$$(10\text{-b}) \qquad T^{r}{}_{r} = (\rho + p)\, g_{r\nu}\, u^{r} u^{\nu} - p$$

$$(10\text{-c}) \qquad T^{\nu}{}_{\nu} = (\rho + p)\, g_{\nu r}\, u^{\nu} u^{r} - p$$

$$(10\text{-f}) \qquad T^{\nu}{}_{r} = (\rho + p)\, g_{r\nu}\, u^{\nu} u^{\nu}$$

donde $g_{r\nu} u^{r} u^{\nu} = g_{\nu r} u^{\nu} u^{r} = 1/2$ por definición del 4-vector velocidad. De donde obtenemos para $T^{r}{}_{r}$ y $T^{\nu}{}_{\nu}$

$$(10\,\text{b-d}) \qquad T^{r}{}_{r} = T^{\nu}{}_{\nu} = \frac{\rho - p}{2}$$

En (10-d) y (10-f) es necesario notar que

$$g_{\nu r}\, u^{r} = u_{\nu}\,,\; g_{r\nu}\, u^{\nu} = u_{r} \;\text{ y }\; u^{r} u^{\nu} = g^{r\nu}$$

Las ecuaciones de Einstein (5) y la expresión (8) para G exigen que $T^{r}{}_{\nu} = 0$; esta condición sólo puede verificarse si U^{r} o U_{ν} se anulan, pero ninguna de ambas puede hacerlo ya que por (11) ello significaría la anulación automática de la otra, lo que es incompatible con la definición del vector velocidad.

En consecuencia esto contradice la hipótesis de partida, que es suponer la existencia de la forma (4) para una métrica con simetría esférica, y por lo tanto la posibilidad de existencia de un horizonte 4-dimensional.

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A re-analysis of τ Ursae Majoris

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Resumen: Se realiza un nuevo análisis de las estrellas Am τ U Ma utilizando nuevas determinaciones de su temperatura efectiva y gravedad superficial y nuevas medidas de anchos equivalentes e identificacions de líneas.

Con el método de las curvas de crecimiento se calculan las abundancias de elementos. Se investiga la existencia de ciertos elementos pesados encontrados en las estrellas Ap más frías, especialmente aquellos con Z entre 41 y 55 pero no existe evidencia de ellos. Lo mismo sucede con los elementos más pesados de la tabla periódica.

Introduction

τ U Ma was the first Am star for which a detailed atmospheric analysis was made (Greenstein, 1948; Miczaika et al, 1956). It was studied together with several F stars using equivalent widths and a relative curve of growth method. Greenstein used however an ionization temperature which was too low and he obtained thus a low effective gravity. Subsequent studies of Am stars utilizing model atmospheres have shown however normal gravities (onti, 1965, van't Veer-Monneret, 1963, Provost and van't Veer-Menneret, 1969; Praderie, 1967). Therefore is was thought that a re-analysis of τ U Ma was in time.

Measurements

The measurement of equivalent widths in the range 4000-4860 A was made upon the microphotometric register of the plates used by Greenstein in his work and loaned generously by him to Dr. C. Jaschek (original dispersion: 2.8 A/mm at Hγ).

Since Greenstein used only the lines common to all his F stars, a new measurement and identification of all lines was made. An equivalent width-central depth relation was established using the value of the equivalent widths measured by Greenstein; those of the remaining lines were obtained from this relation. The line identification was made using conventional methods. Although a large quantity of lines are affected by strong blends, for the construction of the curves of growth only lines which seemed unblended or very little affected by other contributors were chosen.

TABLA 1

Equivalent widths

For each line is specified: element, multiplet no from Moore (1959), wavelenght λ, excitación potential of the lower level, the ordinate of the curve of growth $\log \frac{\omega}{\lambda} . \frac{c}{v}$, the abscissa of the curve of growth $\log \eta$. In the head of each ion a key for the source of the f values and partition functions is given.

Mult.	λ(Å°)	χ(eV)	log gf	$\log \frac{W}{\lambda} \frac{c}{v}$	log η	Remarks
Ca I						
1	4226.73	0.00	−0.55	+0.73	+2.16	a,A
4	4425.44	1.87	−0.33	+0.23	+0.88	
4	4434.96	1.88	+0.01	+0.33	+1.23	
4	4455.89	1.89	−0.54	+0.30	+0.67	
5	4283.01	1.88	−0.37	+0.22	+0.82	
5	4289.36	1.87	−0.42	+0.20	+0.78	
5	4318.65	1.89	−0.15	+0.23	+1.03	
23	4578.56	2.51	−0.82	−0.10	−0.17	
23	4581.40	2.51	−0.52	+0.24	+0.17	
Sc II						
15	4294.77	0.60	−1.28	−0.03	+0.49	b,A
15	4305.72	0.59	−1.22	+0.29	+0.60	
15	4314.08	0.62	−0.04	+0.64	+1.79	
Ti I						
42	4535.57	0.82	+0.19	+0.23	+1.02	c,A
42	4548.76	0.82	−0.21	−0.25	+0.58	
44	4287.40	0.83	−0.17	−0.32	+0.58	
44	4290.93	0.81	−0.19	+0.14	+0.62	
44	4298.66	0.81	+0.19	+0.02	+0.98	
80	4064.20	1.05	−0.50	+0.05	+0.07	
113	4453.31	1.42	+0.32	−0.08	+0.63	
113	4455.32	1.44	+0.39	+0.20	+0.69	
113	4457.43	1.45	+0.46	+0.27	+0.76	
113	4482.69	1.45	−0.60	+0.04	+0.32	
145	4617.27	1.74	0.62	−0.27	+0.65	
146	4471.24	1.73	0.05	+0.17	+0.11	
160	4463.54	1.88	−0.20	+0.04	−0.27	
Ti II						
19	4395.03	1.08	−0.65	+0.78	+2.61	d,A
19	4443.80	1.08	−0.81	+0.69	+2.49	
31	4444.56	1.11	−2.37	+0.40	+0.92	
31	4468.49	1.13	−0.77	+0.68	+2.49	
31	4501.27	1.11	−0.86	+0.68	+2.42	
40	4417.72	1.16	−1.37	+0.62	+1.86	
40	4464.46	1.16	−2.02	+0.38	+1.22	
40	4470.86	1.16	−2.22	+0.22	+1.00	
41	4312.86	1.18	−1.37	+0.61	+1.84	
41	4330.71	1.18	−2.35	+0.27	+0.84	
50	4563.76	1.22	−0.90	+0.65	+2.29	
51	4394.06	1.22	−1.93	+0.45	+1.26	
51	4399.77	1.23	−1.51	+0.62	+1.66	

