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Title: Collaborative Observations of HDE 332077

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Results:

IUE low dispersion observations were made of the Tc-deficient peculiar red giant (PRG) star, HDE 332077, to test the hypothesis that Tc-poor PRGs are formed as a result of mass transfer from a binary companion rather than from internal thermal pulsing while on the asymptotic red giant branch. Previous ground-based observations of this star indicated that it is a binary, but the secondary star was too massive for an expected white dwarf. A deep, SWP exposure was needed to search for evidence of an A-type main-sequence companion. We obtained a 120 minute LWP exposure (LWP 23479), followed by a collborative 1230 minute SWP exposure (SWP 45113). These observations were combined with our earlier IUE and optical data on this PRG star to model the spectral energy distribution of the system.

We found that the SWP exposure, though faint, indicates that the secondary is an A-type star, but to match the LWP and SWP fluxes together, a three-component model is required, particularly to fill-in the LW region. Further constraints on the system require infrared photometry to be obtained.

These results were presented at the 181st meeting of the American Astronomical Society.

Publications:

"IUE Observations of HDE 332077", T. Ake, A. Jorissen, H. Johnson, M. Mayor, and B. Bopp (1992), BAAS, 24, 1280.

IUE Observations of HDE 332077

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The Tc-poor S star HDE 332077 has been found by Jorissen and Mayor (A&A, 260, 115, 1992) to be a spectroscopic binary with an unusually high mass function. According to our current understanding of the Tc-deficient S stars, the abundance peculiarities of the primary should have been the result of mass-transfer from the secondary star when it was on the asymptotic giant branch at an earlier time. The secondary should now be a white dwarf (Johnson, Ake, and Ameen, ApJ, 402, in press). For HDE 332077, Jorissen and Mayor argue instead that the mass function, $B - V$ color, and UV upper flux limits constrain the secondary to be an A-type main sequence companion and the primary to be more luminous than typical S stars. The system is still considered to be a post-mass transfer binary since the mass ratio is reversed for any set of reasonable masses.

We have obtained *IUE* low dispersion spectra of this system. The LWP region is quite unusual. The spectral slope is steep and the absorption line spectrum is washed out, while Mg II 2800 Å is strongly in emission. A trace of spectrum appears on a 20 hour exposure with the SWP, with a mean flux level of 6 x 10^{-16} erg cm^{-2} s^{-1} Å^{-1} in the 1730 – 1980 Å region. The spectral slope in the SWP is indeed that of an A-type star, but it is difficult to match the LWP and SWP fluxes simultaneously with a simple addition of a red giant and early main sequence star.

Abstract submitted for AAS [AAS] meeting

ABSTRACT

We have obtained *IUE* and Hα spectra of the peculiar S-star spectroscopic binary, HDE 332077, argued by Jorissen and Mayor (1992) to be a low-mass, rather luminous ($M_V \sim -3$), and Tc-poor S star with a post-mass transfer A-type main sequence companion. We have found this star to exhibit several unusual characteristics, including broad Hα emission with a strong central absorption and a nearly featureless UV continuum, except for Mg II in emission. The *IUE* data can be approximately fit by a heavily reddened A5 V star with a cooler continuous source (accretion disk?), but none of the models can fit the optical and UV energy distribution uniquely. This system bears on studies that the Tc-deficient peculiar red giants are mass-transfer systems rather than genuine asymptotic giant branch members.

INTRODUCTION

Of the chemically peculiar red giants (PRGs), the S stars have always been difficult to interpret in terms of temperature, luminosity, chemical composition, and evolutionary status. Amongst the red giants, they are extremely rare (< 1% of the stars), which has been attributed both to the delicate balance struck in their atmospheres between carbon, oxygen, and s-process elemental abundances and to the rapid stage of evolution that occurs on the asymptotic giant branch (AGB), of which they are likely members. With a C/O ratio near 1 and an overabundance of s-process elements, members of the class show a wide range of absorption line and molecular band features of exotic species.

