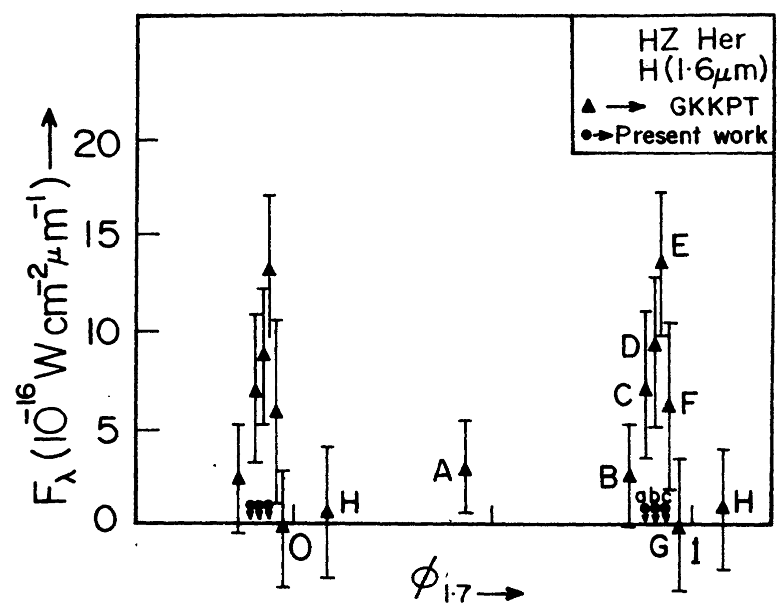

Fig. 1. F (1.6 µm) of HZ Her as a function of binary phase ($\phi_{1.7}$). The filled triangles are the measurements of Gnedin et al. (1986) and the filled circles are from the present work.

3. Discussion

Our observations have demonstrated that the H band excess of HZ Her (of the magnitude$\approx10^{-15}$ W cm^{-2} µm^{-1}) is not a regular phenomenon. An attempt has been made to check for any dependence on 35 day cycle phase (ϕ_{35}). In Fig. 1 of GKKPT, there are 4 data points above 4×10^{-16} W cm^{-2} µm^{-1} level, all of which refer to the observations over a single night. The

Table 1
H Band measurements of HZ Herculis

Data identifier in Fig. 1	Binary phase $\phi_{1.7}$	35^d phase ϕ_{35}	F (1.6 μm) 10^{-16} W cm^{-2} μm^{-1}
A	0.43	0.53	3^x
B	0.84	0.64	2.8^x
C	0.89	0.70	7^x
D	0.90	0.70	9.4^x
E	0.91	0.70	13^x
F	0.92	0.70	6.2^x
G	0.95	0.18	$\sim 0^x$
H	0.07	0.04	1^x
a	0.89	0.56	$<0.8^y$ (5σ)
b	0.91	0.56	$<0.8^y$ (5σ)
c	0.93	0.56	$<0.8^y$ (5σ)

