

## The Unusual S Star Binary HD 191589: A Triple System?

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Received \_\_\_\_\_; accepted \_\_\_\_\_

## ABSTRACT

Recently, we discovered with *IUE* an F0-F2 IV-V companion to the Tc-deficient S star HD 191589. If the magnitude difference is  $\Delta V = 3.7$ , as indicated by several arguments, and  $E(B - V) = 0.0$ , we obtain a value of  $M_V = -1.5 \pm 0.4$  for the peculiar red giant (PRG), too faint for it to be a thermally-pulsing asymptotic giant branch star. According to the binary mass-transfer hypothesis for Tc-deficient PRGs, a white dwarf must be the source of the s-process enhancement of the current primary star, but it cannot be seen because of the presence of the secondary. If such is the case, the F-star companion may also have been contaminated by s-process material.

High-dispersion *IUE* observations indicate an enhancement of Zr II in the photosphere of the F-star as well. Thus HD 191589 is likely a triple system, where what was once the most massive component of the system has polluted both of its companions with s-process material. One of these is the current S star, while the other is the companion still near the main sequence.

## 1. Introduction

The peculiar red giant (PRG) stars are generally thought to be asymptotic giant branch (AGB) stars undergoing the third dredge-up from thermal pulses during double-shell burning. The discovery of lines of the unstable element Tc in the spectra of certain S stars (Merrill 1952) demonstrated the reality of current mixing of nuclearly processed material to the surface. Later surveys proved that such mixing processes occur in most AGB stars, and theorists have been able to reproduce these observations by mixing (called the third dredge up), although it requires special conditions that strain current theories. Many of the abundance peculiarities in spectra of stars in the sequence M-MS-S-C (enhancement of  $^{12}\text{C}$  and s-process elements) are understood as products of the third dredge up accompanying thermal pulses (helium shell flashes) in low-mass stars – those with masses in the range 1-6  $M_{\odot}$ , the upper limit being slightly uncertain.

Certain PRG stars, however, must have been formed through other scenarios, for although they show surface enhancements of s-process elements and carbon (usually taken as evidence of dredge up), their luminosities appear to be too low (from theoretical considerations) for thermal pulsing to have begun. Among such anomalous objects are the barium and CH stars. Furthermore, a large fraction of the bright S stars surveyed to date – 22 out of 58 – do not show Tc lines in their spectra (Little, Little-Marenin, & Bauer 1987, hereafter LLB; Smith & Lambert 1988, hereafter SL). Yet once the third dredge up begins, Tc is expected to be continuously present on the stellar surface. Its absence in many S and MS stars, as in barium stars, consequently was a puzzle.

The discovery that all barium stars are binaries (McClure, Fletcher, & Nemeč 1980) opened the way for an attractive explanation of the puzzle by the evolutionary scenario of mass transfer in a binary system. Later studies have confirmed that all Ba stars are binaries (Jorissen & Mayor 1988) and that their companions are WDs (McClure & Woodsworth

1991). It has therefore been suggested that Tc-deficient S stars also binaries; that is, Tc-poor S stars are evolved Ba stars (Peery 1985, 1986; Smith & Lambert 1986; LLB; Little-Marenin 1989; Jorissen & Mayor 1992).

As noted already by Merrill (1952), the unstable element Tc plays a central role in these considerations (cf. Merrill 1952; Little-Marenin & Little 1979; Peery 1986; Smith & Lambert 1988; LLB; Little-Marenin 1989; Kipper 1991). Tc has no stable isotope; the half life of the only s-process isotope ( $^{99}\text{Tc}$ ) is about 200,000 years. Consequently, Tc is absent in normal, main-sequence stars. In AGB stars, Tc and other s-process elements are produced by slow neutron capture and then dredged to the surface. Since the AGB lifetime of stars is only a few million years, some surface Tc would be expected to survive throughout the AGB lifetime. Moreover, the time interval between dredge-up episodes – something like 50-100,000 years – is shorter than the half life for Tc decay, so that fresh Tc is continually brought to the surface. This theoretical idea appears to find confirmation in the fact that Mira variable stars of all spectral types with  $P \geq 300$  days show Tc lines in their spectra (LLB). If, on the other hand, matter from a mass-losing AGB companion were captured onto the surface of a main-sequence star, the Tc would decay over an interval much shorter than the evolutionary time from the main-sequence to the red-giant region. Therefore, mass transfer and subsequent decay would leave the photosphere of the companion enhanced in carbon and s-process elements but without Tc. Consequently, according to the most popular hypothesis, the Tc deficiency serves as a marker for binary PRG stars which are “accidental” or “extrinsic” rather than “evolutionary” or “intrinsic”(SL; LLB).

Hot compact companions to six of these S stars have indeed been discovered with *IUE*, including the S star HD 35155 (Ake, Johnson, & Ameen 1991), the spectroscopic binary HR 1105 (Peery 1986; Ake, Johnson & Peery 1988), the MS star  $\sigma^1$  Ori (Ake & Johnson 1988), and the S star ER Del (Johnson & Ake 1989). Furthermore, we have inferred the presence of a companion from the UV excess compared to field M giants of similar temperature for

the MS stars HR 363 (Ake, Johnson & Peery 1988) and HD 191226 (Johnson & Ake 1992). A review of four lines of evidence supporting the mass-transfer hypothesis for Tc-poor S and MS stars has recently been given (Johnson 1992), and comprehensive summary of all *IUE* observations of S and MS stars has recently been assembled (Johnson, Ake & Ameen 1993: JAA).

As part of the program for investigating the binarity of Tc-deficient S stars with *IUE* (JAA), we discovered an early F-type companion to the M0S star HD 191589 (Ake & Johnson 1991). The S star HD 191589 was first identified as such by Bidelman (1957), who classified it as a M0 Ib or II star with ZrO and with strong Sr II and Ba II lines. Later it was classified as an M0S star (Ake 1979). It was later shown to lack Tc (Smith & Lambert 1988) and to be a radial-velocity variable (Brown et al 1990). Furthermore, the reality of the s-process enhancements and the Tc deficiency has been confirmed after our discovery of the companion (Lambert 1991: private communication). Because these characteristics made HD 191589 a good candidate for testing the binary hypothesis for S star formation, we observed it with *IUE* to search for ultraviolet light from the putative WD companion. Instead of a WD, we found a much brighter secondary.

## 2. Observations

*IUE* exposures were made in low dispersion using the LWP and SWP cameras (Table 1) and the data were reduced at the Goddard Regional Data Analysis Facility. The discovery observation of the secondary (LWP and SWP) occurred on 6 April 1991, and a second SWP image was taken on 16 April to check on variations in case this was an interacting system as has been found with other Tc-deficient S stars (Ake, Johnson & Ameen 1991). No variations were detected in the SWP region, which is consistent with the fact that no emission lines characteristic of interaction were seen either.

Follow-up high dispersion observations were obtained with the LWP camera to search for abundance anomalies in the secondary star, which dominates the composite light in this wavelength region. Additional low dispersion spectra taken at this time confirmed the lack of variability in the system on a long-term (17 month) basis.

### 3. Analysis of Low Dispersion Spectra

The spectral slope and line spectrum of the SWP spectrum is that of an early F star. In Figure 1, we compare HD 191589 with late A- to early F-type *IUE* standards (Wu et al 1983). The secondary star lies between the F0-F2 standards, or more appropriately, with  $0.28 < (B - V) < 0.36$  since UV spectral types do not always match optical ones as well as with (B-V). The match is very good, and coupled with the lack of variability and emission lines, indicates we are seeing the photosphere of a star. By comparing the measured fluxes of these stars, we can derive an apparent magnitude for the secondary star based on flux ratios in the 1725 – 1985 Å region (Table 2) and find  $V_{F_*} = 11.0 \pm 0.2$ , uncorrected for any reddening.

In the LWP region, we must consider the contribution of the red giant to the observed flux. This requires knowledge of the magnitude difference between the components. Being hybrid spectral types, MS stars have colors similar to those of normal M giants, so we use *UBV* photometry from Lee & Perry (1971) for HD 191589, standard M giant colors from Johnson (1966), and *IUE* observations of the M0 III standard  $\mu$  UMa to determine the flux level of the M0S primary in the UV. Converting the broad band photometry to the visual magnitude energy scale where  $V=0$  is  $3.65 \times 10^{-9}$  ergs  $\text{cm}^{-2} \text{s}^{-1} \text{Å}^{-1}$ , we use the *IUE* F-type standards to model the spectral energy distribution of the entire system. In this analysis, reddening and the component magnitude difference are the main free parameters, with minor adjustments to the spectral types being the other variable. We find HD 191589

is well-fitted from 1500 – 5500 Å ( $1.8 - 6.7\mu^{-1}$ ) by an M0 III + F0 V composite spectrum with no reddening and a magnitude difference  $\Delta V = 3.7$  between the components (Figure 2), resulting in  $V_{MS*} = 7.3$  for  $V_{F*} = 11.0$ .

Using the  $\Delta V$  and  $E(B - V)$  from the composite energy distribution, we find a fit to the LW region using  $\mu$  UMa and an F2 V star works very well (Figure 3), including the filling in of the F star’s Mg II absorption by emission from the PRG. We find that the F star dominates the spectrum up to 3100 Å.

Having measured the spectrophotometric parameters of the system, it should be possible to derive the absolute magnitude of the M0S star. Unfortunately, at *IUE* low dispersion, there are no adequate criteria to unambiguously determine the luminosity class of the secondary, although there is some evidence in the narrowness of the 1850 Å feature that it is not as bright as a giant. Assuming that it is an F0-F2 IV-V star, with  $1.8 < M_V < 2.6$ , we derive  $M_V = -1.5 \pm 0.4$  for the primary star.

#### 4. Analysis of High Dispersion Data

Because of the presence of the F-type secondary, we cannot determine if HD 191589 also has a degenerate companion which, under the binary scenario for Tc-deficient PRGs, would have been the source of the s-process enhancement in the current red giant. It is of great interest then to investigate whether HD 191589 is a triple system with both the PRG and the F-star being enriched in s-process material from a third star, which is now a WD.

The *IUE* low-dispersion spectra do not indicate any large-scale peculiarities in the absorption line spectrum, but they do not have sufficient resolution to study individual s-process features. We obtained a 20-hour LWP high-dispersion image to examine the F-star spectrum. The low dispersion data demonstrates that the F star dominates the

entire region shortward of 3300 Å, with increasing contrast with respect to the red giant as one progresses to shorter wavelengths. The *IUE* high-dispersion spectrum is usable from 2500 – 3200 Å. Analysis of this image is thus a balance between the greater contamination by the PRG at the longest wavelengths, where it is best exposed, and weakness at the shortest wavelengths, where the effects of the red giant are less. We find that the MS star contributes 20% of the light at 3000 Å, but only 7% at 2500 Å.

Due to the complexity of the absorption line spectrum of F stars in the UV, we have computed synthetic spectra using Kurucz (1991) models to identify potential regions for detailed study. Fits of the overall spectrum indicate that model parameters  $T_{eff} = 7250\text{K}$ ,  $\log g = 4.0$ ,  $v \sin i = 15 \text{ km s}^{-1}$  adequately match the spectrum. We have computed synthetic spectra with solar abundances and 10 times overabundances of the s-process elements Sr, Y, Zr, Nb, Mo, Ba, and La, as well as models at other temperatures and gravities. As a check of the calculations, we retrieved other high dispersion data on F stars in the *IUE* archive for comparison with HD 191589 and the models.