It is thought that the S stars are a simple transitional phase through which an oxygen-rich M giant must proceed on the way to becoming a carbon star, *i.e.*, the M-MS-S-SC-C

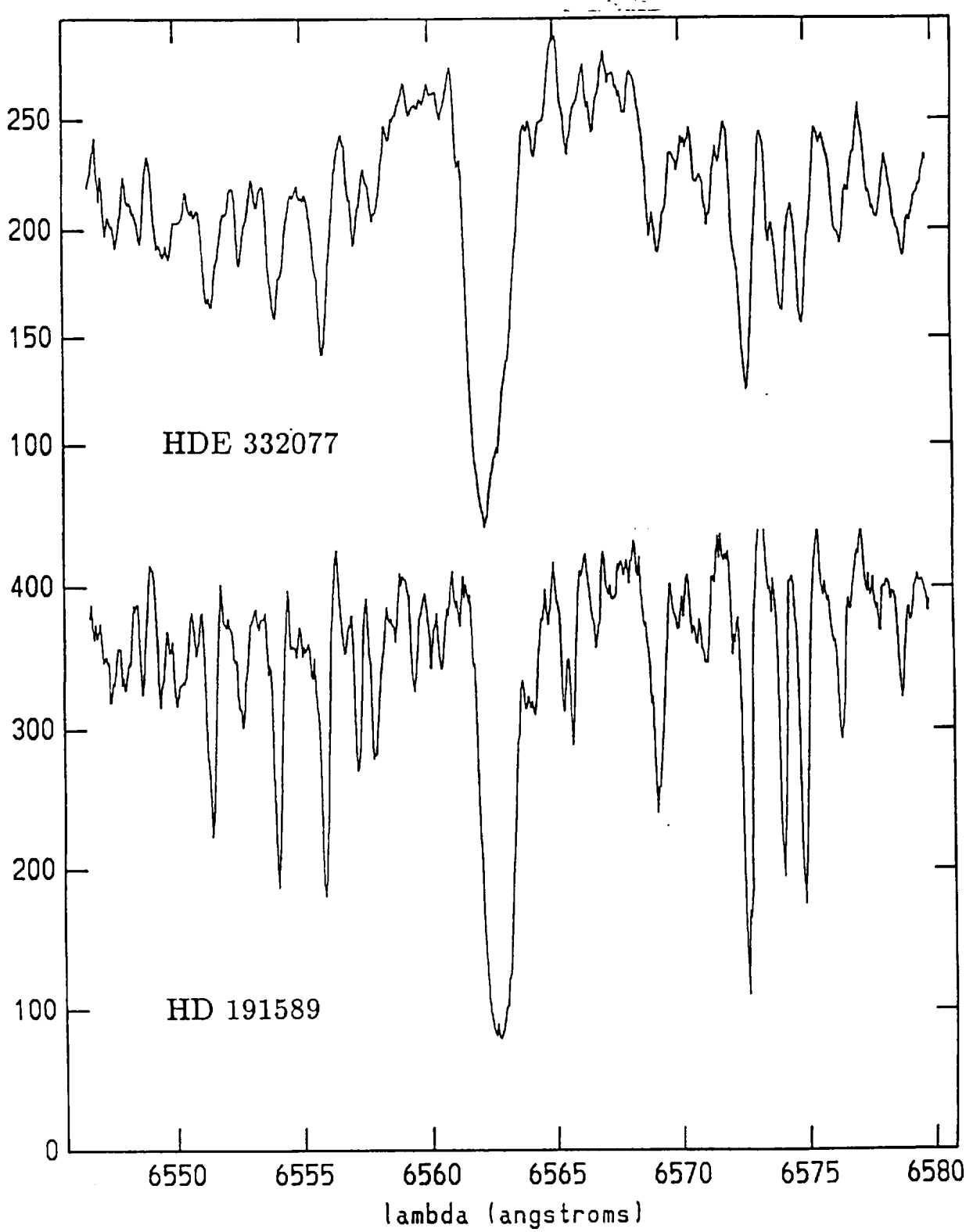
spectral classification sequence is an evolutionary one. During the past decade, it has been becoming evident that this picture is much too simple, and a group of the S stars, like other PRGs (Ba II stars, carbon stars, etc.), have a range of evolutionary histories.