TABLA I (*continuación*)

Mult.	λ(Å°)	χ(eV)	log gf	$\log \frac{W}{\lambda} \frac{c}{v}$	$\log \eta$	Remarks
51	4418.34	1.23	—2.50	+0.37	+0.68	
61	4395.85	1.24	—2.21	+0.38	+0.97	
82	4529.46	1.56	—2.15	+0.60	+0.76	
82	4549.62	1.58	—0.57	+0.84	+2.28	
82	4549.62	1.58	—0.57	+0.84	+2.28	
82	4571.97	1.56	—0.65	+0.84	+2.22	
92	4779.99	2.04	—1.37	+0.39	+1.17	
92	4805.10	2.05	—1.10	+0.53	+1.43	
93	4421.95	2.05	—1.67	+0.29	+0.81	
104	4367.66	2.58	—1.42	+0.41	+0.65	
104	4386.86	2.59	—1.41	+0.32	+0.65	
V I						
22	4379.24	0.30	+0.48	+0.13	+0.38	a,A
22	4406.64	0.30	—0.25	—0.05	—0.36	
27	4111.78	0.30	+0.45	+0.13	+0.33	
Cr I						
1	4254.35	0.00	+0.30	+0.72	+2.97	e,A
1	4274.80	0.00		+0.68		
1	4289.72	0.00		+0.60		
10	4545.96	0.94	—1.30	+0.30	+0.64	
21	4591.39	0.96		+0.18		
21	4600.75	1.00	—1.40	+0.12	+0.48	
21	4626.19	0.96	—1.40	+0.18	+0.52	
21	4652.16	1.00	—1.10	+0.38	+0.82	
22	4371.28	1.00		+0.32		
32	4648.13	2.53		+0.07		
64	4381.11	2.70		—0.18		
81	4501.79	2.90		—0.05		
81	4622.76	2.97		—0.12		
96	4261.35	2.90		—0.03		
96	4272.91	2.89		—0.11		
96	4319.64	2.88		—0.22		
104	4346.83	2.97		—0.01		
127	4458.54	3.00		+0.15		
129	4411.09	3.00		+0.18		
129	4428.50	3.00		+0.03		
145	4724.42	3.07		—0.11		
145	4737.35	3.07	+0.20	+0.12	+0.39	
145	4756.11	3.09	+0.30	+0.08	+0.46	
150	4500.30	3.07		—0.03		
150	4511.90	3.07	0.00	+0.04	+0.14	
155	4209.76	3.09		+0.25		
168	4792.51	3.10		+0.02		
168	4801.03	3.11	+0.20	—0.02	+0.34	
186	4689.37	3.11		—0.09		
186	4698.46	3.13		+0.18		
186	4708.04	3.15	+0.30	—0.05	+0.46	
186	4718.43	3.18	+0.40	+0.02	+0.47	
186	4664.80	3.11		+0.03		
196	4526.11	3.36		+0.04		

TABLA 1 (*continuación*)

Mult.	$\lambda(A^o)$	χ(eV)	log gf	$\log \frac{W\ c}{\lambda\ v}$	log η	Remarks
233	4622.49	3.54		—0.08		
247	4297.74	3.83		—0.06		
Cr II						
18	4217.07	3.09		+0.17		e,A
18	4113.24	3.09		+0.20		
19	4087.63	3.09		+0.18		
19	4088.90	3.09		+0.22		
26	4086.14	3.70		+0.35		
26	4132.41	3.74		+0.64		
26	4229.81	3.81		+0.22		
30	4812.35	3.85	—1.50	+0.38	+1.87	
30	4824.13	3.85		+0.30		
30	4836.22	3.84		+0.13		
30	4848.24	3.85		+0.18		
31	4275.57	3.84		+0.46		
31	4284.21	3.84		+0.48		
44	4555.02	4.05		+0.53		
44	4558.66	4.06	—0.60	+0.73	+2.53	
44	4588.22	4.05	—0.80	+0.65	+2.37	
44	4592.09	4.06	—1.10	+0.54	+2.07	
44	4618.83	4.06		+0.38		
44	4634.11	4.05	—0.90	+0.57	+2.28	
162	4145.77	5.30		+0.35		
165	4081.21	5.30		+0.31		
Mn I						
2	4034.49	0.00		+0.61		e,A
5	4041.36	2.11		+0.57		
5	4070.28	2.11		+0.24		
21	4709.72	2.88	—0.10	—0.03	+0.22	
21	4739.11	2.93	—0.20	—0.10	+0.09	
21	4761.53	2.94	0.00	—0.02	+0.28	
21	4762.38	2.88	+0.50	+0.20	+0.85	
21	4765.86	2.93	+0.10	+0.09	+0.39	
22	4451.59	2.88		+0.29		
22	4470.14	2.93	—0.20	—0.11	—0.58	
23	4265.92	2.93		+0.04		
Fe I						
1	4375.93	0.00	—3.00	+0.59	+2.33	f,A
1	4389.24	0.05		—0.15		
2	4427.31	0.05	—2.48	+0.63	+2.72	f
2	4461.65	0.09	—3.03	+0.48	+2.24	f
3	4199.97	0.09		+0.16		
3	4216.19	0.00		+0.55		
3	4291.47	0.05		+0.17		
18	4139.93	0.99		+0.08		
19	4174.92	0.91		+0.43		
39	4531.15	1.48		+0.44		
39	4547.02	1.55		+0.28		
39	4592.66	1.55	—2.29	+0.41	+1.78	i
39	4602.00	1.60	—3.11	+0.07	+0.87	j

TABLA 1 (*continuación*)

