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New S Stars Found in a Southern Galactic Plane Survey

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ABSTRACT. Based upon the presence of bands of ZrO and LaO, four new S stars have been identified. They were found among more than 700 red spectrograms of cool stars in a survey of the southern Galactic plane.

1. INTRODUCTION

The S stars are a relatively small group among the late-type stars, whose spectra are distinguished by bands of ZrO in the visual/red region; bands of TiO and LaO may also be present. They have been recognized as a class since Merrill (1922) first described them; they were subdivided into five groups by Davis (1934) and subsequently classified on a two-dimensional (temperature/abundance) system by Keenan (1954). According to Keenan's definition, the presence of ZrO bands strong enough to be easily seen at classification dispersion is a necessary and sufficient condition for a star to be called S. Modern spectral analyses show a C/O abundance ratio within about 5% of unity (Scalo & Ross 1976) and a strong enrichment in *s*-process elements. Their effective temperatures cover about the same range as that of the M giants.

Two distinct groups of S stars are now recognized depending on the presence or absence of Tc, an *s*-process element with no stable isotopes, whose lines in the blue region can be seen at resolutions of 30,000 and above: *intrinsic* S stars in which Tc is strong, implying recent production and dredge-up in an asymptotic giant branch (AGB) star, and *extrinsic* S stars which have weak or no Tc lines and are members of binary systems in which the present primary has accreted its *s*-process–enriched material from a former thermally pulsing AGB star which is now degenerate (see, e.g., Van Eck & Jorissen 1999 and references therein). The two types are indistinguishable at the resolutions of the objective-prism surveys in which most S stars have been identified.

Surveys in the visual/red region are particularly effective in identifying stars of type S because they can use the presence of the γ-system of ZrO with (0, 0) bandhead at 6474 Å as the detection criterion. About 1360 Galactic S stars are currently known; this figure includes those cataloged by Stephenson (1984) plus those found in a deep survey of the northern Milky Way by Stephenson (1990), minus those found not to be S stars by several authors (see, e.g., Lloyd Evans & Catchpole 1989 and Van Eck & Jorissen 1999). Here we report four new S stars found serendipitously in a survey for cool supergiants along the southern Galactic plane.

2. OBSERVATIONS

For a number of years, we have been conducting a survey for cool supergiants in the southern Galactic plane; details of the survey and follow-up observations are given in MacConnell et al. (1992). Briefly, we are using an extensive set of photographic near-infrared objective-prism plates taken by MacConnell to search for stars with tapered spectra, with or without molecular bands; as shown by Nassau et al. (1954), red stars with tapered spectra on unwidened near-infrared plates are likely to be heavily reddened late-type supergiants. We then follow up with narrowband photometry of the supergiant candidates on the eight-color system of Wing (1971) to classify each star in two dimensions and to determine the reddening and distance for stars successfully classified. Some kinds of stars, however, cannot be classified unambiguously from the narrowband photometry alone, and for these we require spectroscopic observations.

Stars of type S are especially troublesome in searches for M supergiants. The 6800–8800 Å range of our objective-

prism plates does not include a ZrO band, so that S stars can be recognized on them only when the LaO absorption is quite strong. Furthermore, the Wing system does not have a ZrO filter and so cannot be used to identify S stars with certainty; an S-type spectrum may, however, be suspected by virtue of the star's having peculiar colors on the narrowband system. To resolve such questions, and also to confirm the high luminosities of our best supergiant candidates, we have been obtaining CCD spectrograms of many of our program stars. The spectrograms cover the range 6400–8800 Å and specifically include the 6474 Å band of ZrO. Although our primary concern has been to cleanse our supergiant sample of unrecognized S stars whose distances would be misjudged, it is also of interest to add what we can to our knowledge of the Galactic distribution of the astrophysically important S stars.

Spectrograms of over 700 candidate stars and nearly 100 MK standards have been obtained with telescopes at Cerro Tololo Inter-American Observatory (CTIO), European Southern Observatory (ESO), and Las Campanas Observatory, and the standard IRAF tasks were used to process and display them. They are being classified in a variety of ways and will be published separately in a study of their relation to Galactic structure. Among the spectrograms, four have been found which show the ZrO and LaO bands characteristic of S stars.