In Figure 4, we show changes in two lines that are well-isolated in the *IUE* spectral region, Zr II (UV37) at 2848.2 Å, and a blend of Zr II (24,25) at 3036.5 Å. Models of varying  $T_{eff}$  and  $\log g$  indicate that all lines are relatively insensitive to the choice of temperature and gravity in this region. Not only are the effects small, but the relative line ratios of the Zr II lines with nearby features are sufficiently maintained so that a large abundance enhancement would be detectable.

In Figure 5, we show HD 191589 and archival spectra of two normal F stars,  $\gamma$  Vir (F0 V,  $v \sin i = 28 \text{ km s}^{-1}$ ) and  $\sigma$  Boo (F2 V,  $v \sin i = 3 \text{ km s}^{-1}$ ). We find that compared to both stars, the Zr II lines in HD 191589 are considerably stronger. While the HD 191589 spectrum is unfortunately contaminated by a reseau in the blue wing of the Zr II line, enough of the feature is visible to suggest that it is enhanced as well compared to the other



F stars.

## 5. Conclusions

HD 191589 plays a unique role in the study of the Tc-poor PRG stars. According to the current hypothesis that all Tc-deficient S and MS stars are mass-transfer binaries, a hypothesis rather strongly supported by several lines of evidence (Johnson 1992), HD 191589 must be a triple system consisting of a red giant, a main-sequence star, and a white dwarf. The red giant S star is the most obvious. The white dwarf, although at present undiscovered, is needed to account for the enhanced s-process elements in the red giant. This paper reports the surprise discovery with *IUE* that enhancements of the Zr II lines are clearly seen in the F-star component of HD 191589. Based on synthetic spectra, uncertainties of the temperature and surface gravity were found to have little effect on the relative ratio of the lines in these regions, so the enhancements must be due to an overabundance of s-process elements in the atmosphere of the F star.

## 6. Acknowledgements

We thank the staff of the *IUE* observatory for their help in making these observations. This work was supported by NASA through Purchase Order No. S-30912-F (TBA) and grant NAS5-182 (HRJ).

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TABLE 1  
Summary of *IUE* Observations

Date	Image	Exp Time	
	Number	Disp.	(min)
1991 Apr 6	LWP 20090	Low	30
1992 Nov 21	LWP 24337	Low	30
1992 Nov 21	LWP 24338	High	1180
1991 Apr 6	SWP 41310	Low	270
1991 Apr 16	SWP 41400	Low	85
1992 Nov 21	SWP 46311	Low	45
1992 Nov 22	SWP 46313	Low	60

TABLE 2  
Secondary Star Visual Magnitude  
Determinations from *IUE* Standards

Comparison Star			HD 191589
Name	Spec. Type	$B - V$	$V_{F_*}$
44 Oph	A9 V	0.28	11.20
$\alpha$ Hyi	F0 V	0.28	11.17
$\eta$ Lep	F0 IV	0.33	11.09
78 UMa	F2 V	0.36	10.79
$UBV + IUE$	F0-2 IV-V	0.31	11.0

## 8. Figure Captions

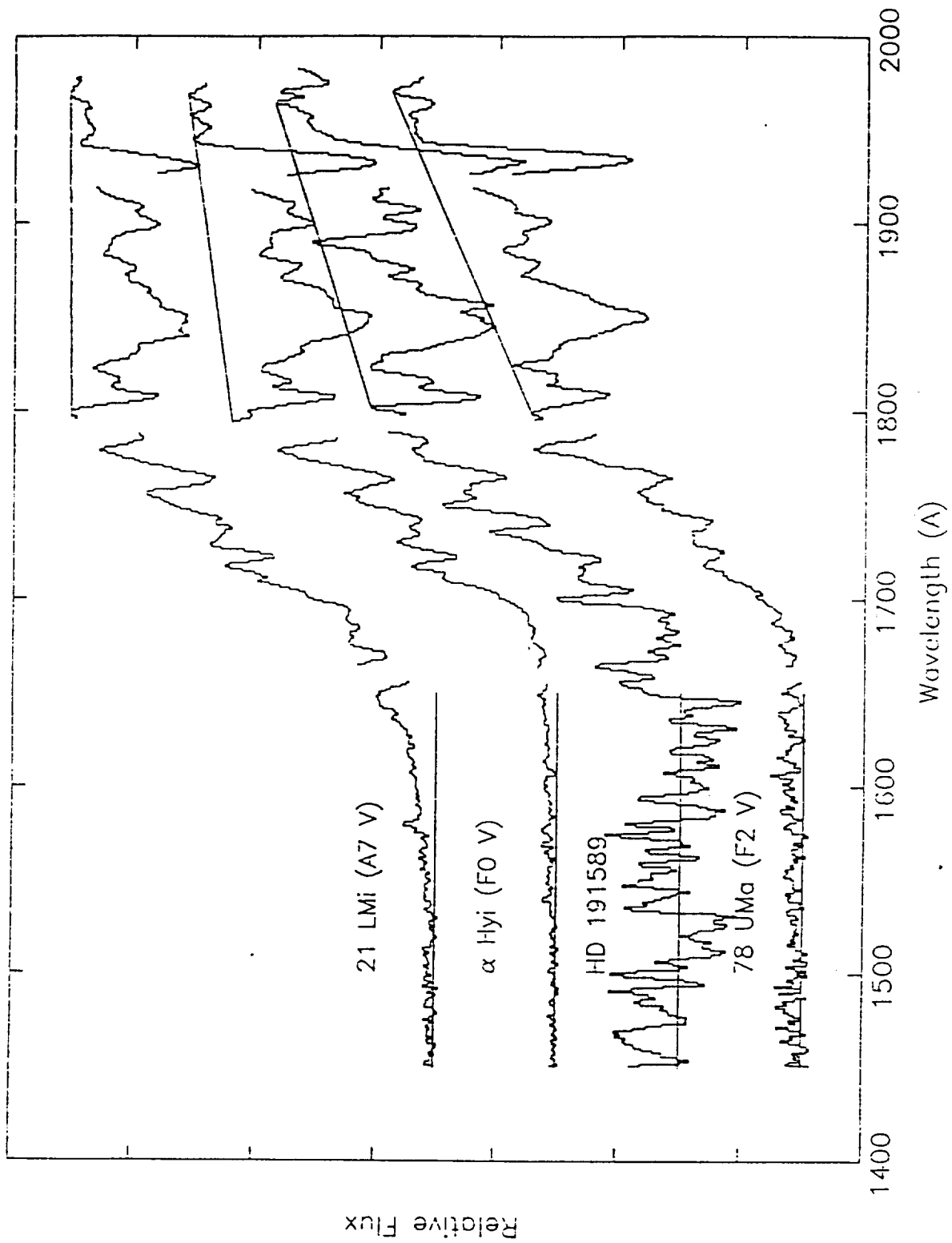
Figure 1. *IUE* SWP spectra of HD 191589 and late A- to early F-type standard stars. The spectral slope from 1800 – 1950 Å and depths of the absorption features at 1850 and 1933 Å are diagnostic of temperature in this region.

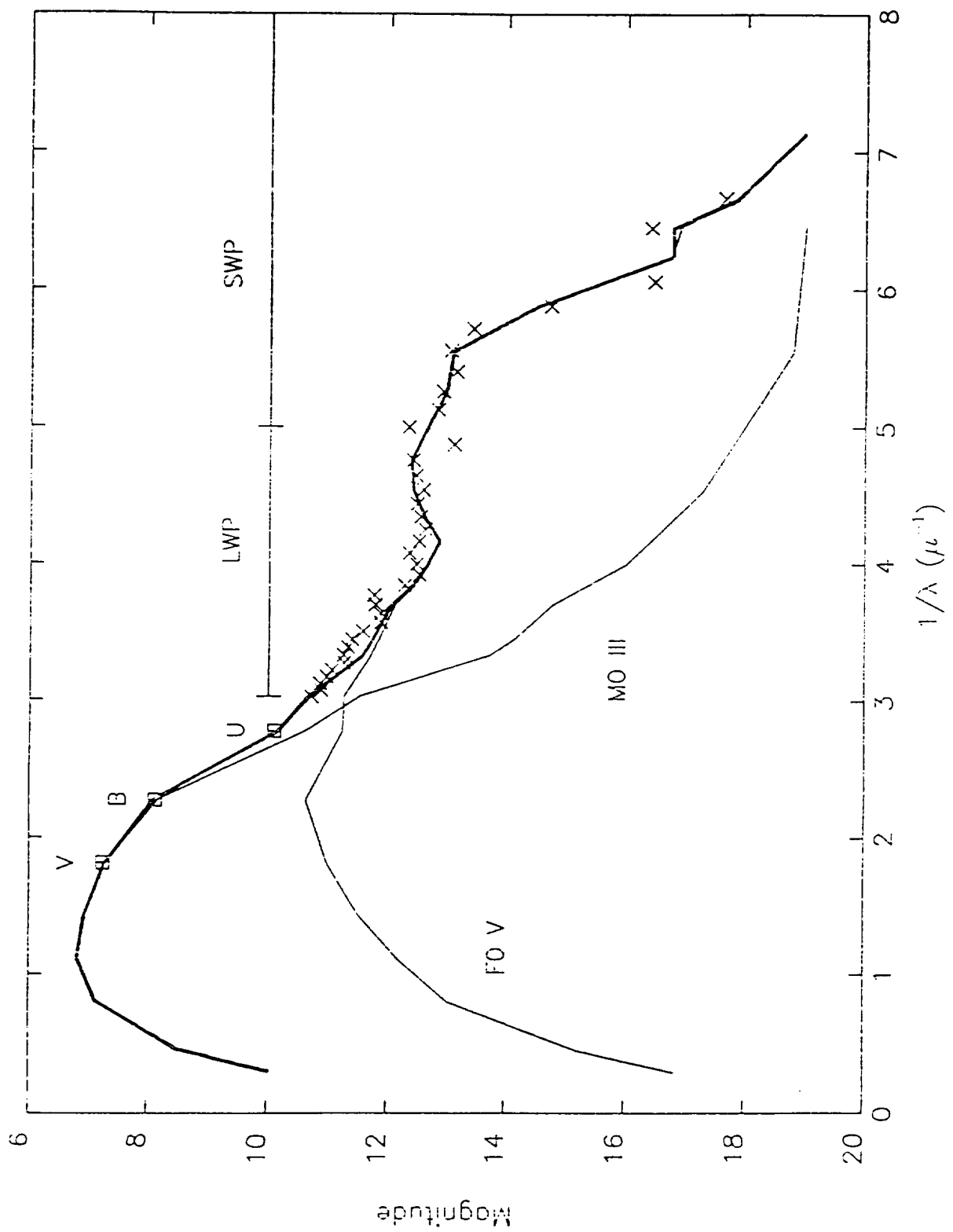
Figure 2. *UBV* (*boxes*) and *IUE* (*crosses*) data for HD 191589 on a visual magnitude scale,  $m_\lambda = -2.5 \log(f_\lambda) - 21.1$ , with a composite standard star energy distribution for an M0 III + F0 V system with  $\Delta V = 3.7$  and  $E(B - V) = 0.00$ .

