Bull. Astr. Soc. India (2001) **29**, 295–299

A high resolution spectroscopic study of XX Ophiuchi

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Abstract. The star XX Oph has been known to exhibit peculiar spectral variabilities since the work of Merrill in 1924. A high resolution spectroscopic study of the XX Oph spectra taken in July 1996 and later in June 1997 also exhibit distinctly different line profiles in several spectral regions, the most pronounced variations being in the sodium D and H_α profiles. We have estimated the displacement velocities of the strong emission line profiles and their absorption components whenever possible and made an attempt to examine possible physical scenarios that can account for its peculiar variability.

1. Introduction

The star XX Oph (MWC 269, HD 161114) has been known to exhibit complex spectroscopic and photometric variations. Only three stars BD + 114673, HD 190073 and MWC 560 are known to exhibit spectra resembling in part the spectra of XX Oph. These features make XX Oph a particularly interesting object of study.

The discovery of XX Oph as a variable star dates back to 1924 (Beljawsky 1924) when it was thought to be a variable star of R CrB type. However, extensive observations of XX Oph and detailed studies on its light variation showed the photographic magnitudes to be fairly constant (Beljawsky 1924, Shapley & Woods 1926). Photometric observations of XX Oph in UBV, VRI and JHKLM pass-bands made between April 1981 and April 1984 showed no significant variability (Kilkenny 1985). The star seemed to show a slight variation in brightness with V ranging from 8.87 to 9.09.

The spectral classification of XX Oph is yet to be established with certainty. Andrillat and Swings (1976) observed P Cygni profiles of the Paschen 6 and He I 10830Å lines in a red spectrum of XX Oph and classified it as P Cygni-type. Lee (1970) following the definition of 'Infrared Stars' of Geisel (1970) classified XX Oph as an 'Infrared Star' The star is also classified in *The general catalogue of variable stars* (Kholopov 1990) as a 'symbiotic object' of spectral type Bpec + M5, featuring deep fadings of long duration. A number of catalogues of symbiotic stars however do not include XX Oph as a member (Allen 1984; Kenyon 1986).

Given such peculiar spectral variability, it is important to study this star at different epochs. The analysis of the various properties of numerous emission and absorption lines is likely to give us a more comprehensive idea of the structure, density and the nature of the causes for its peculiar behaviour. Our present work is aimed at getting some insight into some of these facts.

2. Observations and data reductions

1996 spectra of XX Oph were obtained on July 25 (3 frames, each of exposure time 60 m) and on July 26 (2 frames, each of exposure time 60 m) using '2dcoude', a cross-dispersed echelle spectrograph at the coude' focus of the McDonald Observatory's 107-in telescope (Tull 1995). The wavelength coverage is from 3880-10100Å and the spectral resolution is about 60,000. 1997 spectra of XX Oph were obtained on June 21, and consists of two exposures, each of 60 m duration. A Th+Ar hollow-cathod-lamp exposure was used for wavelength calibration. The CCD data are reduced using the IRAF software package.

3. Description of the spectra

Both the spectra of 1996 & 1997 are rich in singly ionized lines particularly of iron. Several Ti II lines are also quite prominent in them. Lines due to ionized Si, Sc, Cr, S, Mn, Ca and neutral lines of O, Na, Fe, Ti, Ni, and Mg are also present. The forbidden lines of [Fe II] vary in intensity from 1996 to 1997 spectra but are never very strong. They yield an average velocity of ~ -44 km s^{-1} which is comparable to those of permitted lines. Lines of [S II] at 4068Å is definitely present while 4076Å line is weak or absent. Emission lines of ionized metals dominate the spectra. Ionized lines of Mn, Ti, Si, Sc, Ca, Cr, S etc. are represented along with some neutral lines of He, Mg, Na, Ti, Fe and Ni.

Hydrogen lines : In 1996 July spectrum H_α profile at 6562.817Å is characterized by broad wings and narrow emission cores, somewhat similar to profiles seen in certain symbiotic stars, such as Z And. The velocity of central emission peak of H_α is measured to be -20 km s^{-1} on July 25, 1996. June 1997 spectrum show Hα also in emission but with a flat top, the centre at a velocity of -6 km s^{-1} (Fig 1). The base widths are estimated to be respectively 11Å and 15Å in 1996 and 1997 spectra which are quite small compared to a base width of 50Å estimated by Merrill for Hα line on 1950 spectrum.