Mult.	λ(Å°)	χ(eV)	log gf	log $\frac{W}{\lambda}\frac{c}{v}$	log η	Remarks
39	4602.94	1.48	—2.16	+0.48	+1.97	f
39	4632.92	1.60		+0.29		
40	4765.48	1.60		0.00		
41	4383.55	1.48		+0.79		
41	4404.75	1.55	—0.13	+0.74	+3.88	g,h
41	4415.12	1.60	—0.54	+0.76	+3.44	f,g,h
42	4147.67	1.48		+0.49		
42	4202.03	1.48	—0.57	+0.82	+3.48	f
42	4250.79	1.55		+0.67		
42	4271.76	1.48		+0.74		
43	4071.74	1.60		+0.81		
43	4143.87	1.55		+0.69		
68	4408.42	2.19		+0.39		
68	4430.62	2.21	—1.51	+0.54	+2.00	f
68	4442.34	2.19		+0.56		
68	4447.72	2.21		+0.55		
68	4459.12	2.17	—1.21	+0.53	+2.33	f
68	4494.57	2.19	—1.05	+0.57	+2.47	f,g,h
68	4528.62	2.17	—0.74	+0.79	+2.76	f
69	4447.13	2.19		0.00		
71	4282.41	2.17	—0.71	+0.63	+2.52	f,g,h
71	4352.74	2.21	—1.27	+0.51	+2.23	d
115	4630.13	2.27	—2.45	—0.04	+0.98	g
152	4187.80	2.41		+0.76		
152	4210.35	2.47	—0.89	+0.59	+2.38	f
152	4222.22	2.44	—0.92	+0.57	+2.38	f
152	4235.94	2.41	—0.25	+0.75	+241	f
152	4250.12	2.46		+0.63		
152	4260.48	2.39	+0.04	+0.73	+2.39	f
152	4271.16	2.44		+0.62		
217	4067.28	2.55		+0.58		
217	4078.36	2.60		+0.54		
217	4095.98	2.58		+0.46		
273	4242.59	2.72		+0.31		
346	4683.56	2.82		—0.10		
346	4741.53	2.82		—0.06		
347	4687.39	2.82		—0.13		
349	4635.85	2.83		—0.17		
350	4422.57	2.83	—1.05	+0.40	+1.96	f
350	4443.20	2.85		+0.36		
350	4454.38	2.82	—1.15	+0.22	+1.83	f
350	4466.55	2.82	—0.62	+0.62	+2.38	f
350	4476.02	2.83		+0.62		
351	4241.11	2.82		—0.02		
352	4207.13	2.82	—1.14	+0.43	+1.85	f
352	4226.43	2.83		+0.49		
352	4245.26	2.85		+0.51		
354	4107.49	2.82	—0.80	+0.41	+2.18	f
354	4175.64	2.83		+0.55		
355	4154.50	2.82		+0.58		

TABLA I (*continuación*)

Mult.	λ(Å°)	χ(eV)	log gf	log $\frac{W}{\lambda}\frac{c}{v}$	log η	Remarks
355	4184.90	2.82	—0.82	+0.52	+2.16	f
355	4203.99	2.83		+0.60		
355	4213.65	2.83	—1.10	+0.40	+1.18	f
356	4122.52	2.83		+0.70		
357	4091.56	2.82		—0.03		
357	4109.81	2.83		+0.44		
357	4114.45	2.82	—0.45	+0.33	+1.92	f
358	4085.01	2.83		+0.48		
359	4079.85	2.85		+0.34		
409	4661.98	2.98		—0.18		
409	4710.29	3.00		+0.40		
409	4740.34	3.00		+0.16		
413	4326.76	2.94		+0.15		
414	4304.55	2.94		+0.14		
414	4309.38	2.94		+0.53		
415	4365.90	2.98		—0.10		
419	4196.53	2.94		+0.46		
418	4196.53	2.94		+0.46		
419	4160.56	2.94		+0.41		
422	4089.23	2.94		+0.20		
424	4066.60	2.98		+0.37		
467	4712.10	3.00		—0.10		
469	4490.08	3.00		+0.14		
476	4387.90	3.06		+0.30		
476a	4182.38	3.00		+0.42		
476a	4260.14	3.06		+0.51		
478	4273.87	3.06		0.00		
482	4220.35	3.06		+0.42		
482	4248.23	3.06		+0.38		
482	4267.83	3.10		+0.34		
516	4436.93	3.03		+0.16		
517	4343.70	3.03		—0.02		
518	4369.77	3.03	—0.89	+0.34	+1.95	f
520	4298.04	3.03		+0.50		
521	4225.96	3.03		+0.41		
522	4199.10	3.03	+0.18	+0.65	+2.99	h
523	4143.42	3.03		+0.61		
524	4074.79	3.03		+0.49		
554	4568.79	3.25		—0.04		
554	4574.24	3.20	—2.57	—0.04	+0.09	g
554	4598.12	3.27		+0.12		
554	4625.05	3.23	—0.18	+0.44		
555	4504.84	3.25		—0.11		
557	4069.08	3.28		—0.03		
557	4080.89	3.28		+0.06		
558	4073.76	3.25		+0.47		
558	4097.10	3.27		0.21		
558	4098.18	3.23	—0.74	+0.22	+1.87	f
558	4109.07	3.28		+0.12		
559	4067.98	3.20		+0.54		

TABLA 1 (*continuación*)

Mult.	λ(Å°)	χ(eV)	log gf	$\log \frac{W}{\lambda} \frac{c}{v}$	log η	Remarks
559	4085.31	3.23		+0.60		
588	4788.76	3.22	—1.66	—0.06	+1.00	g
588	4839.55	3.25		+0.10		
593	4518.45	3.22		+0.03		
594	4537.68	3.25		—0.09		
597	4285.44	3.22		+0.36		
597	4327.92	3.29		+0.09		
635	4776.07	3.29		—0.10		
638	4594.96	3.26		0.00		
688	4741.08	3.32		—0.15		
689	4168.62	3.35		+0.12		
689	4200.93	3.38		+0.41		
689	4224.18	3.35		+0.57		
691	4306.58	3.42		+0.31		
693	4227.43	3.32	+0.36	+0.71	+2.90	f
693	4238.82	3.38		+0.52		
693	4247.43	3.35	—0.21	+0.60	+2.34	f
694	4154.81	3.35		+0.62		
694	4168.94	3.40		+0.11		
695	4090.98	3.35		+0.08		
695	4114.96	3.35		+0.28		
695	4150.26	3.42		+0.50		
695	4157.79	3.40		+0.56		
695	4158.80	3.42		+0.52		
695	4176.57	3.35		+0.58		
697	4106.44	3.38		+0.27		
698	4065.40	3.42		+0.04		
698	4072.52	3.42		+0.37		
698	4084.50	3.32		+0.49		
700	4090.08	3.38		+0.26		
723	4566.99	3.40		+0.04		
726	4137.00	3.40		+0.52		
752	4705.46	3.53		—0.23		
753	4789.65	3.53	—0.92	+0.24	+1.50	g
755	4547.85	3.53		+0.17		
761	4327.10	3.53		+0.20		
795	4587.13	3.56		+0.10		
799	4201.73	3.56		+0.36		
800	4219.36	3.56	+0.05	+0.62	+2.43	f
819	4572.86	3.64		—0.16		
820	4643.47	3.64	—0.89	+0.27	+1.43	i
820	4673.17	3.64	—0.82	+0.32	+1.53	i
820	4690.15	3.67		+0.01		
820	4701.05	3.67		—0.04		
821	4678.85	3.59	—0.60	+0.27	+1.76	f
822	4638.02	3.59		+0.36		
822	4728.56	3.64		+0.15		
823	4560.10	3.59		+0.08		
825	4495.99	3 64		—0.07		
826	4611.28	3.64	—0.70	+0.52	+1.63	i