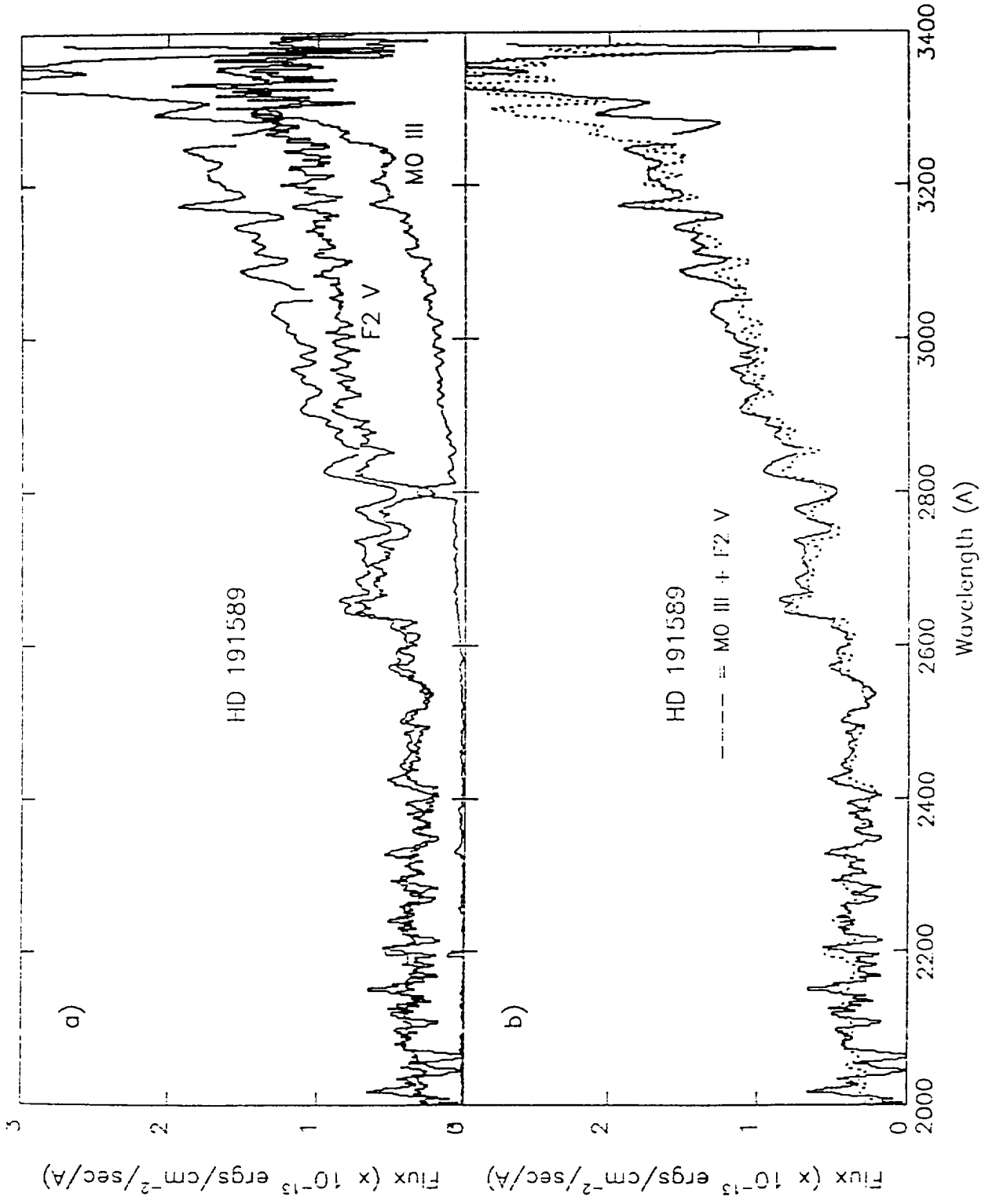
Figure 3. (a). The *IUE* LW region of HD 191589 with M0 III (scaled to  $V = 7.3$ ) and F2 V (scaled to  $V=11.3$ ) standard stars. The crossover wavelength for the two components is at 3100 Å. (b). HD 191589 (*solid line*) compared to the M0 III + F2 V composite spectrum (*dotted line*). Note that the Mg II emission from the M star fills in the absorption of the F star.

Figure 4. Comparison of synthetic spectra in regions of Zr II (UV37) (left panels) and Zr II (24,25) (right panels). Upper plots show the sensitivity of the spectra on s-process abundance; middle plots, on temperature; lower plots, on surface gravity. The Zr II lines are most sensitive to abundance differences.

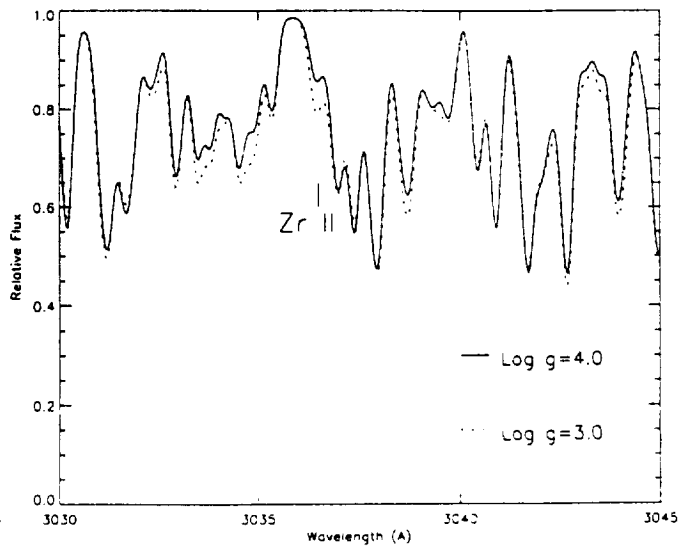
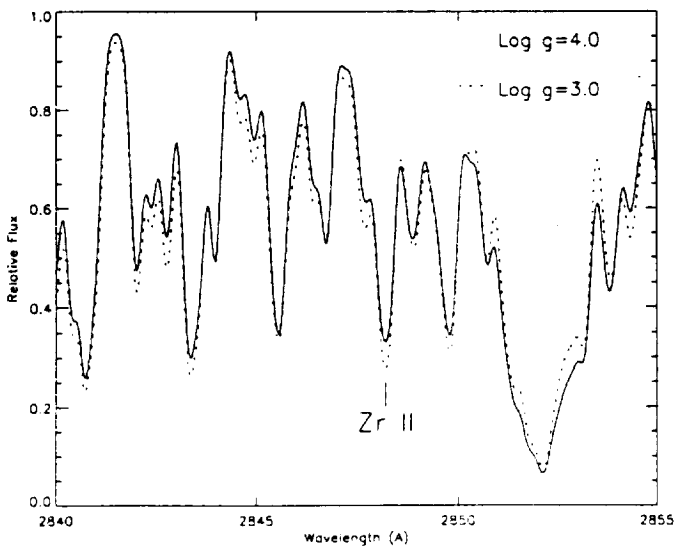
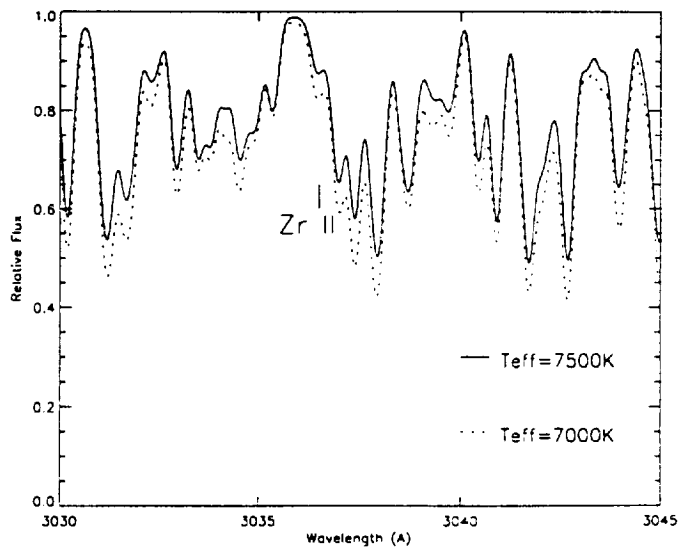
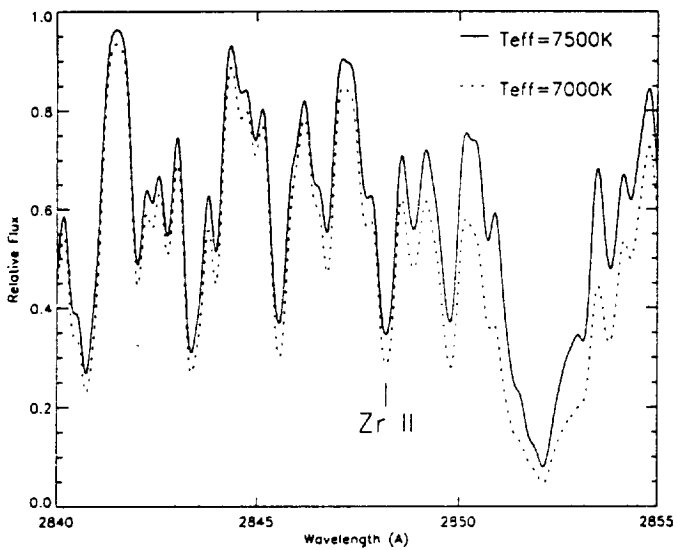
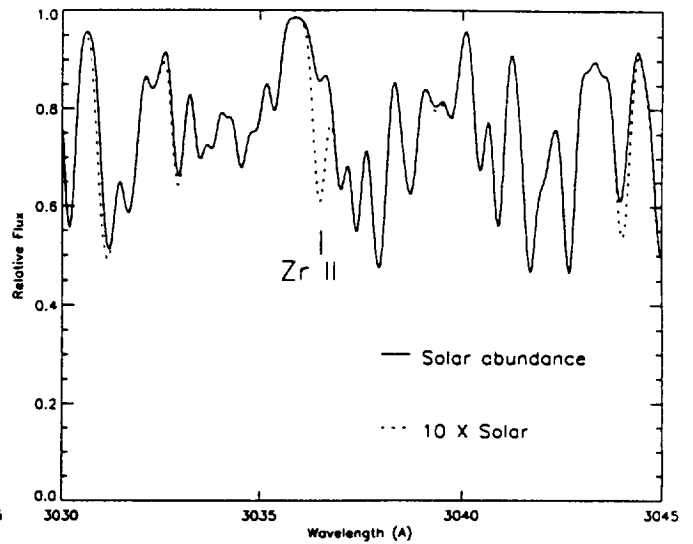
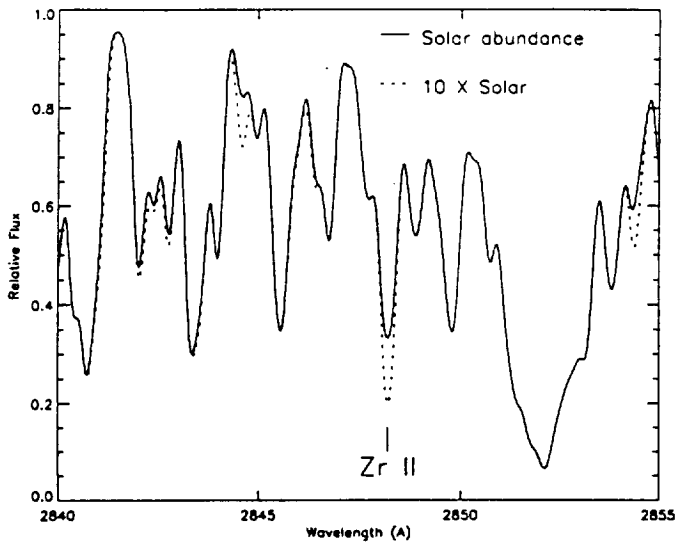
Figure 5. Spectra of HD 191589 (*solid line*),  $\gamma$  Vir (*dotted line*), and  $\sigma$  Boo (*dashed line*) at the Zr II lines in Fig. 4. (a) and (b). In the region of the 3036 Å line, HD 191589 shows a clear enhancement of Zr II. (c) and (d). Though a resonance falls on the blue wing of the 2848 Å line, HD 191589 shows considerably stronger Zr II line than either F star.

