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The spectral behaviour of A-type metallic line spectroscopic binary 41 Sex A

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Abstract. Revised orbital elements of the A3 Vm type single line spectroscopic binary 41 Sex A are presented. Along with many Am stars 41 Sex A also shows a pseudo-luminosity effect, found by Abt & Morgan, quite clearly at a higher dispersion. Metallic lines in its spectra show pronounced variation with phase, the maximum strengths occurring at aproximately 0.25, 0.5, 0.75, and 1.0 of its orbital phase. The star appears to have four abundance patches indicating a quadrupole magnetic configuration. The phase modulated spectral variation in 41 Sex A suggests that it might represent a new class of Am variables.

Key words : Am stars—binary 41 Sex A—spectral variation

1. Introduction

41 Sextantis is a multiple system (HD 93903, ADS 7942); the brightest of the three optical components being 41 Sex A Cowley *et al.* (1969) classified it as an A3 metallicline star and Mendoza *et al.* (1978) give its photometric indices $V = 5.83$, $B - V = +0.16$, $U - B = +0.12$, $V - R = +0.14$, $V - I = +0.21$ and $R - I = +0.07$. Hauck & Curchod (1980) give its temperature index $B2 - V1 = -0.019$, metallic index del m2 $= -0.01$ and $V \sin i = 20$ km s^{-1}. The spectroscopic orbital elements were first deduced by Worek *et al.* (1978). These elements were improved by Raghavender Rao *et al.* (1980). Abt *et al.* (1985) & Worek *et al.* (1986). We have computed the orbital elements for this sharp lined system from the 65 spectra obtained by us between 1978 and 1988 with the Meinel spectrograph of the 1.2 m telescope of the Japal-Rangapur Observatory at a dispersion of 33 A mm^{-1} around Hγ. Table 1 gives our elements, as also the elements obtained from a combined solution from all available data. Figure 1 shows the radial velocity curve.

The metallic lines in this star are usually sharp and a visual inspection of the spectra clearly shows that while many lines vary in strength from phase to phase some may even disappear. The hydrogen lines also appear to vary along with the metals. This is in contrast to other Am stars for which the only established type of variability is photometric variability. Spectroscopic line variations, except Doppler displacements in Am binary systems, are not confirmed. Also, absence of any variability is considered an important clue to the cause of metallicity (Wolff 1983). Jaschek & Jaschek (1959) maintain that the metallicity in these stars is a luminosity effect. Am stars do mimic those

Table 1. The spectroscopic orbital elements of 41 Sex A

Orbital elements	Present study	combined solution
P (d)	6 16706 ± 00016	6 16697 ± 00005
e	055 ± 020	036 ± 010
ω (degrees)	279 5 ± 19 4	291 8 ± 11 9
T_0 (2440000 +)	6850 140 ± 334	6868 830 ± 206
K (km/s^{-1})	44 003 ± 851	45 790 ± 469
V_0 (km/s^{-1})	−5.369 ± 620	−5 104 ± 328
$a \sin i$ (10^6 km)	3 72 ± 07	3 88 ± .04
f (m) ($M_\odot$)	0 054 ± 003	0 062 ± 001