Several lines of analysis, including IUE discoveries of degenerate companions and determinations of orbital motions from radial-velocity measurements, have lead to the concept that the S-type stars without Tc are a distinct class of PRGs. An s-process element with no stable isotope, Tc in the atmosphere of a red giant is direct evidence of the dredge-up of processed material from the interior regions of the star to the surface during thermal pulses when a star is on the AGB. The absence of Tc in a star with enhancements of other s-process elements has been a puzzle usually explained by having the dredge-up mechanism cease long enough for the Tc to decay away, but there are difficulties then with the timing of the dredge-up events and the expected lifetimes of stars on the AGB.

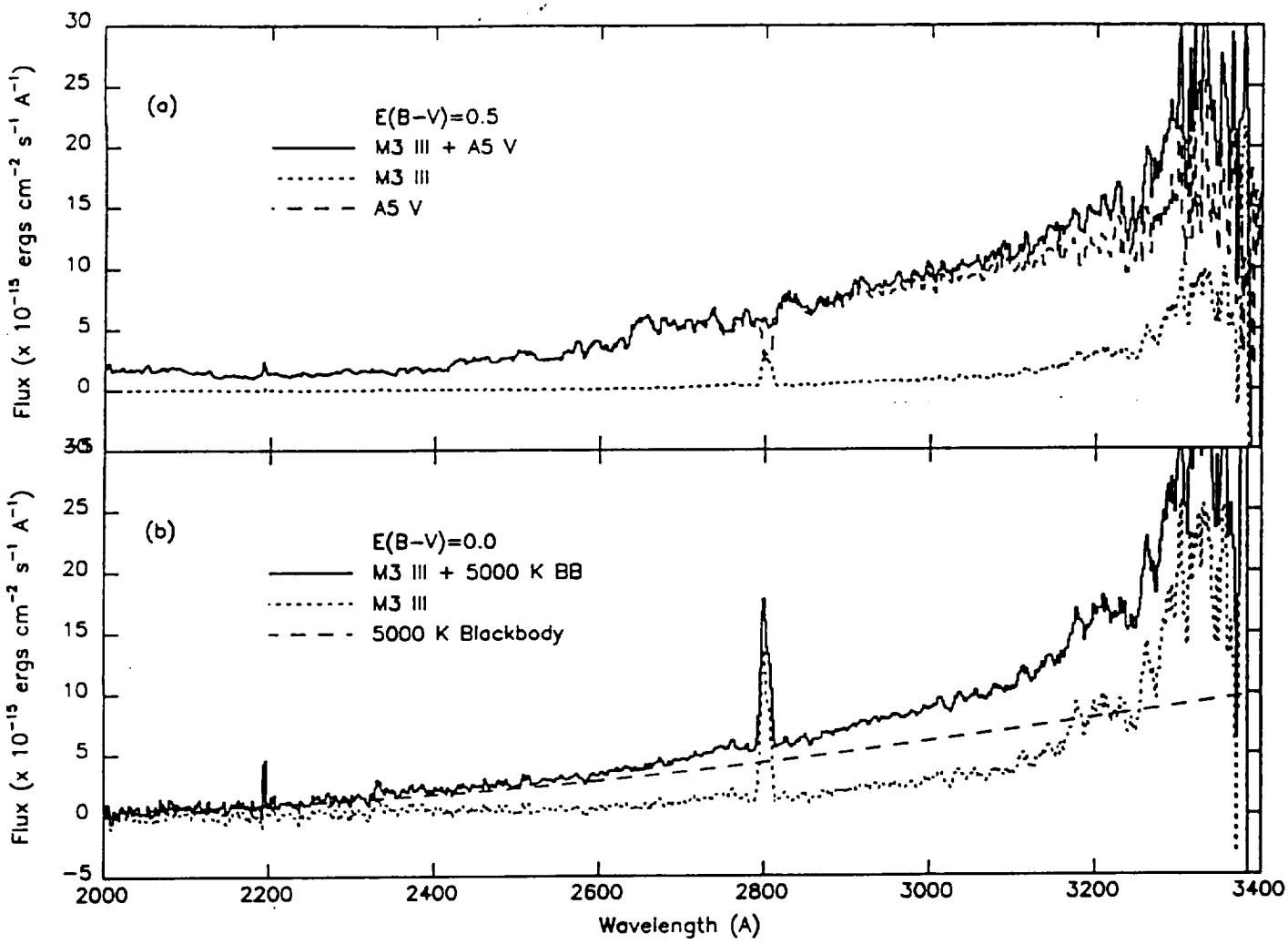
It now appears that the Tc-deficient S stars are binary systems in which mass transfer has played a role in the past (Johnson 1992). Since in many of these systems we have found a more highly evolved, post-AGB companion (a WD), the abnormal peculiarities seen in the current red giant primary could be due to a past transfer of material from the outer atmosphere of the other star when it was once an AGB star. Indeed, some of these systems now show evidence of interaction (optical and/or UV emission lines) indicating that the components are close and intrasystem material is present. The absence of Tc in a star with an otherwise overabundance of s-process elements is then a true indication that no dredge-up is currently taking place, because it took place long ago in the other star.