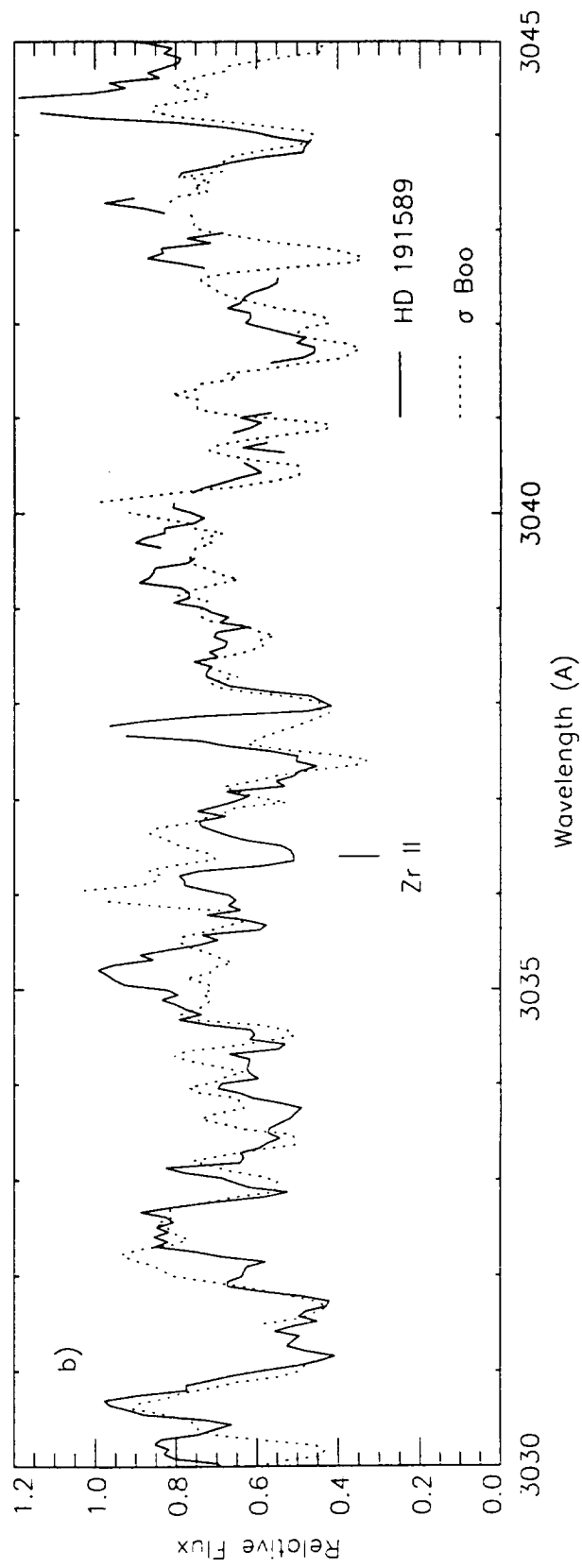
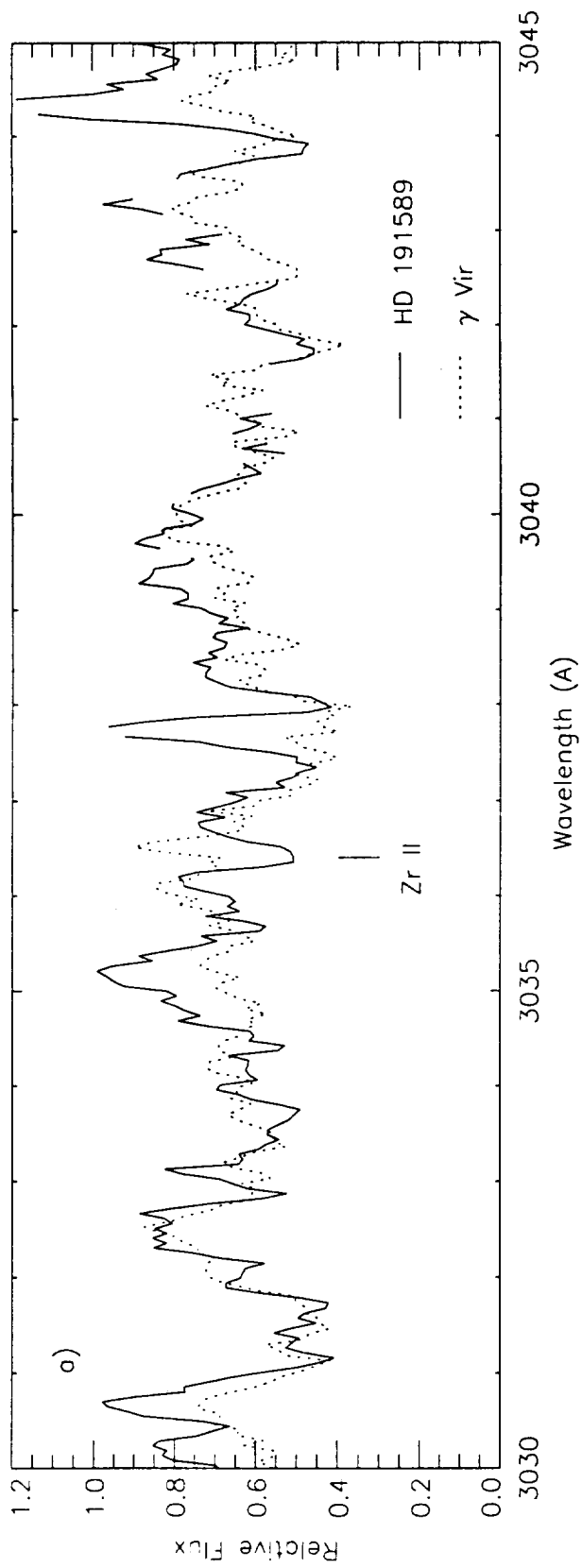


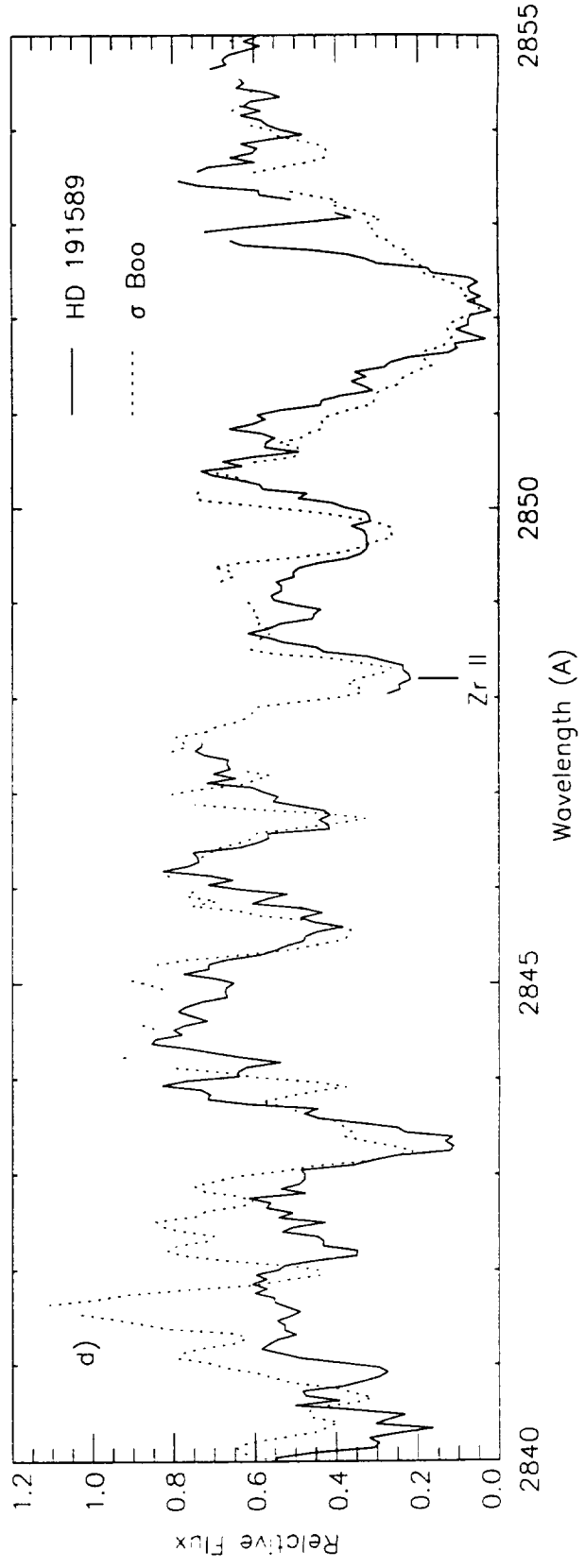
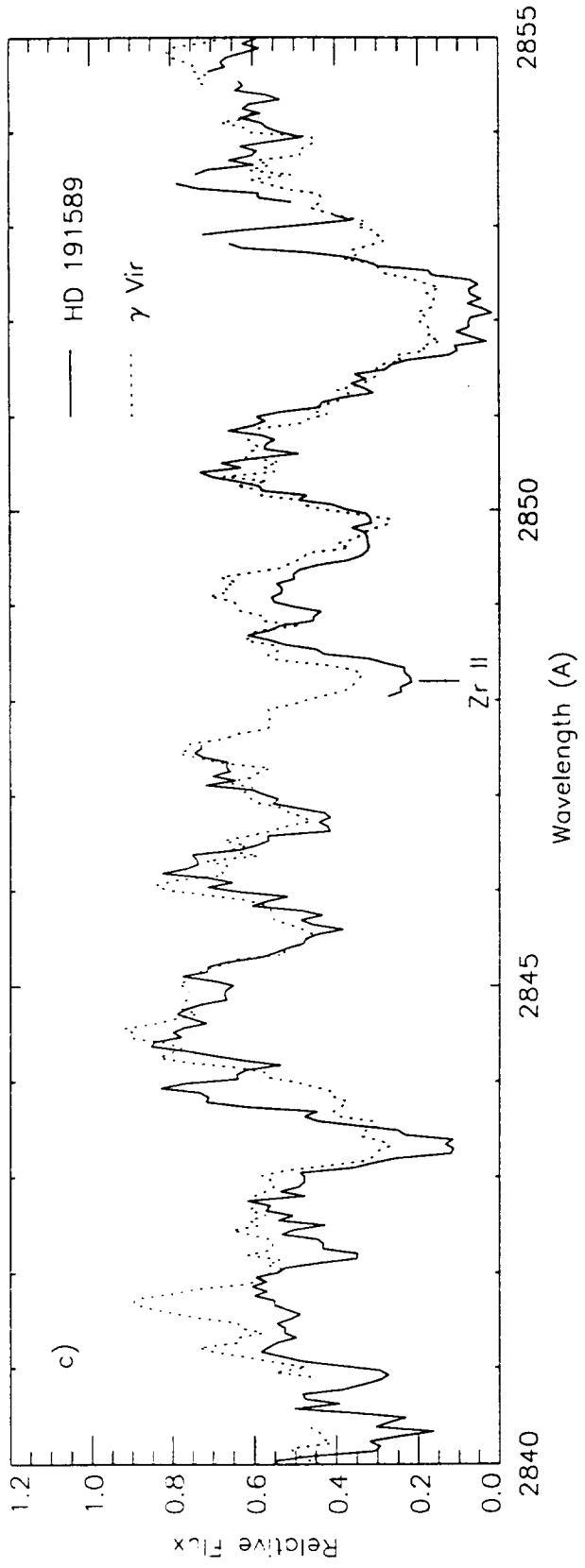












Program ID: SSOHJ

Title: The Unusual S Star System HD 191589

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Results:

IUE low and high dispersion observations were made of the Tc-deficient peculiar red giant (PRG), HD 191589. These observations were to test the hypothesis that the Tc-poor PRGs were formed as a result of mass transfer from a companion rather than from internal thermal pulsing while on the asymptotic red giant branch. Unlike the other PRGs, HD 191589 has an F-type main sequence companion, so that if the hypothesis were correct, the system must be a triple, and the third component should have enriched both of the other stars with CNO and s-process material.

