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THE POSSIBLE IDENTIFICATION OF PROMETHIUM IN HR 465

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ABSTRACT

Evidence is presented for the possible presence of Pm in the Ap star HR 465.

Lines of the rare earth promethium have tentatively been identified in the spectrum of the extremely unusual Ap star HR 465. The identification has been made by using two Lick coudé spectrograms (2 Å mm^{-1}) taken during 1960 and 1961 during the spectral phase corresponding to rare-earth maximum (see Preston and Wolff 1970).

The plates were originally measured by W. P. Bidelman[1] (1970). Among the elements which he could identify were the rare earths Ce, Nd, Sm, Eu, Gd, Tb, Dy, Ho, and Er. However, roughly one-fourth of the lines, many of them moderately strong in intensity, could not be identified. This report is to point out that several of these unidentified lines agree to within tolerable limits (see below) with the laboratory wavelengths and intensities of Pm II (Meggers, Scribner, and Bozman 1951).

The wavelengths and intensities of all laboratory lines of Pm II of intensity 30 or greater in the wavelength region $3400 < \lambda < 4700$ Å are listed in the first two columns of Tables 1 and 2. Although contamination of the Pm II spectrum by Pm I was suspected by Meggers *et al.*, none of the lines in this list was subsequently found to be Pm I (Reader and Davis 1967). Columns (3) and (4) give the corresponding wavelengths and intensity estimates in the stellar spectrum. The stellar lines shortward of 4140 Å were measured on a plate of exceptionally high quality while the other lines are on a somewhat grainy plate.

All the strong lines in Table 1 could be matched with spectral features. Two of the lines did not appear on Bidelman's identification list, but inspection of high-resolution microdensitometer tracings indicated that features are indeed present in the spectrum. All three lines in the wavelength region $\lambda > 4000$ Å are also present on tracings of a 1964 plate and with similar intensities. Note especially in Table 1 that lines marked broad in the laboratory spectrum appear complex in the stellar spectrum in the two unblended cases.

Because of the large density of lines in the spectrum of HR 465—2.75 lines $Å^{-1}$ on the average for lines of all intensity in Bidelman's list and probably somewhat higher counting lines not measured by Bidelman—and the uncertainties in measuring the wavelengths of lines, the probability of coincidences between a list of lines and unidentified stellar features by random chance must be considered. By using a tolerance of 0.11 Å for an "accepted" identification and a spectral density of 3 lines $Å^{-1}$, the expected number of chance identifications was computed from the expression given by Russell and Bowen (1929). It should be remarked that this expression takes into account blends such as these noted in the remarks to Tables 1 and 2.

If only the eleven strong lines in Table 1 are considered, the expected number of identifications by random chance is 5.31 ± 1.66 (s.d.) while the number of identifications was eleven. Of the total of forty-four laboratory lines listed in the tables, thirty-

[1] Dr. Bidelman, however, informs us that the wavelength measurements in HR 465 were originally made by Diane M. Pyper.

Table 1

Lines of Pm II of Laboratory Intensity 80 or Greater

λ_{lab}	I_{lab}	$\lambda_{HR\ 465}$	$I_{HR\ 465}$	ID	Comments
3711.72	80	3711.65	2: d?	Dy II+	Blended region of spectrum
3877.63	80c	3877.55	1d?		
3892.16	100	3892.05	2-3:		Near core of Balmer line; rather broad
3910.26	100	3910.21	3-4d?		Definite blend of strong lines
3919.09	100ℓ	3919.13	2-3d?		
3936.47	80ℓ	**3936.39			Line blended with line at 3936.28 (I = 3) measured by Bidelman
3957.74	100	3957.79		Gd II, Dy II	Blend of strong lines at 3957.79 (Dy II) and 3957.67 (Gd II)
3998.96	100	3998.97	4-5	Zr II	Identified as Zr II but too strong to be attributed entirely to this element
4417.98	100	4418.03	2		
4453.96	80	*4454.02	0		Also on 1964 plate
4529.20	80	*4529.23	0		Weak feature at 4529.23 measured on 1960 plate. Feature of intensity 0 present at 4529.20 on 1964 plate.

Table 2

Lines of Pm II of Moderate Intensity

λ_{lab}	I_{lab}	$\lambda_{HR\ 465}$	$I_{HR\ 465}$	ID	Comments
3427.40	50	3427.36	1	Gd II	Probably not Gd II
3449.81	40	3449.87	3	Dy II+	
3634.26	30+ Sm	3634.29	4	Sm II	Double to violet?
3659.39	30	**3659.45	?		Possible weak feature
3689.78	40	*3689.86?	0		Weak, broad feature
3692.52	30	3692.45	4		Blend?
3697.50	30	3697.46	3d?	Zr II	Appears as blend on tracing
3702.64	40	*3702.67	0		Weak feature
3742.51	30	-----			
3745.86	50			V II, Fe I	Blend of 3745.81 (VII) and 3745.90 (Fe I
3747.10	30	*3747.02	0		Possible weak feature
3750.08	50				Blend with core of H line
3795.66	40	*3795.75	0		
3820.51	30	**3820.51	0^-		Feature in core of strong line of Fe I at 3820.43
3842.93	40	-----			
3899.78	40	**3899.79		Fe I	Identified as 3899.71 (Fe I double)
3944.23	30h	3944.18	0-1 d?		
3980.73	50ℓ	3980.76	0?		
3995.05	30^+ N	*3995.03	0		
4009.97	50	4009.96	0?	Ru II	
4051.50	30	4051.48	0-1 d		
4055.20	60ℓ	4055.12	3?	Dy II	
4075.85	60	4075.83	3-4	Sm II	Observed I indicates blend
4086.10	50w	4086.21	2-3 d		
4192.92	30	-----			
4336.53 } 4342.11 }					In core of H line
4432.51	40	4432.61	2 d ?		
4445.41	50	*4445.45	0		
4446.90	60	4446.87	1		
4473.23	30	4473.28	5		Strong unidentified feature
4500.14	60	*4500.21	0		
4525.19	60	*4525.20	0^-		Very weak feature

Notes to Tables 1 and 2

* Line identified on tracing
** Resolved blend on tracing
c Complex
ℓ Shaded to longer wavelengths
d Double
h Hazy
w Wide

eight were identified with features in the stellar spectrum, three were obscured by Balmer lines so that spectral features could not be distinguished, and three could not be positively identified with stellar lines. Ten of the thirty-eight identifications were made on the basis of the tracings. From the forty-one lines not confused by the Balmer lines in the stellar spectrum, the expected number of coincidences is 19.81 ± 3.20 (s.d.) as compared with the thirty-eight observed. Even if we were to accept a smaller tolerance of ± 0.06 Å, we would find a total of twenty-six coincidences in the two tables; 12.38 ± 2.94 (s.d.) coincidences would be expected by chance. These tests indicate that the large number of identifications made would be improbable by random chance. In addition, the fact that all the strong laboratory lines can be matched with stellar features, blended or unblended, argues in favor of the identification.

The identification of promethium in a stellar spectrum is of special significance since the longest-lived isotope of promethium, ^{145}Pm, has a half-life of only 18 years. Its presence would indicate that Pm must have been manufactured recently in HR 465 and probably near the stellar surface.

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