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# ON THE VARIABILITY OF S STARS AS OBSERVED BY THE HIPPARCOS SATELLITE

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The local part of our Galaxy contains two kinds of cool peculiar red giants of spectral type S: the intrinsic S stars with high luminosity, Tc lines in the spectra, and chemical peculiarities which were produced by intrinsic nucleosynthetic processes and the extrinsic non-Tc binary S stars which have evolved from the barium stars (Iben & Renzini 1983, McClure & Woodsworth 1990). Groenewegen (1993) examined Stephenson's (1984) catalog of S stars, Little et al. (1987), and Smith & Lambert (1988, 1990) and found 27 stars without Tc and 36 stars with Tc. Further he photometrically separated many of these stars into two groups. Simultaneously Jorissen et al. (1993) performed a similar study on the correlation between Tc lines, binary, and infrared excesses.

Recently by use of Hipparcos parallaxes Van Eck et al. (1998) found the intrinsic Tc-rich S stars are thermally pulsating AGB stars of low and intermediate masses while the extrinsic Tc-poor stars comprise mostly low-mass stars on either the red giant branch or the early AGB. The later are binaries with an average mass of $1.6 \pm 0.2$ $M_{\odot}$. Unfortunately Hipparcos parallaxes were not obtained for most of the large amplitude variables. Their division of S-stars is similar to that of Groenewegen (1993) and Jorissen et al. (1993). When a variability type is given for any large amplitude variable it is listed as a Mira.

The Hipparcos photometry (ESA 1997) provides data on many S stars with and without Tc lines in their spectra. Table 1 shows for each observed star the average magnitude, the standard error, and the amplitude (95th - 5th percentile magnitudes), any known periods from the GCVS (Kholopov et al. 1988), and the variability type (Stephenson 1984). The periods from Hipparcos when given are very similar to these. We also included Hipparcos periods for $o^1$ Ori, $\chi$ Cyg, and HR 363. Especially striking is that almost all large amplitude variables (those with amplitudes greater than 1 magnitude) are intrinsic S stars. Those stars with amplitudes of 2.24 mag or greater have periods longer than 220 days. This is in accord with Little et al. (1987) who found that M star Mira variables tend to show Tc for periods greater than 300 days.

V Cnc is the only possible extrinsic S star with a large amplitude. But it is uncertain whether it has Tc lines in its spectrum. If it is an intrinsic S star, then the extrinsic binary S stars would be more unified in their class properties. Their amplitudes would represent the typical pulsations from similar single stars with a mean amplitude of 0.11 $\pm$ 0.07 mag (19 stars). Of the intrinsic S stars, 8 have similar amplitudes while 10 have intermediate amplitudes. Smith & Lambert (1988) found four of these stars NO Aur,