A 1180 minute LWP high dispersion exposure was taken to search for peculiar trace elements in the F star. LWP and SWP spectra were taken to investigate the variability of the system. Synthetic spectra were calculated with solar and s-process enhanced abundances to identify which s-process element spectral features would be relatively unblended in the LWP region. We found that two Zr II lines, at 3036.5 Å and 2848.2 Å, should be resolved at the IUE dispersion. Models of various  $T_e$ ,  $\log g$ , and  $v \sin i$  values were run to determine the parameters of the secondary and select normal F-type field stars for detailed comparison. A  $T_e = 7250\text{K}$ ,  $\log g = 4.0$ , and  $v \sin i = 15 \text{ km s}^{-1}$  model adequately matched the spectrum.

No differences were found between the low dispersion observations and those obtained previously. Thus the system parameters measured earlier, including a spectral type determination of F0-2 IV-V for the secondary, were used in the analysis. Comparisons were made in the  $\lambda 3036$  and  $\lambda 2848$  regions between HD 191589 and IUE archival spectra for  $\gamma$  Vir (F0 V), 76 Tau (F0 V),  $\sigma$  Boo (F2 V),  $\sigma^1$  Eri (F2 II-III),  $\pi$  Sgr (F2 II), and HR 5445 (F5 V).  $\gamma$  Vir and  $\sigma$  Boo gave the closest match to the overall spectrum, confirming that the F star in the HD 191589 system is a slow rotator. Compared to these stars, the Zr II lines in HD 191589 are enhanced, indicating that the F-star has been polluted by s-process material.

Publications:

"The Unusual S Star System HD 191589", Ake, T.B., Johnson, H.R., Jorissen, A., & Wahlgren, G.M. 1994, in *Cool Stars, Stellar Systems, and the Sun*, ed. J.P. Caillault, ASP Conference Series, 64, p.678.

"The Unusual S Star System HD 191589: A Triple System?", Ake, T.B., Johnson, H.R., Jorissen, A., & Wahlgren, G.M. 1996, submitted to A.J.

The Unusual S Star System HD 191589

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Presented at the Eighth Annual Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, 11-14 October 1993, University of Georgia

## Abstract

Through a search for the putative white-dwarf companions with IUE, we have for several years been testing the popular hypothesis that Tc-deficient S and MS stars are not thermally pulsing AGB stars but are mass transfer binaries. Several companions have been discovered, and most evidence supports the idea. Recently, we discovered an F0-F2 IV-V companion to the Tc-poor S star HD 191589, a counter example of this hypothesis unless it is a triple system. In that case, the less evolved F-dwarf companion may also be contaminated by s-process material. We have recently obtained a 20-hour LWP high-dispersion spectrum of this system and have begun generating synthetic spectra of a dF star with enhanced s-process abundances for comparison. We will discuss the technique and present preliminary results of abundance anomalies.

## Introduction

It now appears that the Tc-deficient S and MS stars are binary systems in which mass transfer has played a role in the past (Johnson, Ake, & Ameen 1993 and references therein). In this scenario, the current peculiar red giant (PRG) is not an asymptotic giant branch (AGB) star, but rather was polluted by a companion star when it was on the AGB. This companion is now a white dwarf. Because s-processing is not actively occurring, the Tc has decayed away, leaving a PRG with all the signatures of the late stages of nucleosynthesis (CNO and s-process element anomalies), but without the radioactive Tc.

As part of the program for investigating the binarity of Tc-deficient S stars with IUE, we discovered an early F-type companion to the MS star HD 191589 (Ake & Johnson 1991). Using UBV and IUE photometry, we fit the energy distribution from 1500 to 5500 Å with an M0 III + F0V composite spectrum with a magnitude difference  $\Delta V = 3.7$  and  $E(B - V) = 0$ . Comparisons of the SWP spectra with IUE standards showed that the secondary is an F0-F2 star, while detailed comparisons of an M0 III + F-type composite with the LWP spectrum had a best match when the secondary is an F2 star (Figure 1). Assuming a normal F0-F2 IV-V luminosity for the secondary star leads to a value of  $M_V = -1.5 \pm 0.4$  for the red giant. Because of the presence of the secondary, we could not determine whether the system has a white dwarf companion which, under the binary scenario for Tc-deficient PRGs, would have been the source of the s-process enhancement of the current red giant. It is of great interest then to investigate whether this is a triple system with the main sequence companion also enriched in s-process elements.

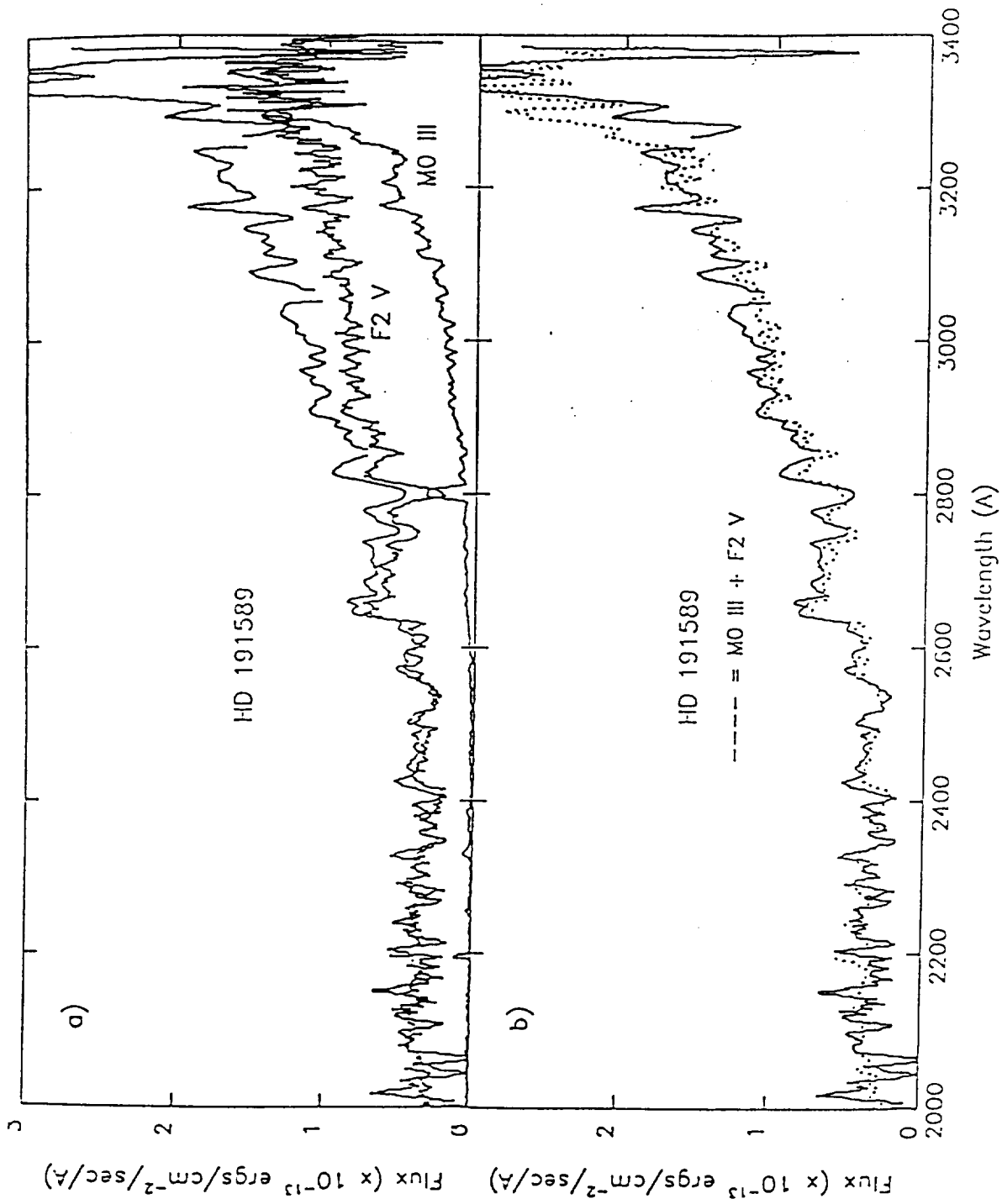


Figure 1: (a) Low dispersion spectrum of HD 191589 with standard star fluxes for an M0 III star scaled to  $V = 7.3$  and F2 V star scaled to  $V = 11.0$ . (b) HD 191589 (solid line) compared to the composite spectrum. Note that the Mg II emission from the red giant fills in the absorption line in the F star, as observed in HD 191589.

## Analysis

We have recently obtained a 20-hour LWP high-dispersion image of HD 191589 to investigate any abundance peculiarities in the F star. Based on modeling the low dispersion fluxes (Fig. 1), the F star dominates the entire region shortward of 3300 Å, with increasing contrast with respect to the red giant as one progresses to shorter wavelengths. The IUE high dispersion spectrum is usable from 2500 - 3200 Å. We find that the MS star contributes 20% of the light at 3000 Å, but only 7% at 2500 Å. Analysis of this image is thus a balance between the added greater composite nature at the longest wavelengths, where it is best exposed, and weakness at the shortest wavelengths, where the effects of the red giant are less.

Due to the complexity of the absorption line spectrum of F stars in the UV, we have computed synthetic spectra using Kurucz (1991) models to identify potential regions for detailed study. Initial fits of the overall spectrum indicate that stellar parameters estimated from the low dispersion deconvolution are appropriate. We find that model parameters  $T_{eff} = 7250\text{K}$ ,  $\log g = 4.0$ ,  $v \sin i = 15 \text{ km s}^{-1}$  adequately matches the spectrum for our initial analysis. We have computed models with solar and 10 times overabundances of the s-process elements, as well as models at other temperatures and gravities, to investigate the sensitivities of lines to various conditions. As a check, we have begun to retrieve other high dispersion data on F stars in the IUE archive for comparison with HD 191589 and the models.