As part of studying the incidence of S-star spectroscopic binaries with the CORAVEL radial velocity spectrometer, Jorissen and Mayor (1988) discovered that the S3,1 star HDE 332077 exhibited a larger than usual velocity amplitude and a broad cross-correlation

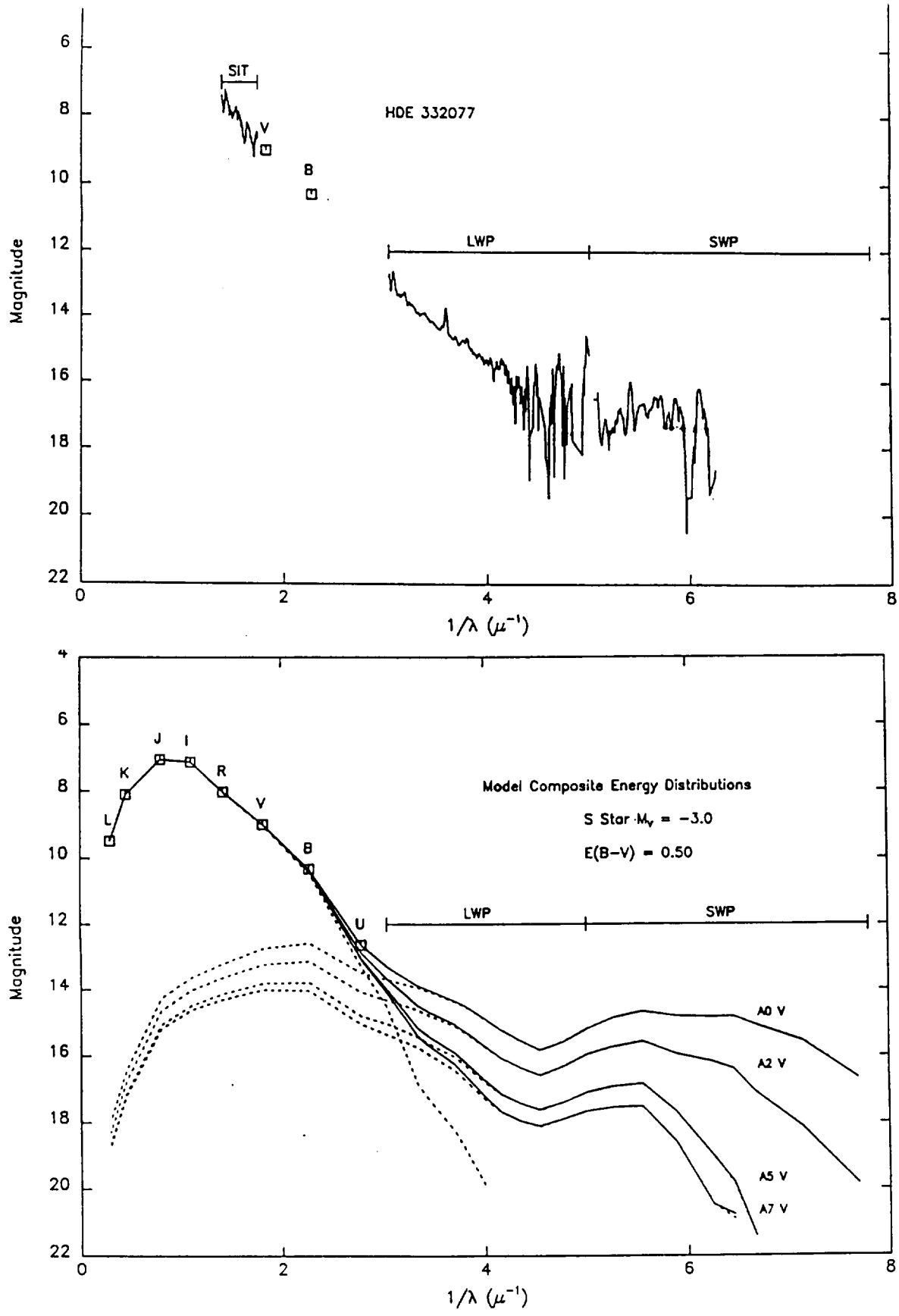
dip suggesting broadened absorption lines. Further observations lead to the determination of the orbit (Jorissen and Mayor 1992) and a mass function for the secondary of 1.2 $M_\odot$. By assuming possible He-core masses for the primary star, constraints can be placed on the mass of the secondary, and they have argued that it must have a mass larger than $\sim$1.6 $M_\odot$, which is too large for a white dwarf. The broadened lines can be attributed either to a normal luminosity class III giant in synchronous rotation, or a more luminous, lower gravity star with large macroturbulence, of which they favor the latter due to other constraints on the system. A two-hour SWP exposure only yielded upper limits to the flux from the secondary. They also find from a high resolution exposure covering the 4262 Å region that HDE 332077 is Tc deficient. In all, they favor a picture of HDE 332077 being a reddened, luminous ($M_V \sim -3$), Tc-poor S star with an A0 - A7 main sequence companion.