In both 1996 and 1997 spectra, H_β, H_γ and H_δ are observed in emission. The absorption component of H_β is at a velocity of ~ -334 km s^{-1} in 1996 spectrum and a sharp emission peak at a velocity of ~ -19 km s^{-1}. In 1997 spectrum the H_β absorption feature has a broad structure and the emission profile has a central dip corresponding to a velocity of ~ -25 km s^{-1}. The base width of H_β emission lines extends upto ~ -6Å and ~ -4Å respectively, in 1996 and 1997 compared to a base width of 16.6 Å found by Merrill in his 1949 spectra. The absorption component of Hα is out of our spectral range falling between two orders. Hγ central emission has a velocity displacement of ~ -21 km s^{-1}; its absorption component is displaced by ~ -332 km s^{-1} in 1996 spectrum. In 1997 spectrum the emission line is at a velocity of ~ -23 km s^{-1} and the absorption component is displaced by ~ -147 km s^{-1}.

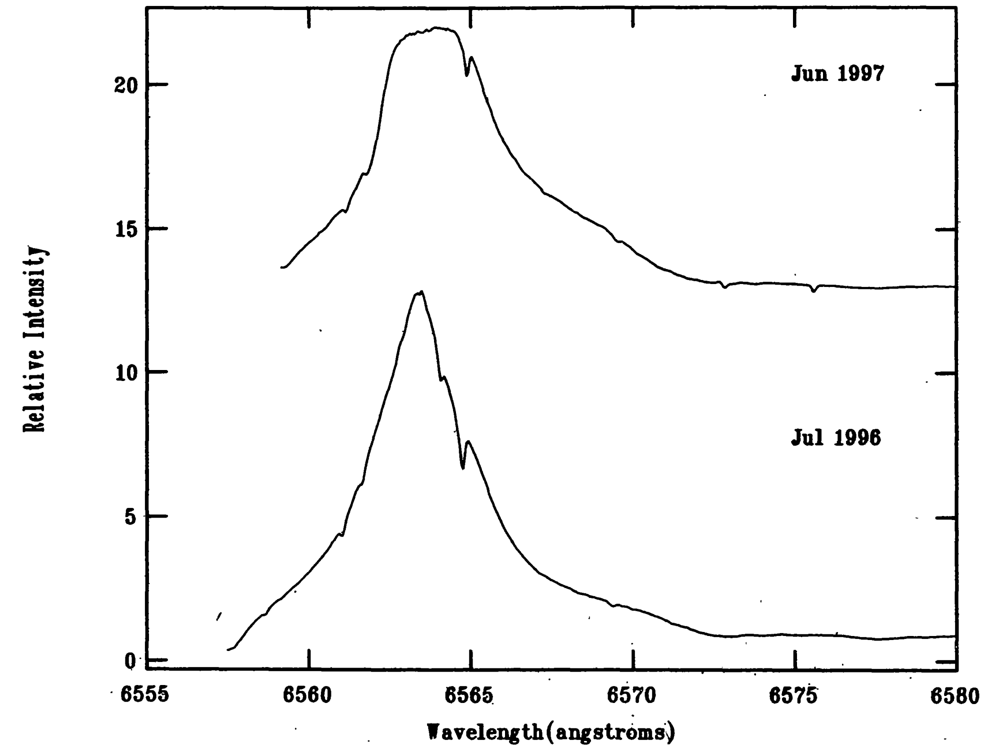

Figure 1. A comparison of the H_α profile in 1996 and 1997 spectra.