In Figure 2, we show the models from 2500 to 3100 Å for both solar and s-process enhanced compositions. There are few regions where abundance anomalies will be readily apparent. To assist in the selection of interesting regions to investigate further, we also show the ratio of the spectra. This highlights the s-process lines, which are mainly due to Zr II. From these plots, we choose to first analyze the Zr II (24, 25) line at 3036.5 Å and Zr II (UV37) 2848.2 Å.

In Figure 3, we illustrate the changes in these lines by varying  $T_{eff}$  by  $\pm 250\text{K}$  and  $\log g$  from 3.0 to 4.0. Not only are these effects small, but the relative line ratios of the Zr II lines with nearby features is sufficiently maintained so that abundance anomalies will be detectable.

In Figure 4, we show HD 191589 and two normal F stars,  $\gamma$  Vir (F0 V,  $v \sin i = 28 \text{ km s}^{-1}$ ) and  $\sigma$  Boo (F2 V,  $v \sin i = 3 \text{ km s}^{-1}$ ) in the 3036 Å region. We find that the Zr II line in HD 191589 is quite stronger. In Figure 5, we compare the same stars at 2848 Å. While the HD 191589 spectrum is unfortunately contaminated by a reseau in the blue wing of the Zr II line, enough of the feature is visible to suggest that it is enhanced as well



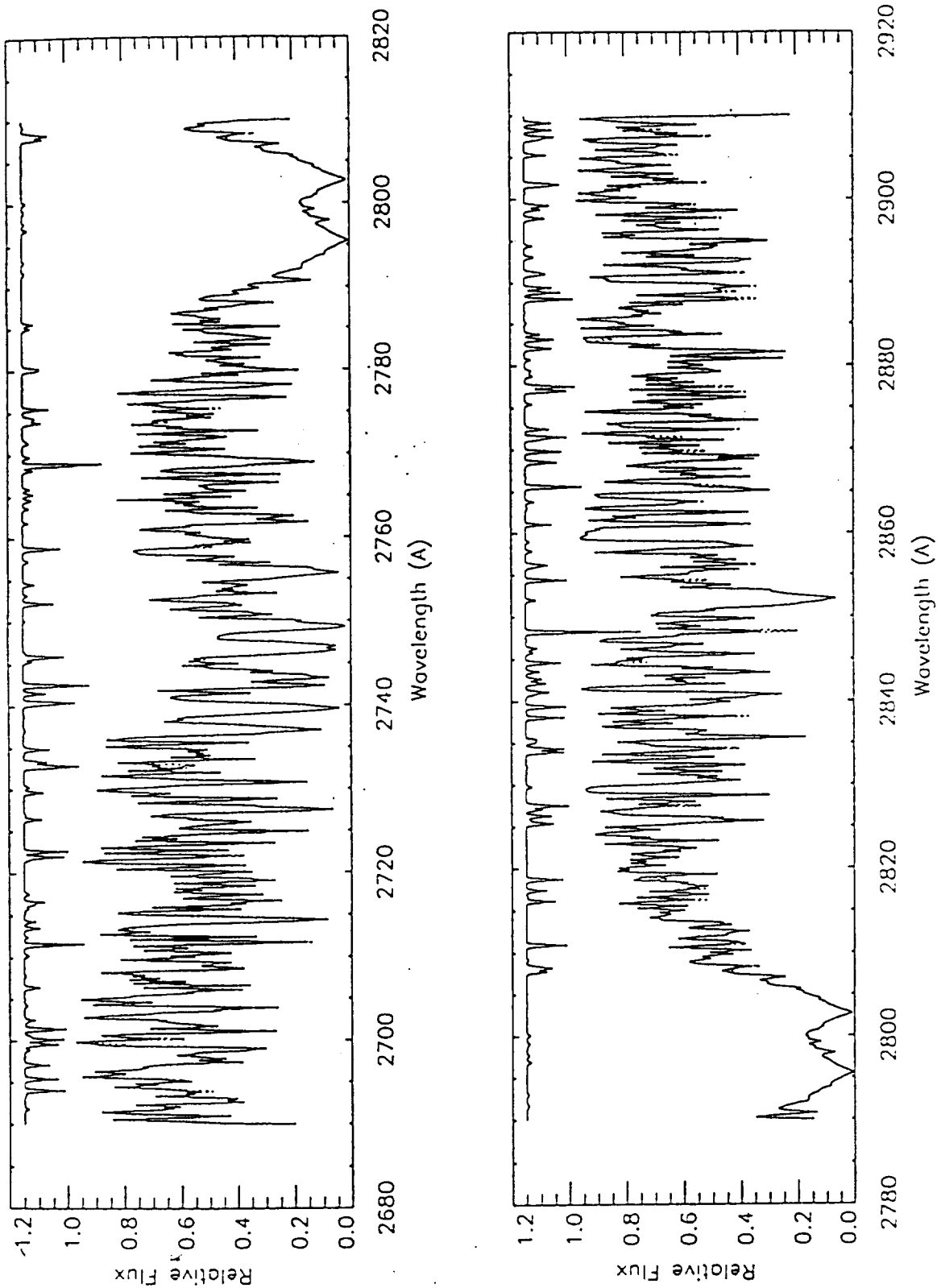
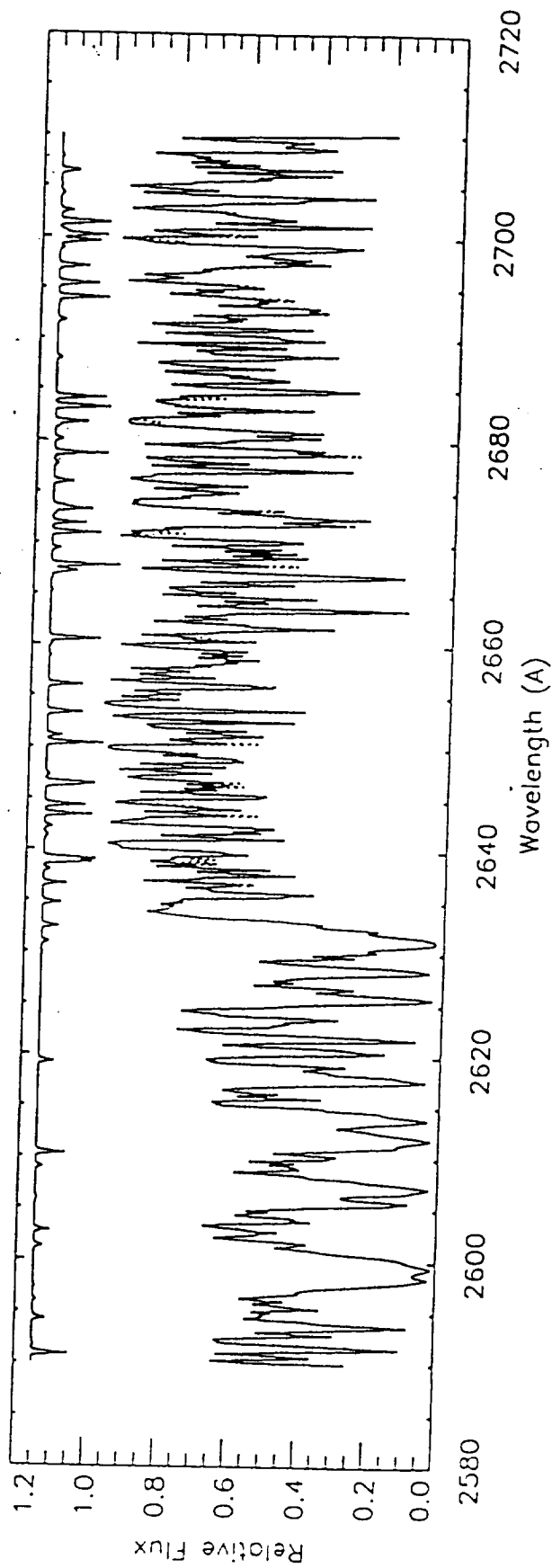
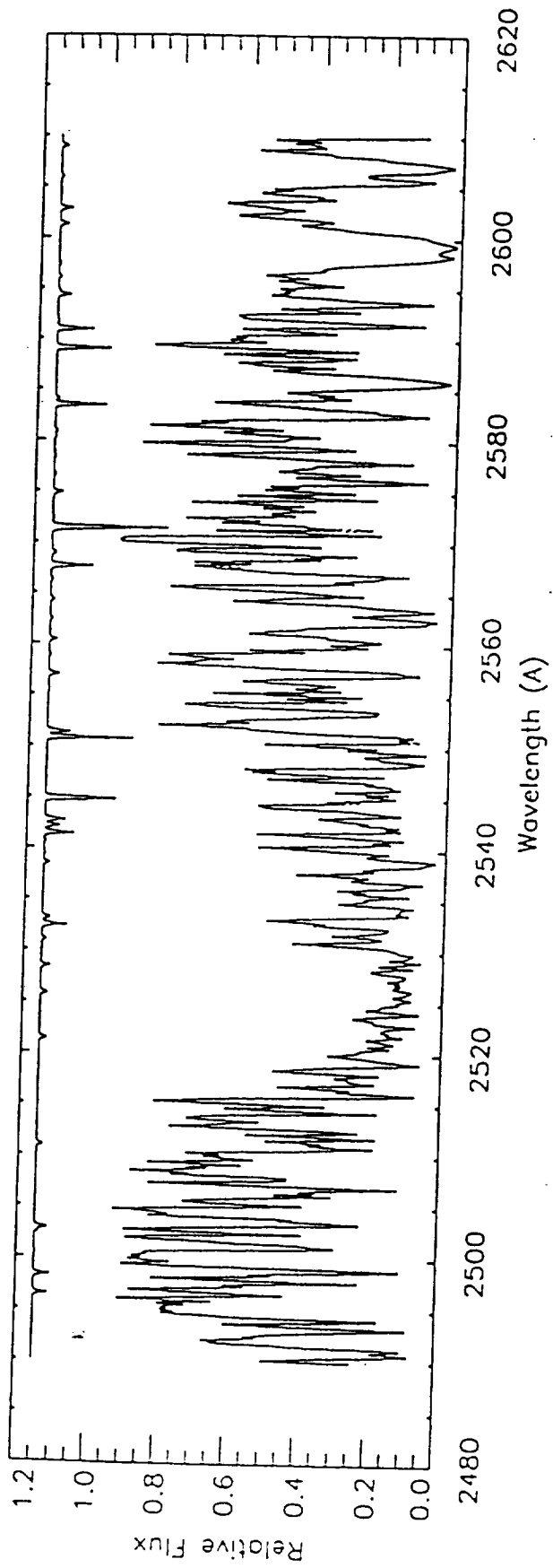
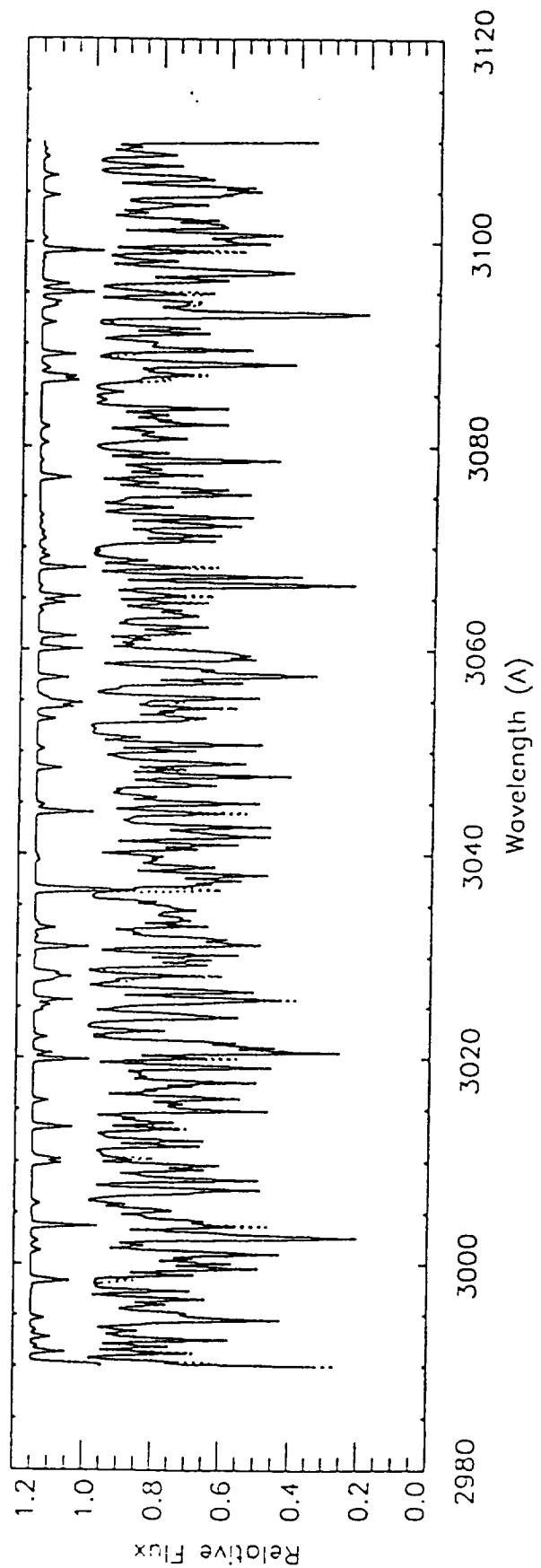
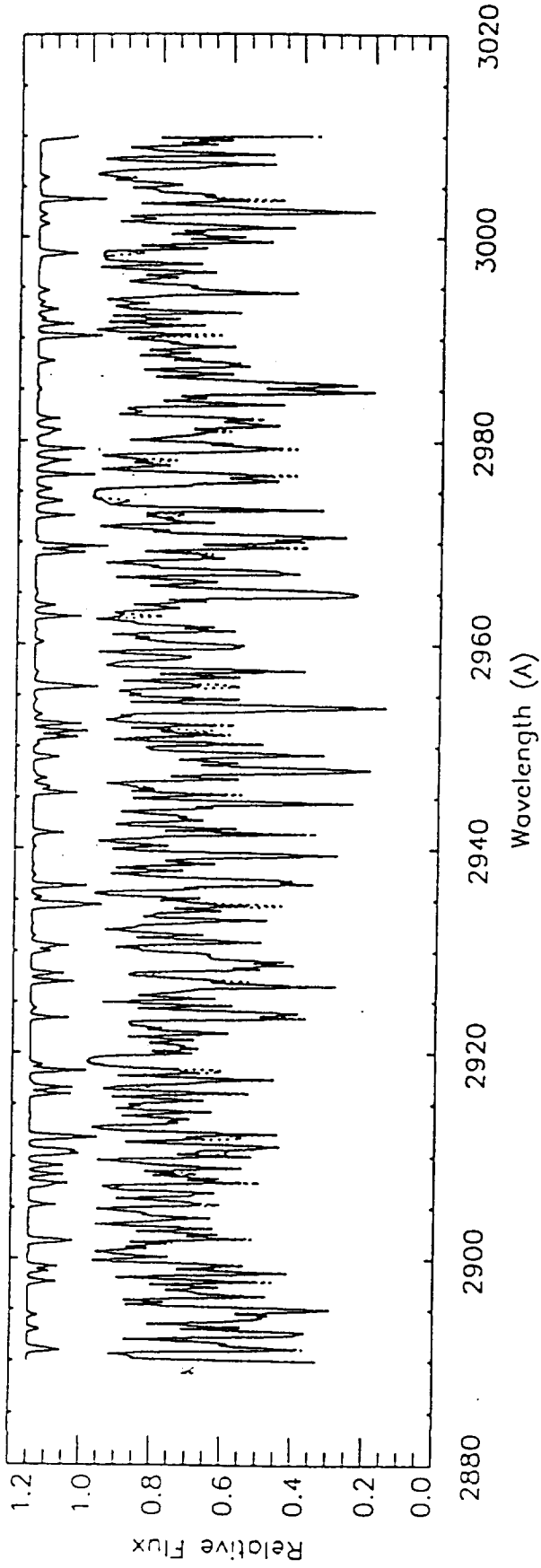