TABLA I (*continuación*)

Mult.	λ(Å°)	χ(eV)	log gf	log $\frac{W}{\lambda}\frac{c}{v}$	log η	Remarks
827	4495.57	3.59		+0.05		
828	4438.35	3.67		+0.06		
828	4446.84	3.67		+0.13		
828	4484.23	3.59	—0.66	+0.41	+1.71	f
829	4523.40	3.64		—0.11		
830	4388.41	3.59		+0.44		
830	4423.86	3.64		+0.09		
830	4433.22	3.64		+0.44		
830	4469.38	3.64	—0.35	+0.32	+1.98	f
830	4476.08	3.67		+0.62		
830	4485.68	3.67		+0.26		
849	4309.04	3.62		+0.22		
903	4360.81	3.63		+0.04		
906	4088.57	3.62		+0.26		
906	4236.76	3.62		—0.01		
906	4243.37	3.62		+0.14		
906	4246.09	3.63		+0.44		
971	4593.54	3.93		—0.08		
973	4392.58	3.86		—0.20		
976	4276.68	3.86		+0.08		
993	4264.74	3.94		—0.18		
994	4243.79	3.87		+0.03		
1073	4085.98	4.14		+0.23		
1103	4112.97	4.16		+0.33		
1103	4125.62	4.20		+0.45		
1133	4734.10	4.28		—0.06		
1206	4749.93	4.54	—1.48	+0.02	+0.09	j
Fe II						
27	4416.82	2.77	—2.34	+0.63	+2.51	i,A
37	4515.34	2.83	—2.41	+0.71	+2.35	i,k,l
37	4520.22	2.83	—2.55	+0.69	+2.25	i,k,l
38	4508.28	2.84	—2.30	+0.69	+2.66	i,k,l
38	4522.63	2.83	—2.10	+0.83	+2.67	i,k
38	4541.52	2.84	—2.57	+0.64	+2.23	i
38	4576.33	2.83	—2.90	+0.58	+1.91	l
38	4583.83	2.79	—1.82	+0.77	+2.99	i,l,k
38	4620.51	2.82	—3.27	+0.47	+1.57	l
Co I						
16	4020.90	0.43	—1.59	+0.17	+0.60	a,B
27	4699.18	1.04		+0.11		
28	4121.32	0.92	—0.03	+0.44	+1.68	
29	4110.53	1.04	—0.80	+0.30	+0.81	
58	4068.54	1.95	—0.49	—0.08	+0.32	
58	4086.30	1.87	—0.27	+0.29	+0.64	
150	4478.32	3.09	—0.33	—0.30	+0.43	
150	4517.09	3.11	+0.27	—0.18	+0.15	
Ni I						
52	4331.64	1.67		+0.15		m,A
86	4462.46	3.45	—0.41	+0.24	+0.74	
86	4470.48	3.38	—0.13	+0.25	+1.08	

TABLA I (*continuación*)

Mult.	λ(A°)	χ(eV)	log gf	log $\frac{W\,c}{\lambda\,v}$	log η	Remarks
98	4648.66	3.40	—0.01	+0.59	+1.22	
98	4686.22	3.58	—0.49	+0.31	+0.60	
98	4715.78	3.53	—0.19	+0.46	+0.94	
98	4756.52	3.47	—0.21	+0.22	+0.95	
113	4703.81	3.64		+0.36		
146	4763.95	3.64		+0.14		
168	4437.57	3.66		+0.10		
197	4072.91	3.83		—0.02		
Ni II						
9	4244.80	4.01		+0.23		
9	4362.10	4.01		+0.34		
10	4192.07	4.01		+0.27		
Zn I						
2	4722.16	4.01		+0.49		
2	4810.53	4.06		+0.49		
Sr II						
1	4077.71	0.00	+0.18	+1.04	+4.02	n,B
1	4215.52	0.00	—0.11	+0.89	+3.76	
3	4305.45	3.03		+0.53		
Y II						
5	4358.73	0.10	—0.71	+0.36	+1.50	ñ,B
5	4398.02	0.13	—0.35	+0.45	+1.83	
13	4374.94	0.41	+0.76	+0.69	+2.70	
14	4177.54	0.41	+0.66	+0.88	+2.54	
Zr II						
40	4317.32	0.71	—1.60	—0.30	—0.49	e,A
42	4150.97	0.80	—1.02	+0.27	+0.10	a
43	4050.32	0.71	—1.30	—0.60	—0.23	e
Ba II						
1	4554.03	0.00	+0.17	+0.78	+3.20	a,B
4	4166.00	2.71	—0.39	+0.22	+0.42	
La II						
8	4662.51	0.00	—2.04	+0.02	+0.44	a,B
24	4333.76	0.17	—0.60	+0.46	+1.76	
25	4322.51	0.17	—1.62	—0.04	+0.70	
52	4605.78	0.71	—1.68	+0.13	+0.22	
53	4364.66	0.65	—1.76	+0.01	+0.15	
75	4286.97	1.94	+0.28	+0.38	+1.17	
75	4692.50	1.75	—0.52	—0.07	+0.52	
76	4269.50	1.77	+0.03	+0.01	+1.02	
77	4378.10	1.77	—0.65	—0.13	+0.32	
81	4719.93	1.95	—0.55	—0.07	+0.30	
Ce II						
1	4186.60	0.38	+0.67	+0.39	+1.18	a,C
1	4248.68	0.20	—0.06	+0.20	+0.58	
1	4562.36	0.00	—0.07	+0.28	+0.76	
1	4628.16	0.04	—0.14	+0.29	+0.67	
2	4137.65	0.04	+0.09	+0.46	+0.87	
2	4382.17	0.20	—0.17	+0.11	+0.48	
2	4418.78	0.38	+0.03	+0.12	+0.55	

TABLA I (*continuación*)