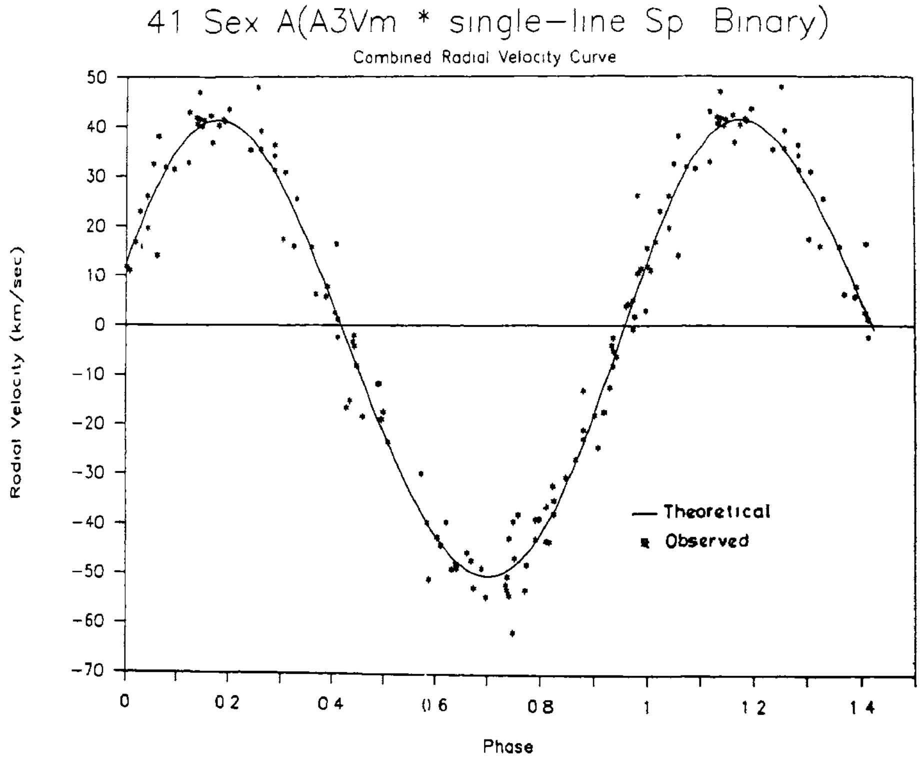

Figure 1. Combined radial velocity curve of 41 Sex A.

metal lines usually strengthened in giants and their spectrum is often classified as type III (Jaschek & Jaschek 1987). Abt & Morgen (1976) demonstrated this pseudo-luminosity effect in a group of Am stars from a visual examination of their 125 A mm^{-1} plates. We show here that 41 Sex A fits in this scenario and that it is the first of its kind to show phase dependent spectrum variation among Am stars.

2. Observations

Abt & Morgan (1976) characterize the Am spectrum by a three tier system, namely, Sp(K), Sp(m39) and Sp(m43). We confirm this phenomenology based on our study of 25

Am stars at a higher dispersion of 66 A mm^{-1} around Hγ. Many spectral line features in 20 out of 25 Am stars were found to match or resemble those of giants in 'm39' (λλ 3850-4100) region and dwarfs in 'm43' (λλ 4250-4340) region. At this dispersion, we found more spectral features showing the above phenomenon than those indicated by Abt & Morgan For example, the features at λ 4032 Å and λ 4176 Å appear to be luminosity-sensitive as they vary more strongly than the other metallic lines. A detailed paper on the MK morphological study of our sample of Am stars is in preparation. A similar study of 41 Sex A reveals that at a phase around 0.37, for example, its spectrum resembles an ordinary A3 dwarf, and at phase 0.54 it shows typical Am characteristics [Sp(K) = A3 V, m 39 = F2 III/IV and m 43 = F0 V], thus exhibiting a phase modulated spectral variation. To confirm this effect eight best spectra at a dispersion of 33 A mm^{-1} with a fairly good orbital phase coverage are scanned. It is at once apparent from these tracings that many metallic-lines in its spectrum are varying differentially with phase. Some of these lines are found to blend heavily with the hydrogen lines, in particular Hγ, and Hδ; and hence the hydrogen lines also appear to vary in phase with metals. About a dozen metal lines including Sr II 4077 Å line listed in table 2, are found to show considerable phase dependent variation; their averaged central line depth variation with phase is shown in figure 2. This clearly shows a trend—concentration of the elements about the orbital phases of approximately 0.25, 0.5, 0.75, and 1.0, with two strong peaks around 0.25 and 0.75 and weak ones around 0.5 and 1.0. This indicates a nonuniform distribution of the metallicity on the surface of the star and the probable presence of abundance patches in different strengths. The presence of magnetic fields in some strength is required for the separation of the elements on its surface is the obvious conclusion from the above findings.

Table 2. Variation of central line depths of metallic lines with phase

Element, phase Å	098	218	370	479	630	743	790	980
4032 MnI, FeI	125	154	103	.179	090	.238	.111	.171
4046 FeI, ZrII	.139	211	156	191	100	124	.130	.127
4063 FeI, CrII	.184	176	.132	212	.096	249	135	210
4077 SrII	377	349	.284	.360	243	370	.249	.290
4172 FeI, CrI, TiI	132	.191	.151	.104	089	.279	.166	096
4176-8 FeI blend	198	.282	.160	229	176	.320	177	180
4198 FeI	163	206	.120	.171	.132	.162	.135	137
4226 CaI	156	270	129	194	.124	248	.183	111
4272 FeI, VI, TiII	148	.220	121	.149	212	177	.171	.159
4290 CrI, TiI	085	264	094	.198	.150	.193	.126	.168
4301 TiI, TiII, CrI bl.	.186	307	.136	.208	.220	.196	159	.281
4308 FeI, TiI, TiII, YII	214	348	.145	.242	.211	159	.208	.294
Average	.173	248	142	.202	144	.230	.162	184