Figure 2. Comparison of synthetic spectra for  $T_{eff} = 7250\text{K}$ ,  $\log g = 4.0$  models with solar abundances (solid line) and s-processed enhanced by a factor of 10 (dotted line). The ratio of the models is plotted at the top to highlight the s-process enhancements. In the UV, it is difficult to observe s-process enhancements except in a few well-chosen regions. Initially we concentrate on Zr II 3036.5 Å and 2848.2 Å.





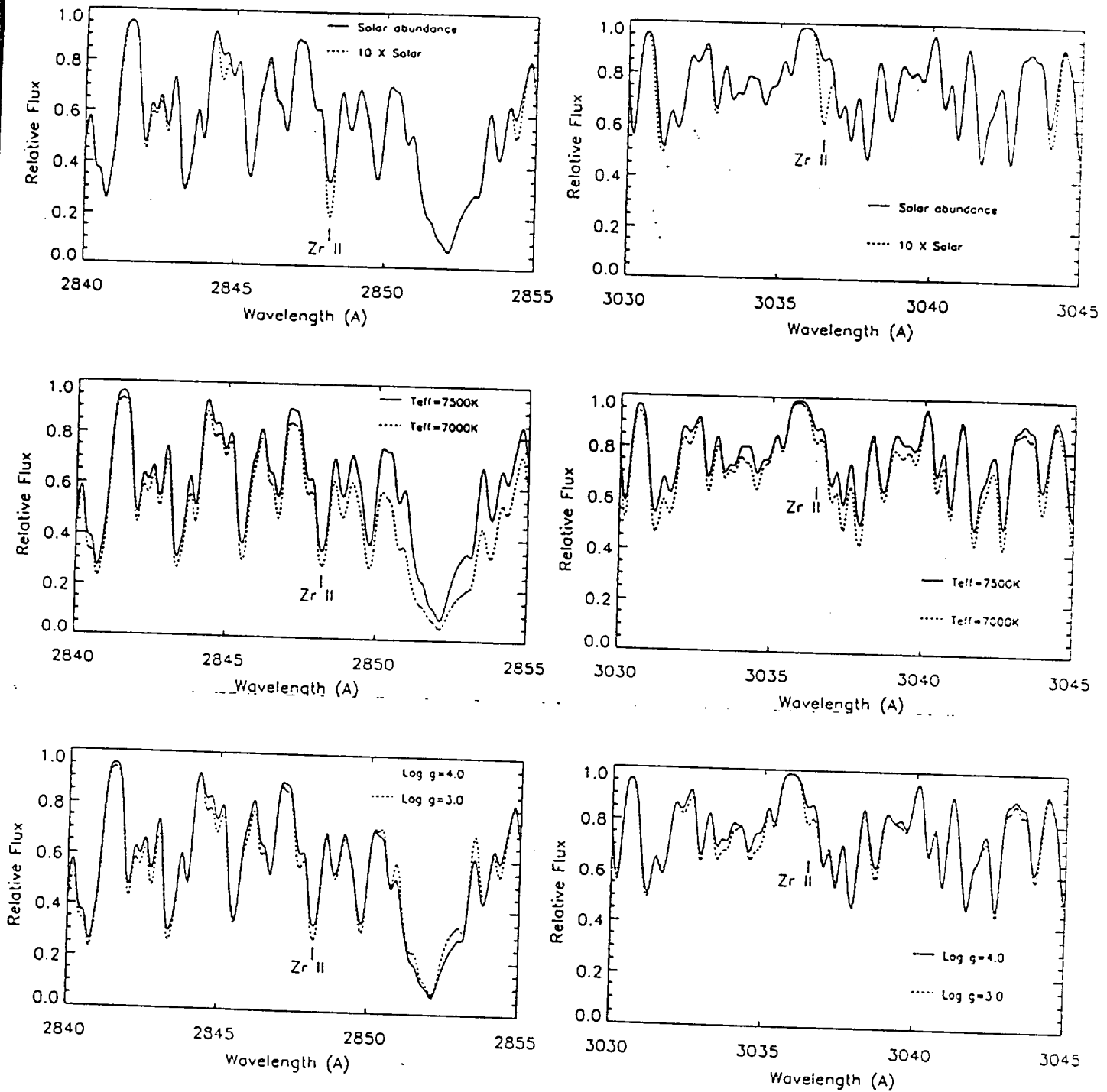


Figure 3: Abundance, temperature, and surface gravity effects on the selected Zr II lines. The effects of temperature and gravity are not only small, but relative ratios of Zr II with nearby lines are also maintained. Zr enhancements of 10 times solar abundance are clearly seen in these lines.