Mult.	λ(A°)	χ(eV)	log gf	log $\frac{W}{\lambda}\frac{c}{v}$	log η	Remarks
2	4460.21	0.00	+0.02	+0.21	+0.84	
2	4523.08	0.04	—0.45	+0.07	+0.32	
2	4560.96	0.20	—0.70	—0.08	—0.06	
3	4483.90	0.38	—0.14	0.00	+0.35	
4	4073.48	0.00	+0.05	+0.22	+0.84	
6	4593.93	0.22	—0.26	+0.13	+0.39	
11	4118.14	0.22	—0.13	+0.05	+0.46	
36	4222.60	0.12	—0.44	+0.35	+0.29	
57	4486.91	0.29	—0.62	—0.05	—0.06	
60	4083.23	0.70	—0.04	+0.20	+0.17	
81	4255.78	0.70	—0.27	+0.14	—0.04	
82	4068.84	0.70	—0.36	+0.03	—0.17	
112	4120.83	0.32	—0.74	—0.05	—0.23	
202	4449.34	0.61	—0.34	+0.15	—0.02	
Nd II						
10	4156.08	0.18	—0.49	+0.49	+1.56	a,C
19	4075.27	0.06	—1.38	+0.24	+0.74	
19	4133.36	0.32	—1.15	+0.09	+0.74	
50	4144.56	0.20	—1.72	+0.23	+0.29	
50	4462.98	0.56	—0.84	+0.16	+0.90	
Sm II						
3	4676.91	0.04	—1.39	—0.30	+0.19	a,C
36	4434.32	0.38	—0.75	+0.16	+0.59	
36	4642.24	0.38	—1.12	—0.18	+0.19	
45	4424.34	0.48	—0.42	+0.31	+0.84	
Eu II						
1	4129.73	0.00	—0.31	+0.54	+2.03	a,C
1	4205.05	0.00	—0.08	+0.63	+2.26	
Gd II						
15	4212.00	0.42	—0.46	+0.29	+0.78	a,C
17	4162.73	0.49	—0.75	+0.08	+0.42	
32	4215.02	0.43	—0.58	+0.07	+0.63	
43	4316.05	0.66	—0.66	—0.19	+0.36	
62	4483.33	1.06	—0.70	—0.16	+0.00	

REMARKS:

Sources of f-values:

a	Corliss and Bozman, 1962
b	Kurucz, 1973
c	Wolnik and Berthel, 1973
d	Roberts, Andersen and Sorensen, 1973
e	Holweger, 1967
f	Wolnik, Berthel and Wares, 1970
g	Garz and Kock, 1969
h	Bridges and Wiese, 1970
h	Bredges and Wiese, 1970
i	Wolnik, Berthel and Wares, 1971
j	Richter and Wulff, 1970
k	Roder, 1962
l	Baschek et tl., 1970 (raised by +0.2)
m	Garz et al., 1970
n	Penkin, 1964
ñ	From a relation Corliss and Bozman vs. Holweker
o	Lambert and Wagner, 1968

Sources of partition functions:

A	Bolton, 1970
B	Cayrel and Jugaku, 1963
C	Aller and Everett, 1972

Table 1 gives the line intensities and other pertinent data taken from Moore (1959). In the table are also given $\log \frac{W}{\lambda} \frac{c}{v}$ and log η. Here v is the most probable velocity of the atoms given by

$$v = \sqrt{\frac{2kT}{M} + \zeta_t^2}$$

M is the mass of the atom, T the gas kinetic temperature, k the Boltzmann constant and ζ_t the turbulent velocity. The sources of f-values and partition functions are listed in the remarks to the table.

Curve of growth analysis

From the different theoretical curves published, Wrubel's curves for the scattering mechanism and the Milne-Eddington, model were selected. The family of curves for $\frac{B0}{B1} = \frac{2}{3}$ and for log a = — 2.6 was chosen. Here

$$a = \frac{\Gamma}{4\pi \Delta \nu_0} \; ; \quad \Delta\nu_0 = \frac{\nu_0}{c} \cdot v$$

Γ is the effective damping constant; both collision with neutral hydrogen atoms and classical radiation damping were considered. I has been assumed that the continuous absorption is due to the neutral hydrogen to the negative hydrogen and to Rayleigh scattering; tables of these, for a large range of temperature and electron presure, were calculated with the IBM/360 computer of the La Plata University. The formulae used were those given by Mihalas (1967).

Atmospherical parameters

Baschek and Oke (1965) determined effective temperature and gravities for certain Am, Ap and normal A-type stars through the use of the spectrum scanning technique. They obtained for τ U Ma.

$$\theta_{eff} = 0.67 \quad \log g = 4.0$$

Another means of obtaining the stellar effective temperature uses effective temperature-color index relations. Matsushima (1969) gives a relation between uvby photometric system and effective temperature from stellar atmospheres computations. As b-y = 0.217 (Strongren and Perry, 1965) one obtains

$$\theta_{eff} = 0.686$$

Geneve's photometric systems gives another through $(B_2 - V_1)$ index (Hauck, 1968). Using the relation
mean for determine effective temperatures

$$\theta_{eff} = 0.727 \, (B_2 - V_1) + 0.649$$

one obtains

$$\theta_{eff} = 0.736$$

Finally, one wants mention here that Praderie (1967) in her analysis of Am stars gives for τ U Ma $\theta_{eff} = 0.68 \pm 0.02$, accord to the results of Oke and Conti (1966) and the Hγ profile.

The following parameters were finally adopted:

$$\theta_{eff} = 0.69 \quad \log g = 4.0$$

With these values and for an optical depth $\tau_{st} = 0.1$ the values of the other atmospherica lparameters were obtained interpolating in Mihalas models (1964).

This value of the optical depth was chosen because of van't Veer-Menneret's work (1963) on 63 Tau where he showed that $\tau = 0.1$ is the most representative depth from the consignation and excitations level of the atmosphere.

In particular, lor Pe was found to be 0.973. This value was also determined using the equivalent widths of the hydrogen lines (published by Greenstein 1948) as suggested by Unsold (1941). It resulted log Pe = 2.81 which is very different from the previous one. This is due to the fact that the hydrogen lines are formed in deeper layers than $\tau = 0.1$ which is representative mostly for the lines of metals. On the other hand it must be remembered that not all but only a few hydrogen line could be used for the above mentioned calculation.

The microturbulent velocity

The microturbulent velocity was determined using a plot of $\log \frac{W}{\lambda}$ vs. log g f λ for lines of several elements. As Fe is the element with major number of lines, it influences greatly in the determination.

