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KAPPA PEGASI — A QUADRUPLE SYSTEM OF POSSIBLE LOW TOTAL MASS

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RESUMEN

El análisis de los espectros del Observatorio de Lick y de recientes espectros de alta dispersión del Observatorio de Kitt Peak indican que κ Pegasi es un sistema cuádruple con sus cuatro espectros visibles bajo condiciones favorables. Se presentan elementos orbitales espectroscópicos provisionales para el sistema Aab, para el AB y para el Bb. Se ha encontrado que el sistema Bab era el conocido previamente como un sistema espectroscópico de 5.97 días de período. Se ha encontrado que la masa total está solamente entre 2 y 3 masas solares. De esta manera, la más brillante de las cuatro estrellas: Ba (F5IV) —o posiblemente todas las cuatro estrellas— deben tener una masa anormalmente pequeña para su luminosidad. Este sistema parece ser similar a otros tantos que tienen componentes aparentemente superluminosas. Tales sistemas son de interés respecto a la evolución estelar.

ABSTRACT

Analyses of early Lick Obs. spectra and recent high dispersion Kitt Peak National Obs. spectra indicate that κ Peg is a quadruple system having all four spectra visible under favorable conditions. Preliminary spectroscopic orbital elements are presented for the AB system, and for Bb. The Bab system has been found to be the previously known 5.97-day spectroscopic system. The total mass is found to be between 2 and 3 solar masses only. Thus the brightest of the four stars Ba(F5IV) —or possibly all four of the stars— must have an abnormally small mass for its luminosity. This system appears to be similar to several others which have apparent overluminous components. Such systems are of interest in regard to stellar evolution.

Kappa Pegasi (ADS 15281; $\alpha = 21^h40^m.1$, $\delta = 5°11' < 1900 >$, $m_v = 4.14$, F5 IV) was discovered ɔ be double by Burnham (1883). Since then, it .as been well observed as a visual binary. Three .efinitive visual orbits exist by Luyten (1934), by 'outeau and Morel (1972), and by Beardsley and 'reakiron (unpublished) in which the elements were omputed using Herschel's method. The three orbits re in close agreement. Astrometric orbits exist by an de Kamp (1947) using Sproul Observatory maerial, by Gatewood (unpublished) using Allegheny)bservatory Series I[1)] and by Hayes (1974) using \llegheny Observatory Series I and II. Hayes was ınsuccessful in his attempt to combine Series I and II into a single solution, presumably due to a troublesome magnitude term. The authors are presently deriving a spectroscopic orbit for the 11.54-year period from the center-of-mass motions of star A and star B; each star being also a spectroscopic binary (Beardsley and King 1975). The final spectroscopic orbits will permit a parallax to be derived independent of the trigonometric values. The authors also intend to remeasure both Allegheny Series on SAMM at the U.S. Naval Observatory and reduce the measures using modern reduction techniques. It is hoped that a parallax derived in this way, together with the parallax derived from the spectroscopic orbit, will permit a significant improvement of the overall parallax accuracy and thus also improve the accuracy of the masses.

[1] Kappa Pegasi, was sectored to 10th magnitude in eries I and to 12th magnitude in Series II.

TABLE 1
SUMMARY OF VISUAL ORBITS

	P(yrs.) (s.e.)	T (s.e.)	e (s.e.)	a (s.e.)	i (s.e.)	ω (s.e.)	Ω (s.e.
Luyten	11.53	1909.86	0.30	0″.21	109°	131°	111°
Couteau and Morel	11.558	1979.13	0.288	0″.255	108°.4	126°.9	111°.
Beardsley and Breakiron	11.544	1909.703	0.280	0″.230	107°.7	126°.4	112°.
	±0.009	±0.085	±0.009	±0″.003	±0°.6	±2°.4	±0°.
Adopted Mean	11.54 ± 0.01			0″.23 ± 0″.01			

TABLE 2
SUMMARY OF ASTROMETRIC RESULTS

	α (s.e.)	$\pi_{x_{abs}}$ (s.e.)
v. d. Kamp ... (α_{vis})	0″.0426 ± 0″.0056	0″.039 ± 0″.008
Gaewood (I) ... (α_{pg})	0″.0383 ± 0″.0064	0″.024 ± 0″.010
Yerkes Obs.		0″.024 ± 0″.022
McCormick Obs.		0″.019 ± 0″.012
Adopted Mean	0″.0407 ± 0″.0042	0″.031 ± 0″.006

Since the spectroscopic results are not final, we present only a preliminary summary of results.

Assume $\Delta m_v = 0.1 \pm 0.1$ (Beardsley and King 1975)

$$\Delta m_{pg} = 2.5 \log \left[1 \Big/ \left(\frac{1}{1 + 10^{0.4\Delta m_V}} \frac{\alpha_V - \alpha_{pg}}{a} \right) - 1 \right]$$

For $\Delta m = 0.1$, we have $\Delta m_{pg} = 0.0 \pm 0.10$.

The color difference between A and B is essentially 0, hence we can adopt $\alpha = 0''.0407 \pm 0''.0042$.

Using Beardsley's and Breakiron's values:

$P = 11.544 \pm 0.009$ and $a = 0''.230 \pm 0.003$ and our adopted $\pi = 0''.031 \pm 0''.006$, we have

$$\Sigma \mathcal{M} = \frac{a^3}{p^2 \pi^3} = 3.06 \pm 1.91$$

$$B = \frac{0.0407}{0.23} + 0.477 = 0.654 \pm 0.032.$$

Distance modulus = 2.54

Hence: $\mathcal{M}_B = 2.0 \pm 1.2\ \mathcal{M}_\odot$; $\mathcal{M}_A = 1.1 \pm 0.8\ \mathcal{M}_\odot$

and

$$M_{v_A} = 2.31 \pm 0.18;\ M_{v_B} = 2.41 \pm 0.18,$$

where $m_{v_A} = 4.85$; $m_{v_B} = 4.95$

$$\mathcal{M}_A / \mathcal{M}_B = 0.55.$$

It is interesting to note that B is the more ma sive star of the visual pair in agreement with va de Kamp (1947). Also, as we have indicated, st A is a spectroscopic binary with both spectra visib and both stars perhaps early F in spectral type. F this star the mass is certainly low. The possibili of low-mass subgiants is of increasing interest i regard to present theories of stellar evolution. A we stated before the authors will continue their e forts to improve the accuracy of the parallax.

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DISCUSSION

Strand: It seems to me that the quoted parallaxes in the paper are in complete agreement, when the accuracy of each is considered. I doubt that much improvement in your mean value can be obtained.