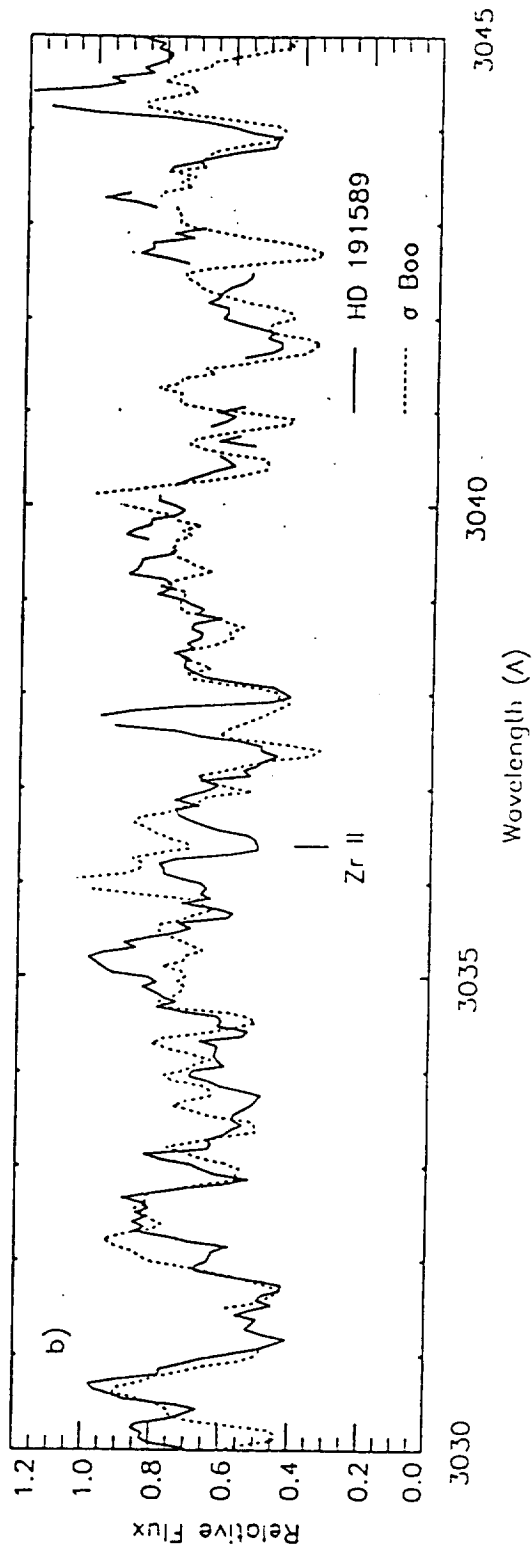
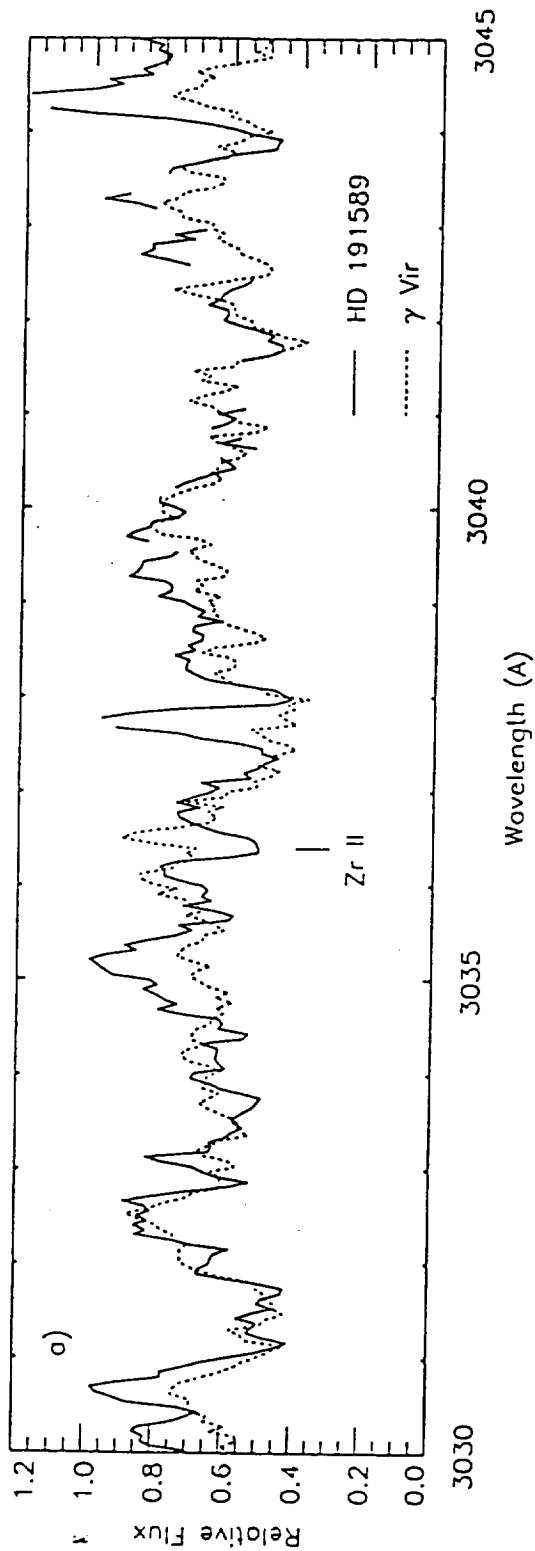


Figure 4: (a) HD 191589 (solid line) and  $\gamma$  Vir (dotted line) at Zr II (24,25) 3036.5 Å. (b) HD 191589 and  $\sigma$  Boo as in (a). HD 191589 shows a considerably stronger Zr II line than either F star.

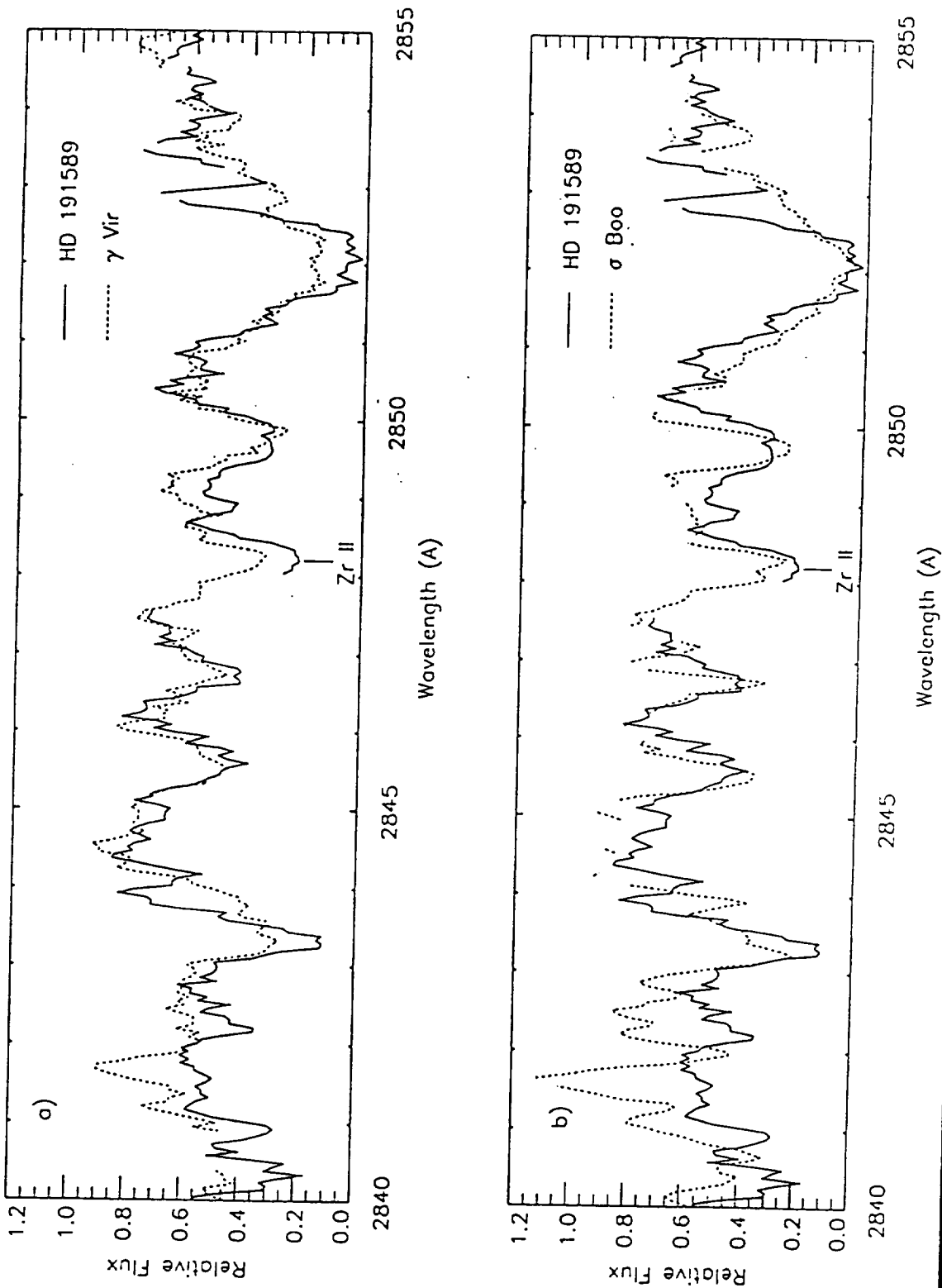


Figure 5: HD 191589,  $\gamma$  Vir, and  $\sigma$  Boo near Zr II (37) 2848.2 Å as in Fig. 4. Though a reseauux falls on the blue wing of the line in HD 191589, the line appears enhanced compared to the F stars.

compared to the other F stars. We also note that Nb II (1) at 2849.6 Å, which is not in the Kurucz line list, appears enhanced in HD 191589.

### Conclusions

Our initial attempts at comparing the spectrum of HD 191589 with an s-process enhanced model is encouraging, but no definitive results are yet available. From the models, we can say that

- Small abundance changes (2-5 times) will not be observable at IUE resolution.
- While several s-process lines appear enhanced, further detailed comparisons with normal F stars are required to improve the atomic line data for quantitative measurements.
- Finally, we have not begun to take into account the effects of the red giant in the spectrum. We have noted that some lines appear to be double, and a radial velocity curve from optical monitoring will soon be available. The effects of the PRG will require careful analysis, particularly since adequate IUE spectra may not be available for S stars.

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# REPORT DOCUMENTATION PAGE

*Form Approved*  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

<b>1. AGENCY USE ONLY (Leave blank)</b>	<b>2. REPORT DATE</b> July 1996	<b>3. REPORT TYPE AND DATES COVERED</b> Contractor Report	
<b>4. TITLE AND SUBTITLE</b> The Unusual S Star Binary HD 191589		<b>5. FUNDING NUMBERS</b>  Code 684.1 Contract: S-30912-F	
<b>6. AUTHOR(S)</b>  PI: T. Ake, H. Johnson, A. Jorissen, and G. Wahlgren			
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b>  Computer Sciences Corporation 4061 Powder Mill Road Calverton, MD 20705		<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>  CAN 4124	
<b>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b>  NASA Aeronautics and Space Administration Washington, D.C. 20546-0001		<b>10. SPONSORING/MONITORING AGENCY REPORT NUMBER</b>  CR-203625	
<b>11. SUPPLEMENTARY NOTES</b>  Technical Monitor: D. West, Code 684.1			
<b>12a. DISTRIBUTION/AVAILABILITY STATEMENT</b>  Unclassified-Unlimited Subject Category: 90 Report available from the NASA Center for AeroSpace Information, 800 Elkridge Landing Road, Linthicum Heights, MD 21090; (301) 621-0390.		<b>12b. DISTRIBUTION CODE</b>	
<b>13. ABSTRACT (Maximum 200 words)</b>  Recently, we discovered with <i>IUE</i> an F0-F2 IV-V companion to the Tc-deficient S star HD 191589. If the magnitude difference is $\Delta V=3.7$ , as indicated by several arguments, and $E(B-V) = 0.0$ , we obtain a value of $M_v = -1.5 \pm 0.4$ for the peculiar red giant (PRG), too faint for it to be a thermally-pulsing asymptotic giant branch star. According to the binary mass-transfer hypothesis for Tc-deficient PRGs, a white dwarf must be the source of the s-process enhancement of the current primary star, but it cannot be seen because of the presence of the secondary. If such is the case, the F-star companion may also have been contaminated by s-process material.  High-dispersion <i>IUE</i> observations indicate an enhancement of Zr II in the photosphere of the F-star as well. Thus, HD 191589 is likely a triple system, where what was once the most massive component of the system has polluted both of its companions with s-process material. One of these is the current S star, while the other is the companion still near the main sequence.			
<b>14. SUBJECT TERMS</b>  IUE, S Star		<b>15. NUMBER OF PAGES</b>  19 plus Appendix	
		<b>16. PRICE CODE</b>	
<b>17. SECURITY CLASSIFICATION OF REPORT</b>  Unclassified	<b>18. SECURITY CLASSIFICATION OF THIS PAGE</b>  Unclassified	<b>19. SECURITY CLASSIFICATION OF ABSTRACT</b>  Unclassified	<b>20. LIMITATION OF ABSTRACT</b>  Unlimited