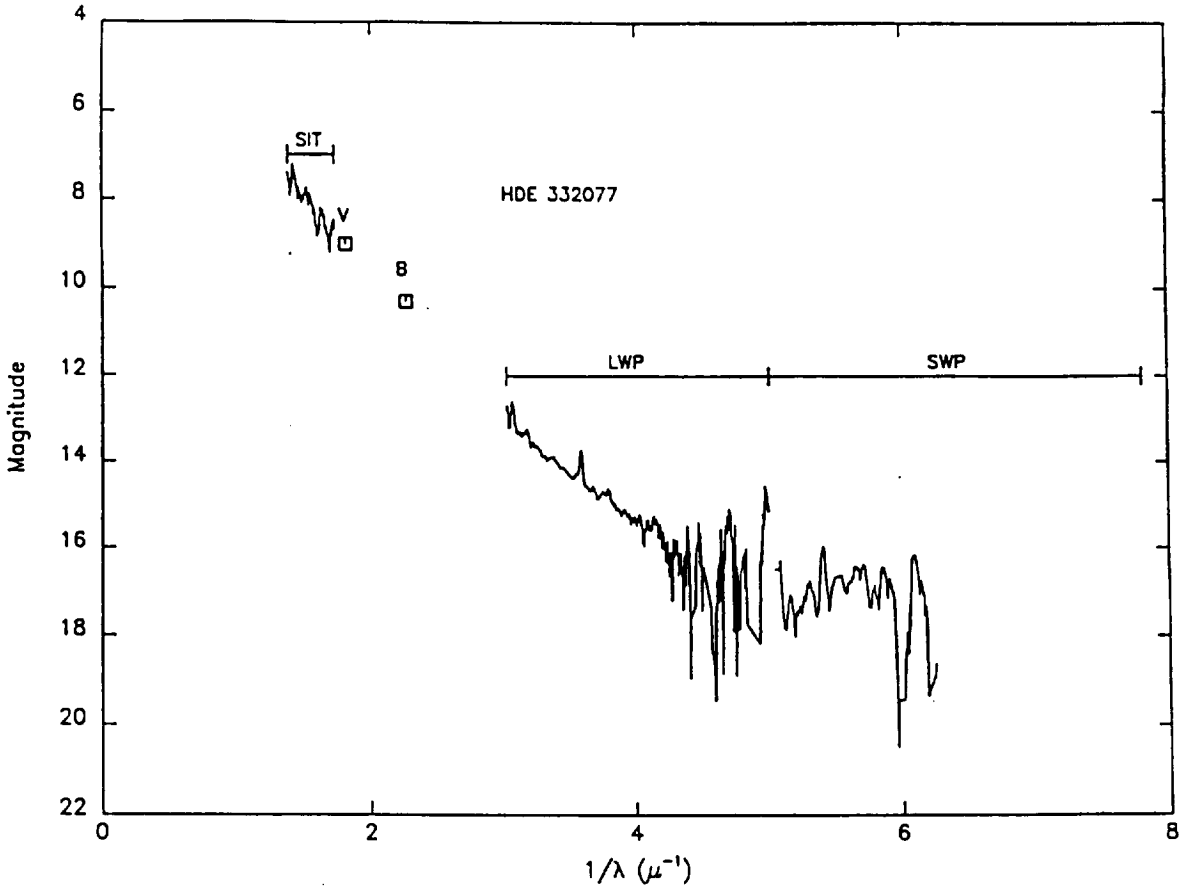
Hα observations of HDE 332077 and the M0S star, HD 191589. Hα is weakly in emission in HDE 332077, with a FWHM of 400 km s^{-1}, and a comparison of the absorption lines confirms that the lines are abnormally broad.