3. THE NEW S STARS

The four new S stars are presented in Table 1. Column (1) gives our plate-coded survey designation (see MacConnell et al. 1992), and columns (2)–(5) give the J2000 positions, magnitudes, and colors from the USNO-A1.0 Catalogue (Monet et al. 1996). Columns (6)–(8) give the observatory, date, and dispersion in Å pixel^{-1} of our spectroscopic observations, and column (9) gives identifications in the *IRAS* Point Source Catalog (PSC) for two of the objects. The four stars have very similar optical colors; note, however, that M50 is much fainter than the others yet is one of the two detected by *IRAS*.

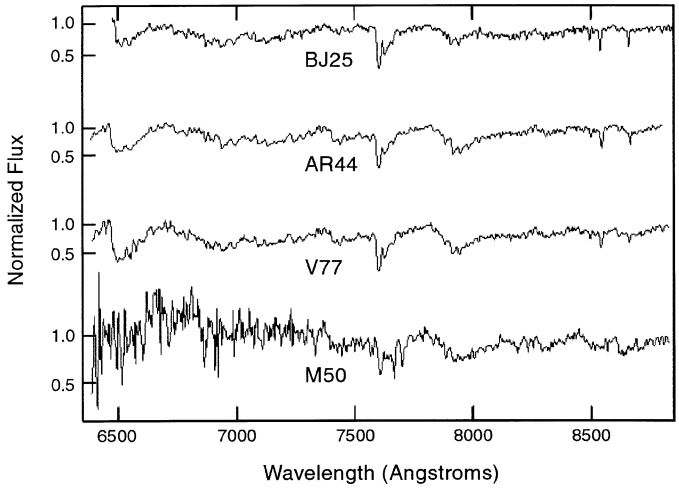

FIG. 1.—Normalized spectra of the four new Galactic S stars. The 6474 Å band of ZrO is clearly present in BJ 25, AR 44, and V77, although it is lost in the noise in the much fainter M50. All four stars show broad absorptions due to LaO around 7400 and 7900 Å.

The normalized spectra are shown in Figure 1. The top three spectra are well exposed and very similar to one another; their most prominent absorptions are those of ZrO (degrading longward from 6474 Å), the atmospheric A band, and the Ca II infrared triplet. LaO is present around 7400 and 7900 Å, although the latter band is confused by the overlapping (2, 0) band of CN; TiO may be weakly present near 7100 Å. The spectrum of the faintest star, M50, is very noisy at the shorter wavelengths, making the detection of ZrO problematical; its assignment to the S class is therefore based on the presence of the two LaO features. We attribute the absence of the Ca II triplet absorption lines to the level of noise.

Narrowband Wing photometry has also been obtained for the four stars; the faint star, M50, was observed twice with accordant results. Again, the four stars appear very similar to one another. They are very red, with color temperatures in the range 1500–2100 K. They all show absorption at filter 1 (7120 Å) which is likely to be due to TiO, but which in no case is stronger than that of a normal M1.6 star.

TABLE 1

NEW S STARS ALONG THE SOUTHERN GALACTIC PLANE

Name (1)	R.A.(J2000) (2)	Decl.(J2000) (3)	R (mag) (4)	$B-R$ (mag) (5)	Observatory (6)	Date (7)	Dispersion (Å pixel^{-1}) (8)	*IRAS* PSC (9)
V77	06 58 22.97	−08 23 56.0	13.1	4.6	CTIO	1985 Nov 28	4.0	06559 − 0819
AR 44.....	07 24 04.11	−12 18 57.3	11.8	4.4	CTIO	1989 Feb 4	4.2	
M50.....	13 00 04.47	−61 21 20.2	16.0	4.3	CTIO	1986 Feb 26	4.0	12569 − 6105
BJ 25	15 37 26.31	−56 47 15.6	11.9	4.3	ESO	1994 Apr 1	1.9	