3. Discussion and conclusions

Diffusion process may be involved in producing the observed abundance anomalies in Am stars (Michaud 1970; Conti 1970b; Watson 1970 & Smith 1971) which operate uniformly over the whole surface of the star. A new dimension, however, arises from the

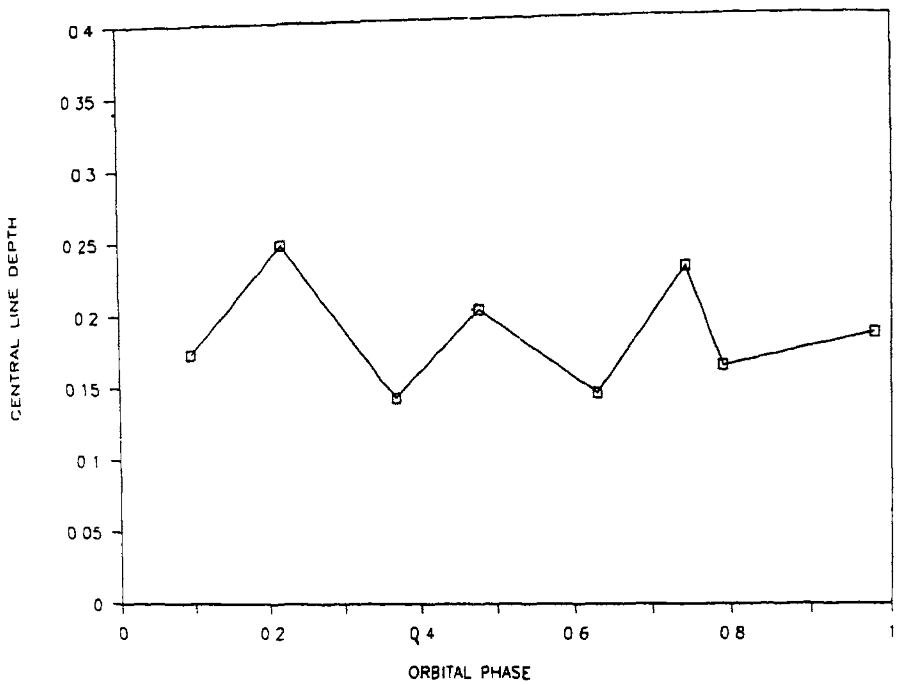

Figure 2. 41 Sex A Variation in the central line depths of metallic lines with phase

observed abundance peaks in 41 Sex A which appears to be an evolved, early Am star only at some phases. Its colours and $T_{eff} = 8100$ K (Guthrie 1987) suggest that it is not an Ap star and it cannot be a δ Delphini star either, as calcium is normal or overabundant in these stars (Jaschek & Jaschek 1987). It appears to support a variable magnetic field configuration which might be similar to those reported for Am stars by Babcock (1958). If present, we do not know if the strength of these fields is sufficient to allow diffusion to take place. Abt & Levy (1985) point out that tidal distortion in close binaries could slow down their rotation and make them stable synchronous rotators so that diffusion can take place. This appears to be the case for Am binaries with periods less than 10 days.

The phase modulated spectral variation, nonuniform surface metallicity and the abundance patches, which most likely represent the geometry of the surface magnetic fields in 41 Sex A, are some of the characteristics hitherto unnoticed in Am stars. These characteristics appear to be transitional between Am and Ap stars and therfore 41 Sex A might represent a transitional class with more pronounced Am characteristics than of Ap stars. A spectrophotometric analysis with a good phase coverage at a higher dispersion is desirable to confirm our findings. Some Am binaries like WW Aur (Kitamura *et al.* 1975-76), 3 ν Oph and 32 Vir (Abt 1961; Eggen 1976; Abt & Levy 1985) may reveal 41 Sex A type characteristics. An estimation of the magnetic field strengths on such systems would help to understand the peculiar spectrum variability of the 41 Sex A type Am stars.

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Discussion

Vardya : Has magnetic field been observed in this star, 41 Sex A? If not is it possible to estimate the minimum field you expect?

Sreedhar Rao : We do not have magnetic field estimations for 41 Sex A. It is possible to estimate the strength of mag. fields and the minimum field expected could be around 1000 gauss.

Kameswar Rao : Could you explain why Sr II lines do not show variations whereas Fe I + II lines show these phase-dependent variations? Could it possibly be due to Zeeman splitting of lines, since anyway you are involving magnetic fields?

Sreedhar Rao : Sorry, Sr II lines also show variations with phase along with the iron lines. Although some Am stars are known to have magnetic fields, it is not yet confirmed.