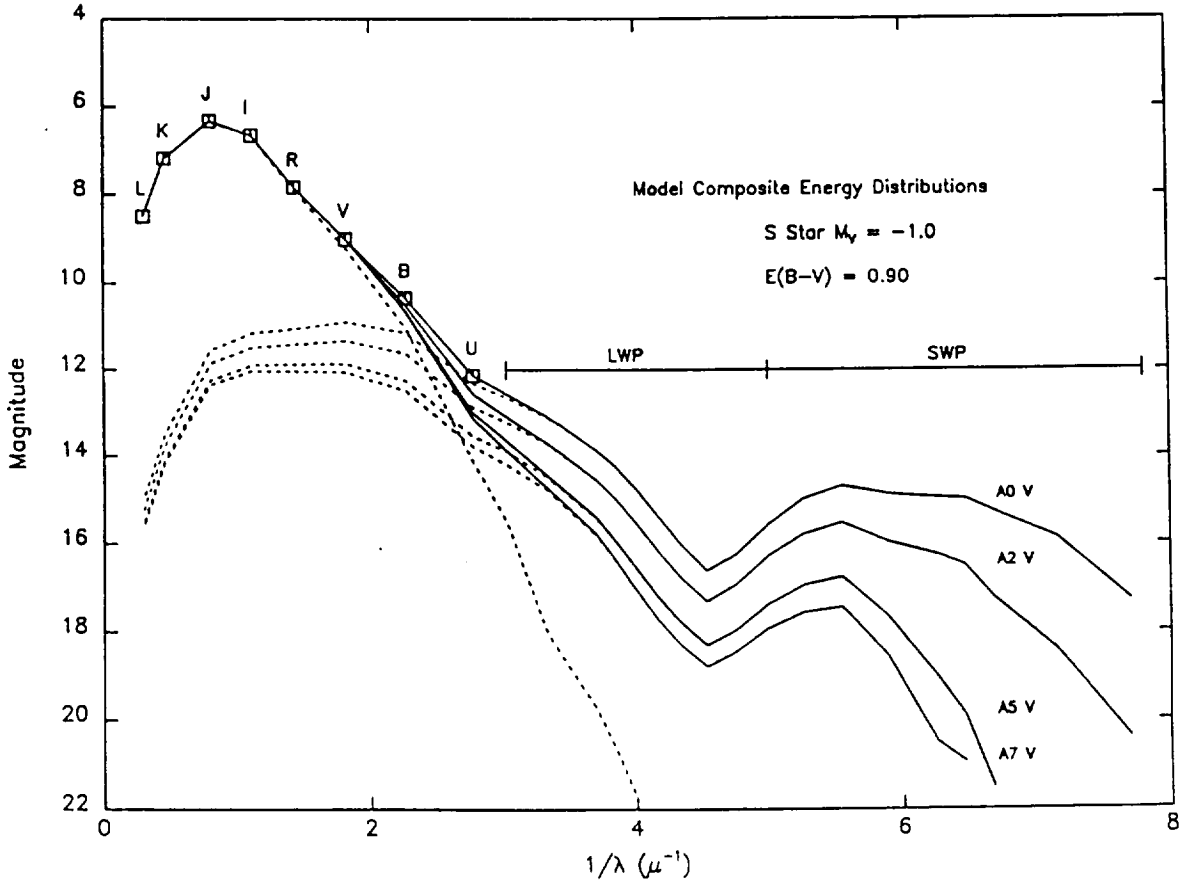


The LWP spectrum is quite unusual. The spectral slope is steep, and the absorption line spectrum is nearly gone. Mg II, however, is strongly in emission. The general appearance is that of a red giant star whose absorption spectrum has been filled in by a continuous underlying source. We can fit the LWP spectrum with a reddened A5 V star with $E(B-V) = 0.5$, although with a normal luminosity of $M_V = -1.5$ for the S star. The composite model, however, predicts that the Mg II emission from the red giant should just fill in the absorption from the A star. Thus the observed Mg II emission (as well as that for Hα) requires an excitation mechanism other than just a normal AGB star with a main sequence companion. The composite also indicates that an absorption spectrum, though weak, should be seen, particularly the Fe II edges at 2400 and 2600 Å and lines due to Fe II and Cr II near 2750 Å.