First, Corlis and Bozman's gf values were used and two different values resulted for neutral and ionized atoms:

$\zeta_t = 4.1$ km/seg for neutral atoms
$\zeta_t = 4.5$ km/seg for ionized atoms

This rather bizarre result was found in several other Am stars.

In a second attemp, new values of gf were used, with the interesting result that an unique value for both neutral and ionized atoms results:

$$\zeta_t = 3.30 \text{ km/seg}$$

This microturbulent velocity is relatively low compared to the values obtained for other Am stars, bus it is in good agreement with the result obtained by Smith (1973) in a recent investigation about the microturbulence in A stars.

Table 2 gives the values of the parameters obtained presently, and those of Greenstein. When comparing, it should be kept in mind that Greenstein used a different representative depth in the atmosphere, namely $\tau_{st} = 0.25$. It is evident that the values used by Greenstein for temperature and effective gravity were too lew.

Abundances

Having thus obtained the fundamental parameters, one can proceed with the determination of abundances, following the well known technique of the curve of growth. The curves for several elements are given in figures 1, 2, 3, 4 and 5.

TABLE 2

Atmospherical parameters of τ UMa

	Miczaika et al 1956	Present analysis
τ_{st}	0.25	0.1
V_{turb}	3.8 km/seg	3.30 km/seg
θ_{ion}	0.86	0.826
log P_e	+0.12	0.97
log P_g	+2.9	4.20
log g	2.2	4.0

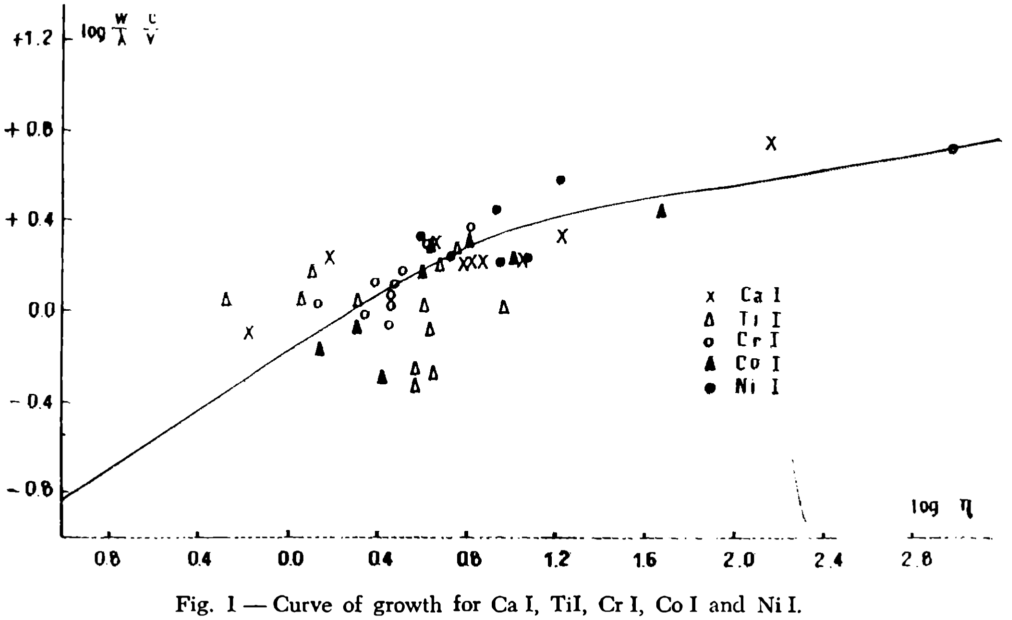

Fig. 1 — Curve of growth for Ca I, TiI, Cr I, Co I and Ni I.

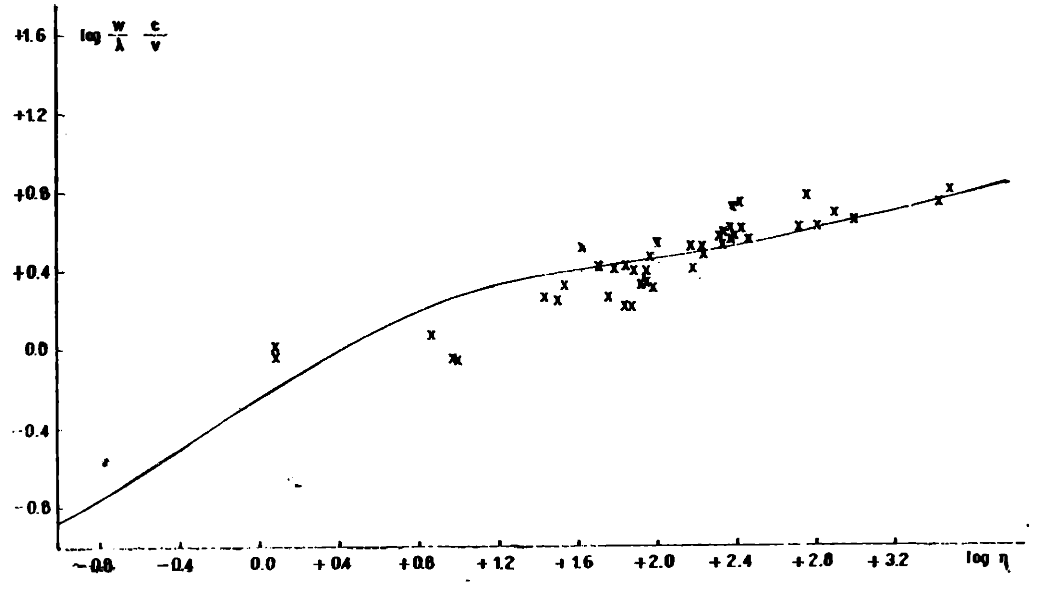

Fig. 2 — Curve of growth for Fe I.