x: Gnedin *et al.* (1986)
y: Present work

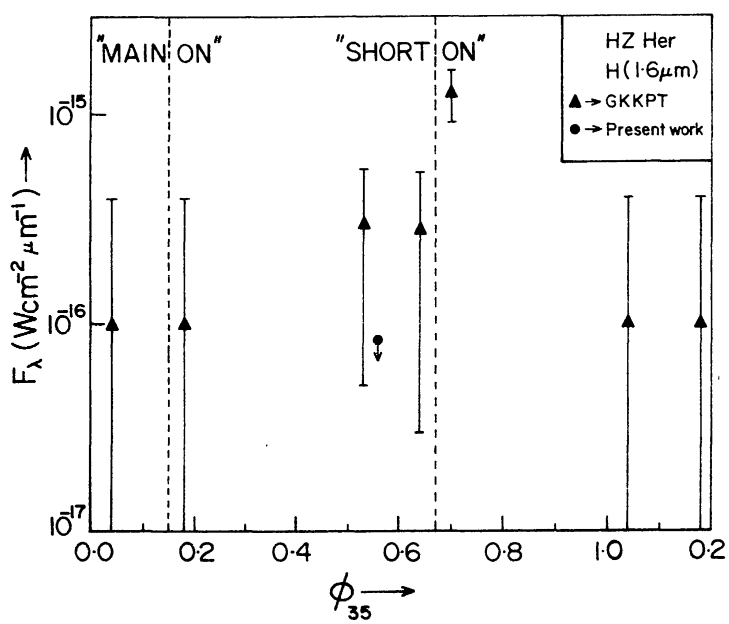

Fig. 2. F (1.6 μm) of HZ Her as a function of the 35 day cycle phase (φ_{35}). The filled triangles are the measurements of Gnedin et al. (1986) and the filled circle is from the present work. The dashed vertical lines represent the phases of "main-on" and "short-on".

observations correspond to the 35 day cycle phase $\phi_{35}=0.70\pm0.01$ as determined by interpolating between the two nearest known "turn-on"s before and after the measurements of GKKPT (cycle # 128 and # 140, Ögelman, 1987). The errors on ϕ_{35} represent the uncertainty corresponding to a range of the period between 34.85^d and 35.10^d (see Ögelman, 1987 for details). Similarly our observations correspond to $\phi_{35}=0.56\pm0.07$ which is obtained by extrapolation from the last known "turn-on" (cycle # 140). We list in Table 1, the data points with binary and 35 day cycle phases, for comparison of our observational conditions with those of GKKPT. Fig. 2 shows the *H* band measurements as a function of ϕ_{35}. Middleditch *et al.* (1983) from their measurements of HZ Her at $(\phi_{35}, \phi_{1.7})=(0.00, 0.19)$ in a wide 1.0-2.4 μm band have reported a dc flux density equivalent to $\approx 10^{-18}$ W cm^{-2} μm^{-1} at 1.6 μm.

Considering all the data points, one may make the following remarks: The infrared excess at 1.6 μm observed by GKKPT is not a regular phenomenon dependent only on the binary phase ($\phi_{1.7}\approx 0.91$) as suggested by them. Phase of the 35 day on/off state may be in someway related to be infrared emission mechanism. The *H* band excess has been seen only at $(\phi_{35}, \phi_{1.7})=(0.70, 0.89\text{-}0.92)$. The value of ϕ_{35} seems crucial, as our measurements at identical values of $\phi_{1.7}$ but at a different ϕ_{35} do not show the emission. It is interesting to note that the ϕ_{35} during the observed infrared excess emission is right in the middle of the "short-on" state of the X-ray emission of Her X-1 which appears at $0.6\leqslant\phi_{35}\leqslant0.8$ (Trümper *et al.* 1986). To ascertain that it is not a mere coincidence, further observations at similar $(\phi_{35}, \phi_{1.7})$ are needed. Even if the interrelation between the near infrared excess emission with the "short-on" phase of 35 day cycle is established, its physical interpretation in terms of the precession of the accretion disk or the neutron star, is far from clear. In addition, the infrared luminosity requirement as per GKKPT's measurements ($\gtrsim 10^{36}$ erg sec^{-1}) is probably too high to be generated by reprocessing of the X-radiation ($\approx 2\times10^{37}$ erg sec^{-1}) from Her X-1, by either the accretion disk (Hayakawa, 1981) or the optical companion (London and Cominsky, 1983).

Observations at various wavelengths in optical and X-rays show wide variety of time variability (see references in GKKPT) near the X-ray eclipse ($\phi_{1.7}\approx0.0/1.0$). Hence it could be that the infrared excess observed by GKKPT is also a similar non-repetitive transient phenomenon. It is perhaps premature to interpret or model the infrared observations till more measurements are available. Simultaneous infrared observations along with X-ray and optical band will be very useful.

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