NOTE.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

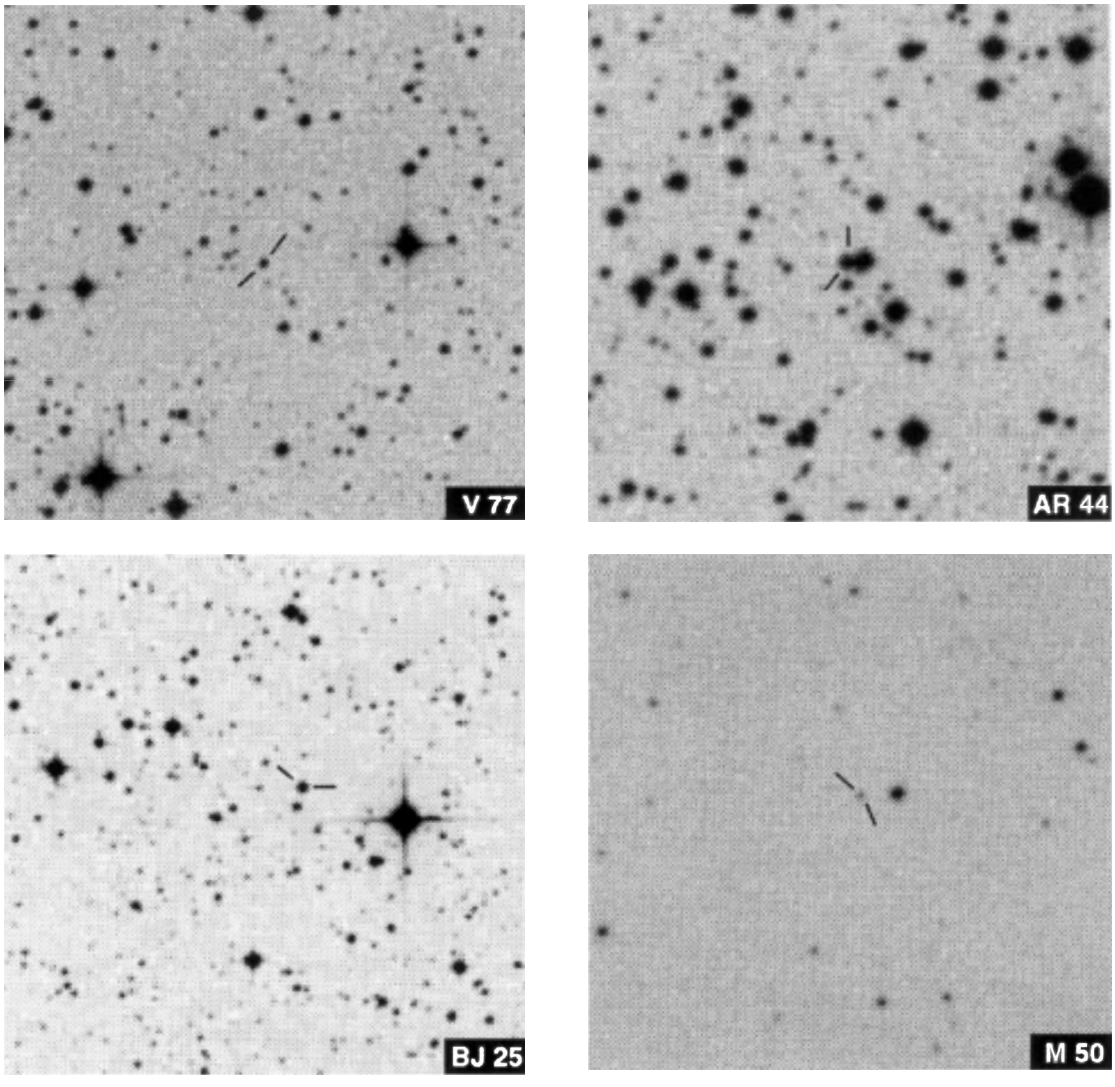

FIG. 2.—Finding charts in V for the new S stars. Charts are 5′ on a side and have north at the top and east to the left.

The CN (0, 0) band at filter 8 (10975 Å) appears to be somewhat enhanced; the CN at filter 4 (8120 Å) is even stronger but is evidently contaminated by LaO. Our automatic classification program, which employs the presumed absorptions by TiO and CN for two-dimensional classification, listed all four stars as reddened supergiants of types K5–M1. Their colors are abnormal, however, in that they show absorption by LaO at filter 2 (7540 Å) which is not present in M supergiants. Although filter 2 is not well centered on the LaO band, it is sufficiently affected to allow many S stars to be recognized, or at least suspected.

All four stars are relatively pure S stars in that TiO is only weakly present. Of the four, M50 is the reddest and V77 has the strongest ZrO and LaO bands, although the differences among these stars are small.

Finding charts, made from the V plates of the STScI Digitized Sky Survey, are given in Figure 2. AR 44 has a bright (and presumably optical) companion about 10″ to the west which was excluded from our observations.

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