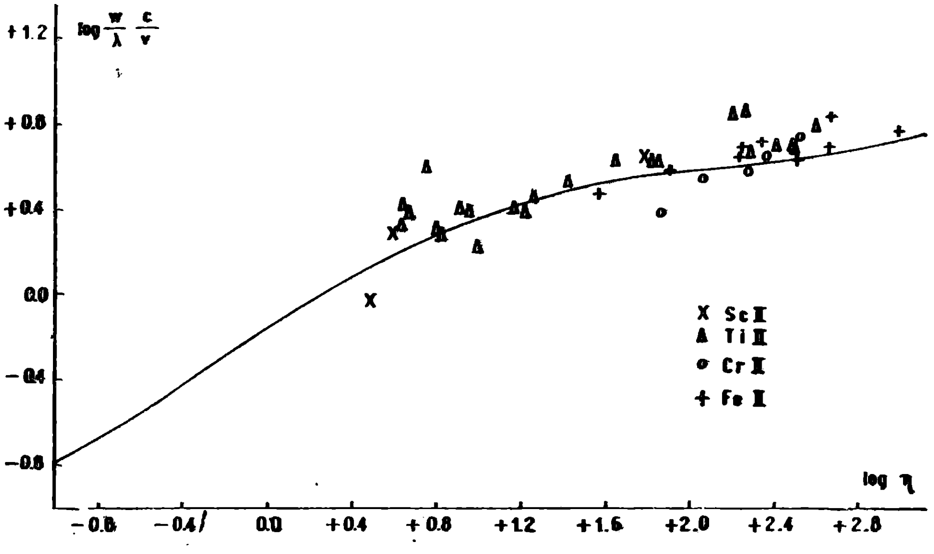

Fig. 3 — Curve of growth for Sc II, Ti II, Cr II and Fe II.

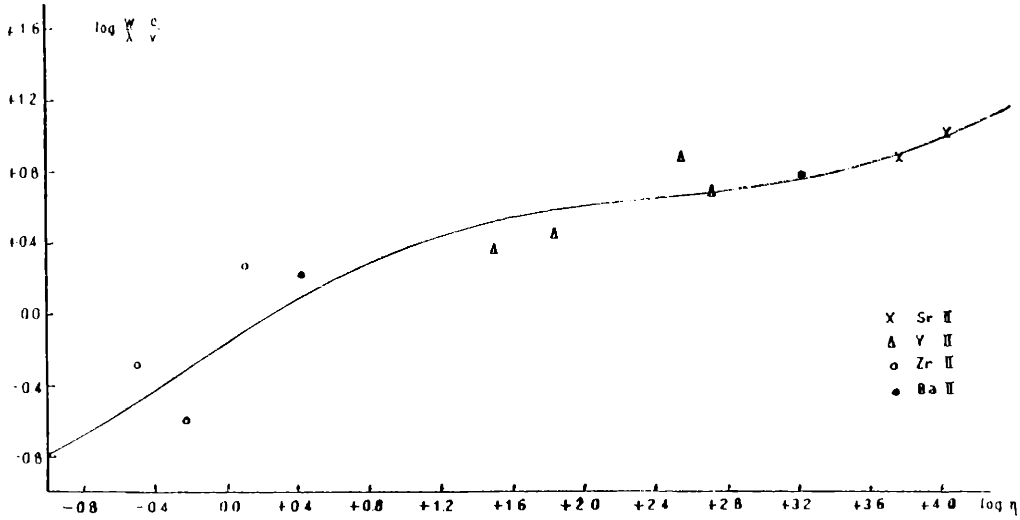

Fig. 4 — Curve of growth for Sr II, Y II, Zr II and Ba II.

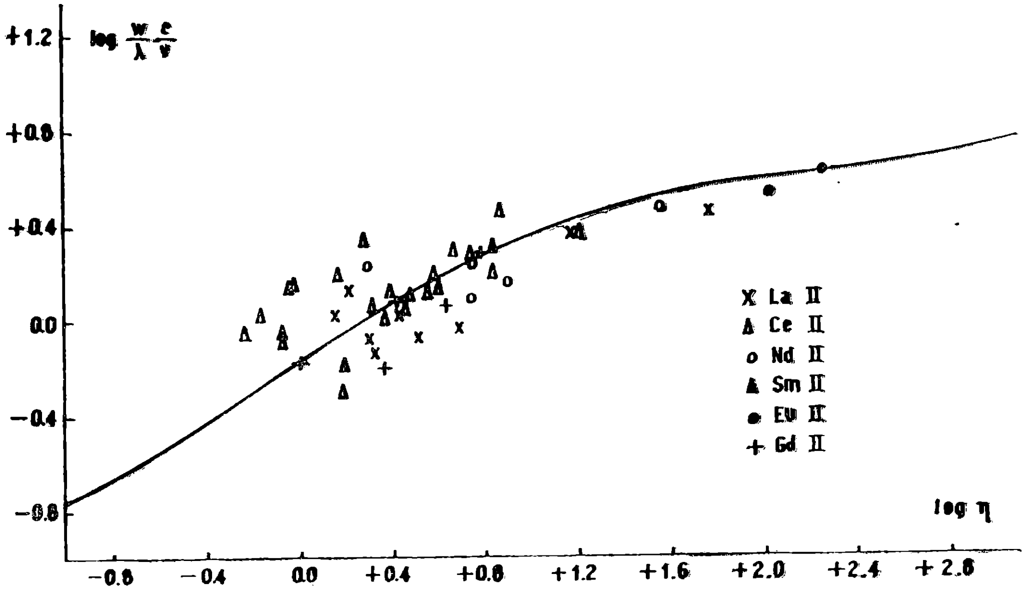

Fig. 5 — Curve of growth for the rare-earths.

Table 3 summarizes the abundances of τ U Ma compared with the normal scale of abundances derived by Aller (1968). For Iron the most recent determination of = 7.28 (Foy, 1972).

The quality of the abundance determination, according to the number of lines, the source of the oscillator strength and the scatter for one element, is indicated by number (5: the highest quality). The abundances will be discussed in detail below.

The main results are that both Ca and Sc are deficient, which is characteristic of the Am stars; the iron peak elements, except V and Mn, whose abundances are not well determined, are overabundant. Of the heavier elements, Sr and Y are the most enhanced ones.

There is no evidence of the existence of elements with atomic number between 41 and 55 (Mo, Pd, Ag, Cd, Xe) which are present in some of the coolest Ap stars (see Jaschek and Jaschek, 1971). Ba (Z = 56) is also present. The rare earth group is represented by La, Ce, Pr, Nd, Sm, Eu, and Gd). Definetely absent are Tb, Dy, Ho, Cr, Tm, and Lu.

TABLE 3

Abundances

For each element is specified: element, absolute abundances of τ UMa log ε_*, the relative abundances compared to the sun [log ε] = log ε_* — log $\varepsilon_\odot$, the quality of the abundance determination, the results of previous analysis (Miczaika et al, 1956, van't Veer - Menneret, 1966).