Table 1: Hipparcos Photometry of Various S Stars

| Name | HD | HIP | Average mag. | Standard error | Ampl. (mag.) | Period (days) | Sp. Type |
|---|---|---|---|---|---|---|---|
| | | | Stars with Tc lines | | | | |
| T Cet | 1760 | 1728 | 5.4391 | 0.0334 | 0.66 | 158.9 | M5S |
| R And | 1967 | 1901 | 10.7054 | 0.0114 | 2.97 | 409.3 | S6,6e |
| W And | 14028 | 10687 | 8.0759 | 0.2264 | 2.24 | 395.9 | S7/1e |
| $o^1$ Ori | 30959 | 22667 | 4.7029 | 0.0052 | 0.09 | 30.29 | S3/1 |
| NO Aur | 37536 | 26718 | 6.2431 | 0.0111 | 0.17 | | M2S |
| R Gem | 53791 | 34356 | 7.5292 | 0.4569 | 3.78 | 369.9 | S5/5 |
| AA Cam | 54587 | 35045 | 7.5787 | 0.0079 | 0.48 | | M5S |
| Y Lyn | 58521 | 36288 | 6.8979 | 0.0051 | 0.75 | | M6S |
| | 63733 | 38217 | 7.9816 | 0.0021 | 0.08 | | S4/3 |
| NQ Pup | 64332 | 38502 | 7.5320 | 0.0155 | 0.22 | 120. | S5/2 |
| RS Cnc | 78712 | 45058 | 5.4500 | 0.0267 | 0.93 | | M6S |
| HR 4647 | 106198 | 59588 | 6.1429 | 0.0101 | 0.51 | | M4S |
| S UMa | 110813 | 62126 | 8.9095 | 0.1489 | 3.01 | 225.9 | S3/6e |
| ST Her | 142143 | 77619 | 6.9206 | 0.0262 | 0.71 | 148 | M6.5S |
| S Her | 152276 | 82516 | 8.2809 | 0.2368 | 4.10 | 307.3 | M4Se |
| OP Her | 163990 | 87850 | 6.1059 | 0.0102 | 0.35 | 120.5 | M5S |
| | 170970 | 90723 | 7.4571 | 0.0027 | 0.11 | | S3/1 |
| T Sgr | 180196 | 94706 | 10.8263 | 0.2237 | 3.97 | 394.7 | S5/6e |
| $\chi$ Cyg | 187796 | 97629 | 6.1696 | 0.1686 | 5.19 | 402.3 | S7/1.5e |
| AA Cyg | 190629 | 98856 | 8.1592 | 0.0376 | 1.01 | 212.7 | S6/3 |
| | 191630 | 99758 | 6.7577 | 0.0046 | 0.15 | | S4,4 |
| | 199799 | 103476 | 7.2485 | 0.0168 | 0.27 | | MS |
| HR 8062 | 200527 | 103828 | 6.1764 | 0.0046 | 0.18 | | S4/1 |
| X Aqr | 211610 | 110146 | 10.1887 | 0.1796 | 3.66 | 311.6 | S6,3 |
| $\pi^1$ Gru | 212087 | 110478 | 5.4957 | 0.0119 | 0.80 | | S5,7: |
| HR Peg | 216672 | 113131 | 6.3460 | 0.0164 | 0.23 | 50 | S4/1 |
| | | | Stars without Tc lines | | | | |
| | 310 | 621 | 7.5704 | 0.0038 | 0.09 | | S3.1 |
| | 6409 | 5091 | 7.4622 | 0.0043 | 0.10 | | M2wkS |
| HR 363 | 7351 | 5772 | 6.3950 | 0.0045 | 0.09 | 7.494 | S3/2 |
| BD Cam | 22649 | 17296 | 5.0956 | 0.0035 | 0.10 | | S4/2 |
| | 29704 | 21688 | 8.2551 | 0.0098 | 0.24 | | S: |
| | 35155 | 25092 | 6.8824 | 0.0115 | 0.21 | | S3/2 |
| V613 Mon | 49368 | 32627 | 7.7492 | 0.0041 | 0.16 | | S3/2 |
| NZ Gem | 61913 | 37521 | 5.5874 | 0.0033 | 0.08 | | M3S |
| V Cnc | 70276 | 40977 | 9.2621 | 0.1521 | 2.59 | 272.1 | S3/6e |
| DE Leo | 90254 | 51008 | 5.6925 | 0.0055 | 0.06 | | M3S |
| | 96360 | 54396 | 8.0759 | 0.0060 | 0.19 | | M3Swk |
| | 119667 | 67070 | 8.5417 | 0.0024 | 0.05 | | M1Swk |
| | 150922 | 81970 | 7.8030 | 0.0049 | 0.08 | | M2S |
| | 151011 | 82038 | 6.6890 | 0.0029 | 0.05 | | Swk |
| | 165774 | 88940 | 8.2111 | 0.0032 | 0.07 | | S4,6 |
| V1743 Cyg | 184786 | 96198 | 6.0075 | 0.0092 | 0.18 | | M5S |
| | 191226 | 99124 | 7.3741 | 0.0020 | 0.07 | | M3S |
| | 191589 | 99312 | 7.3682 | 0.0017 | 0.06 | | S |
| | 215336 | 112227 | 7.9295 | 0.0019 | 0.06 | | Swk |
| GZ Peg | 218634 | 114347 | 5.0336 | 0.0117 | 0.24 | 92.7 | M4S |

HD 63733, ST Her, and HD 170970 to have wavelengths of the $\lambda$ 4262 line just at the boundary between Tc-rich and Tc-poor stars. Three have amplitudes in the extrinsic S star range. However a resolution of 0.18 Å is insufficient to cleanly separate the two types of S stars. According to Jorissen et al. (1993) HD 63733 and HD 170970 are really extrinsic S stars being binary and lacking infrared excesses. Ake & Johnson (1988) discuss $o^1$ Ori which is another outlyer in the Tc-rich stars. It has a white dwarf companion and intrinsic S star features. Hence the other S stars in the intrinsic list with amplitudes like those of the binary stars should be studied carefully to make sure they are in the correct category.

Adelman (1998) found that BD Cam was pulsating with a period of 24.76 days with an amplitude of almost 0.20 magnitudes. This was superimposed on the binary period of 596.21 $\pm$ 0.19 days found by Griffin (1984). HD 35155 acts in a somewhat similar manner with the intrinsic variations superimposed on an eclipsing behavior which is related to the orbital motion (Jorissen et al. 1992, 1996). As both are extrinsic binary S stars, we might expect that the other extrinsic S stars exhibit somewhat similar behavior. In making comparisons between Hipparcos light curves, a difficulty is that the sampling depends on where the star is in the sky. Many observations are closely bunched rather than sampled in a more random manner. The Hipparcos light curves of these stars (except for V Cnc) look like random samples of pulsating stars with periods of order a month. A complete demonstration requires photometry which samples the light of these stars every few days.

Of the intrinsic S stars, T Cet shows a systemic decline of about 0.8 mag. with pulsations superimposed. The large amplitude intrinsic S stars tend to have fragmentary light curves for the most part with suggestions of pulsation. The smaller amplitude stars have light curves often resembling those of the extrinsic S stars. But AA Cam shows a definite minimum as does HD 63733.

The intrinsic S stars show a range in amplitude variability with periods between 30 and 419 days. But many such stars still have periods to be determined. It is possible that all the large and medium (0.3 - 1.0 mag.) amplitude variables are intrinsic S stars and the small amplitude variables are extrinsic S stars. Thus the conclusion of Little et al. (1987) that Miras with periods greater than 300 days tend to be what are known as intrinsic S stars is confirmed and extended.

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