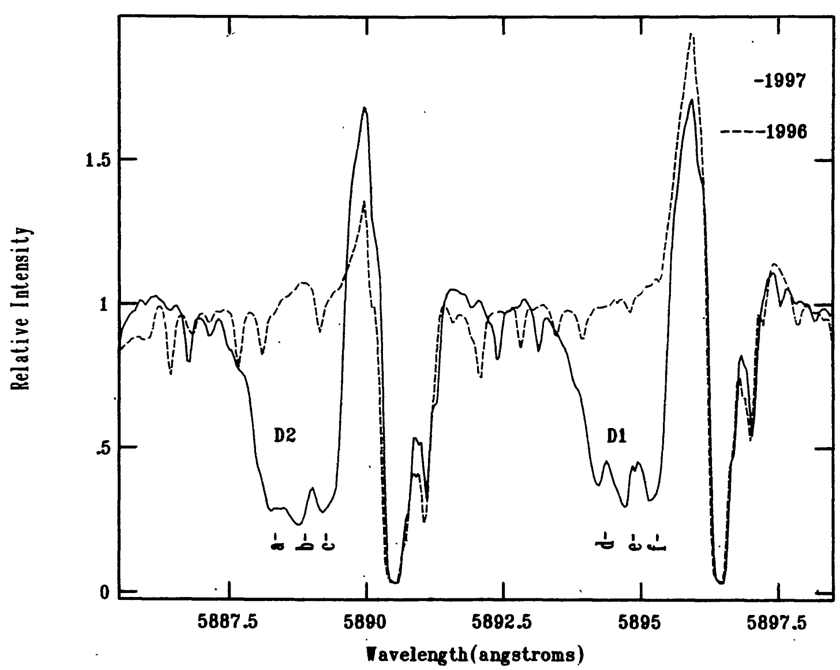

Figure 2. Sodium D regions in 1996 and 1997 spectra. In 1997 spectrum the blue shifted components of D lines designated by a, b, c, d, e and f are at velocities of -131, -104, -82, -128, -112 and -76 km s^{-1}, respectively. Similar absorption components are not noticed in 1996 spectrum.

Helium lines : He I lines at 3888.646, 3964.724, 4471 doublet, 4713.143, 4920.35 and 5015.675Å are observed in absorptions. As most of these lines appeared in blends, their displacement velocities could not be estimated accurately. He I 3888.646Å line in absorption is blended with the absorption component of H8 emission line, He I 3964.724Å line in absorption is blended with the absorption component of 3968.47Å Ca II (H) line, He I 4920.35Å line in absorption is blended with the absorption component of Fe II 4923.921Å line and also He I 5015.675Å line in absorption is blended with the absorption component of Fe II 5018.434Å line. 4143.76Å line in absorption too appears broad and blended.

Oxygen lines : Several permitted O I lines with a relatively low excitation potential are detected in both 1996 and 1997 spectra. These include 7774Å and 8446Å triplets and a weak 6726.4Å doublet.

Sodium D Lines : The sodium D profiles in 1996 (dashed curve) and in 1997 (solid curve) are shown in figure 2. The large difference between the sodium D profiles are clearly visible from the figure. In 1997 spectrum the blue shifted components of D lines designated by a, b, c, d, e and f (Fig 2) are at velocity displacements of -131, -104, -82, -128, -112, and -76 km s^{-1} respectively; similar absorption components are absent in 1996 spectrum. This obviously implies that the star was at a very different state of activity undergoing rapid changes during this epoch, which are likely to be mass loss episodes.

Other lines : We have identified a large number of Fe I and Fe II lines in both 1996 and 1997 spectra. Fe I and Fe II lines give similar velocities, an average of ~ -41 km s^{-1}. The absorption components of Ca II H (3968.47Å) & Ca II K (3933.664Å) are complex with broad absorption components.

Among other stronger emission lines are the infrared Ca II triplet. Ca II 8542.089Å and Ca II 8662.14Å appear in emission with largely displaced absorption components. K I lines at 7664.907Å and 7698.979Å are clearly observed in emission in both 1997 and 1996 spectra. The average velocity measured from the displacements of central emissions of these lines is found to be ~ -35 km s^{-1} in 1997 and ~ -41 km s^{-1} in 1996. The blue shifted absorption components have an average velocity ~ -63 km s^{-1} in 1997 and ~ -64 km s^{-1} in 1996.

4. Discussion and conclusions

The velocities derived from metallic lines appear essentially the same as those found by Merrill (1961) on several occassions. An interesting feature is two very distinct H_α emission regimes characterized by displacement velocities. The spectra obtained during the years 1945, 1959, 1960 and 1996 show a velocity ~ -20 km s^{-1}, the two years 1926 and 1997 have a very different velocity of ~ -6 km s^{-1}. The spectral nature of XX Oph is distinctly different at different episodes. To trace the history between these epochs one requires a continuous monitoring of the star, following its spectral behaviour when it is in emission to the state when its spectrum exhibits both emission and absorption. A close observation of these gradual changes is likely to reveal interesting information regarding the star's physical environment. It is possible that the unique structure and mass loss from XX Oph can be understood in terms of evolution of a closely interacting binary.

The strong emission lines of XX Oph indicate a large emitting atmosphere, but the cause of such an extended atmosphere is not yet clear. As both permitted and forbidden lines of various elements and ions yield similar velocities, the emitting regions seem relatively quiescent. As the absorbing layers seem to be more active, high dispersion spectra of XX Oph which show strong and numerous displaced absorption lines are likely to provide more information on its nature. The availability of the spectral characteristics of the star for a number of years would allow us to sketch a more detailed spectroscopic history of this star.

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