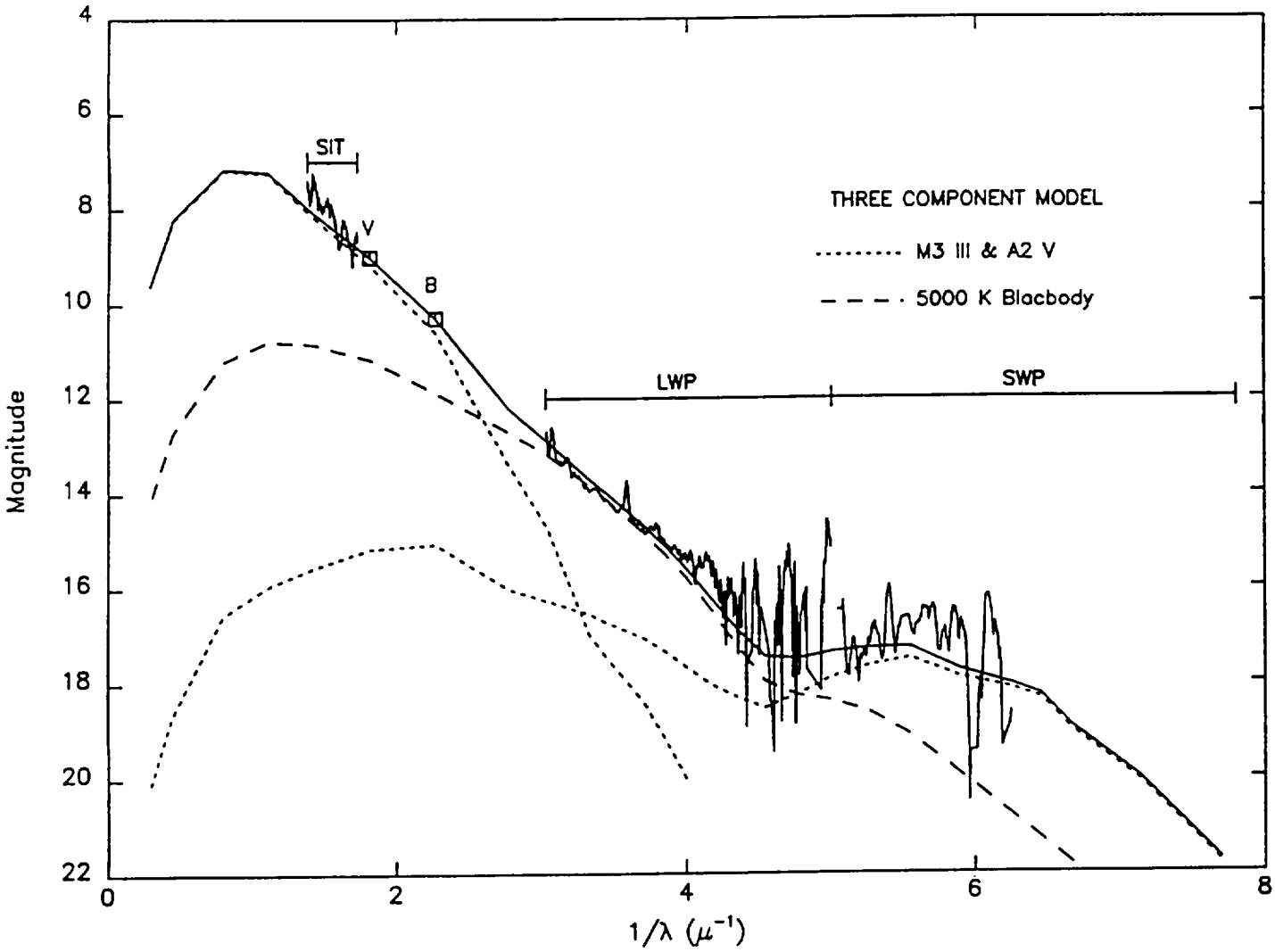


New *IUE* SWP and a SIT spectrum from 5800 - 7200 Å taken at the Palomar 60-inch telescope allow us to analyze the energy distribution from 1600 - 7200 Å. We have generated a family of curves using the method of Parsons (1981), combining broadband photometry and UV data on a common energy magnitude scale of various spectral types and reddenings. Here we show all data on HDE 332077 with Jorissen and Mayor's derived parameters. It is not possible to fit both the LWP, SWP and SIT data simultaneously.





By increasing the reddening and reducing the luminosity of the S star, we get an improved match, but the 2200 A interstellar depression appears to be too strong.



To match the entire energy distribution, we need a three component model: the S star, the main sequence companion, and added continuum in the LWP region. The added flux perhaps comes from a cool accretion disk, which would also be the source of the enhanced Hα and Mg II. The fit, however, is still not satisfactory.

CONCLUSIONS

We have not been able to derive a unique model for HDE 332077 as of yet. *Infrared photometry is particularly needed to help resolve the question of reddening.*

HDE 332077 poses several problems and thus provide opportunities for better understanding the Tc-deficient PRG binaries. Evidence in the past has indicated that the progenitors of the S stars are not as massive as A-type main sequence stars, but rather they are evolved F-G stars. As a group, their space motions are like those of dF5 stars, and only late-type companions have been found for the S stars: π^1 Gru (G0 V), T Sgr (F3 III-IV), W Aql (F5-8), WY Cas (G), and and HD 191589 (F0-2 IV-V). HDE 332077 would be the first instance of an S star with an A-type companion. And if it is as luminous as $M_V = -3$, it could be a true thermally-pulsing AGB star and should show Tc. Furthermore, unless HDE 332077 is a triple system including a white dwarf, it is a counter example to the hypothesis that Tc-deficient PRGs are polluted stars.

REFERENCES

Jorissen,A. & Mayor, M. A&A, 198, 187.

Jorissen, A. & Mayor, M. 1992, A&A, 260, 115.

Parsons, S.B. 1981, ApJ, 247, 560.

Johnson, H.R. 1992, in *IAU Symp. 151, Evolutionary Processes in Interacting Binary Systems*, eds. Y. Kondo, R. Sistero, R. Polidan , p. 157.

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16. Abstract

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