Element	log ε_*	[log ε]	Quality	[log ε] Miczaika et al	[log ε] van't Veer-Menneret
Na	P			+0.9	
Mg	P			+0.2	
Al	P			+0.5	
Si	P			+0.2	
Ca	5.4	—1.0	1	—0.6	—0.3
Sc	2.7	—0.3	1	—1.1	—0.7
Ti	5.0	+0.4	5	—0.2	+0.4
V	3.6	—0.5	1	—0.4	+0.4
Cr	6.3	+1.1	5	+0.3	+0.8
Mn	4.8	—0.1	1	+0.3	+0.6
Fe	7.8	+0.6	5	+0.2	+0.7
Co	4.8	+0.2	2		
Ni	6.1	+0.4	2	+1.0	
Zn	P			+0.7	
Sr	3.3	+0.4	3	0	+0.9
Y	2.5	+0.9	2	+0.1	+1.0
Zr	2.5	—0.2	1	—1.0	+0.6
Ba	2.7	+1.00	1	+0.1	
La	3.0	+1.0	2	0.00	+1.3
Ce	2.4	+0.4	3		
Nd	3.4	+1.5	1		
Sm	2.5	+0.9	1		
Eu	2.6	+1.6	1		
Gd	2.6	+1.5	1		

P: elements which are present but only with a few number of blended lines.

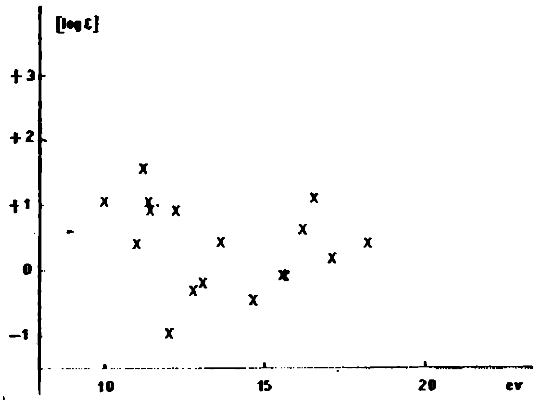

Fig. 6 — The dependence of the relative abundances [log ε] in τ U Ma from the 2ª ionization potential.

In view of recent results indicating the presence of very heavy elements ($Z < 71$) a careful search was made for them. No evidence was found for any element heavier than the rare earth group. This could constitute a major difference with cool Ap stars if it could be confirmed in other Am stars. With the different atmospheric parameters used by the authors (mainly temperature and electron pressure) one must expect different abundances. A glance at table 3 shows this to be true. A comparison with Miczaika et al. values shows that their abundances are in general lower by a factor five. The differences with van't Veer-Menneret are not large.

Since this author considered his abundances as provisional we will not analize them further.

In the following detailed analysis the element are collected groupwise.

Sodium, Magnesium, Aluminium and Silicon

These elements are present with only a few number of blended lines. So, one can not obtain a good estimation of their abundances.

Calcium and Scandium

Scandium is represented with only three lines belonging to a same multiplet; a weak underabundance results but the determination is not very accurate. The estimation of Ca abundance is also in accurate; we have only a group of eight lines well identified.

The Iron group

Except for Vanadium, Manganese and Cobalt, the abundances are derived from many well classified lines. The error can not be larger than $\triangle \log \varepsilon = \pm 0.03$.

The abundance of Vanadium is derived of only three weak lines, so the error in the determination is very large.

The abundance of Mn is obtained from lines that are in the region λ 4700-4800, when the quality of the plate it bad and the continuum very difficult to fix.

Cobalt is also represented by only very weak lines, which show a considerable scatter.

Strontium, Yttrium and Zirconium

Strontium is represented by the most strong lines; his abundance seems to be low.

Yttrium and Zirconium are present with four and three lines respectively. The overabundance of Y seems to be real but the abundance of Zr seems to be affected of a large error.

Barium, Lanthanum and the rare-earths

The abundances of these elements are not of very great accuracy because they are represented by only a few number of lines; but the overabundance seems to be real.

Finally, the dependence of the abundances on three different factors is studied: a) the second ionization potential; b) the atomic number and c) the solar abundance.

One can see that there is no correlation in cases a) and b), but that a relation exists in case c): the lower the normal element abundance is, the higher is the overabundances in τ U Ma. The peculiar elements Ca, Sc and also Zr (not well determined) which are underabundant, and Cr, Fe and Ni which seem to be overabundant, show a deviation respect to the general behaviour.

Discussion

The spectral anomalies of τ U Ma can be due to of the following factors:

a) an anormal structure of the atmosphere
b) an anormal chemical composition.

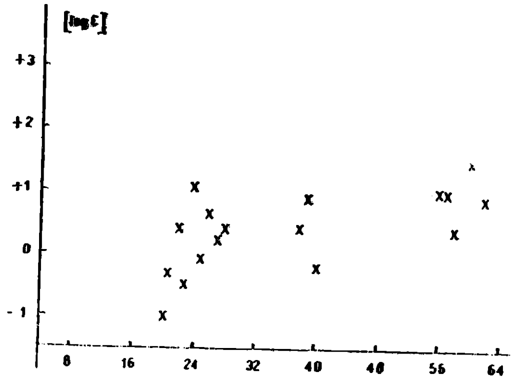

Fig. 7 — The dependence of the relative abundances [log ε] in τ U Ma from the atomic number z.

One can see from the analysis that the atmospherical parameters are the proper of a normal main sequence star with the same effective temperature.

Then, it is supposed that the anomalous line intensities are due entirely to real abundance differences. Several mechanisms has been proposed to explain these anomalies observed in Am stars.

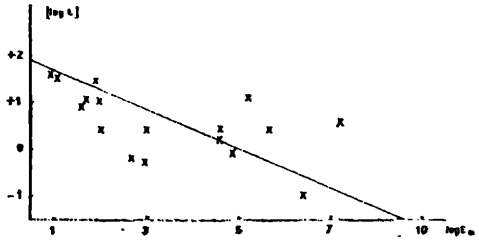

Fig. 8 — The dependence of the relative abundances in τ U Ma from normal (solar abundances $\log \epsilon_0$.

Following the work of Michaud (1970) on the diffusive separation of elements in Ap stars, several investigators (Watson, 1971 a, b; Smith, 1971; Stickland-Whelan, 1972) have applied the theory of element separation to the Am stars.

This process can explain satistactorily the result showed in fig. 7, specially the overabundance of the heavier elements. In agreement with this theory they are pushed outward because they are less abundant a priori.

The deficiency of Ca and Sc can also be explained by this process; it is related to the fact that their ionic states are near the configuration of Ne and Ar respectively.

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