formed for a number of CP stars. Most of the concerned spectra have their resonance lines in this range. However, line identification is generally hampered by the high density of competing transitions.

Fuhrmann devoted special interest to the well-known CP2 star HR 465, while others like HR 7775, HR 4072, $\varkappa$ Cnc, α2CVn, HD 101065, as well as their "normal" congeners π Cet, ν Cap and Vega were preferably used for comparison purposes. The spectra show a huge number of absorption lines, most of which belong to FeII and CrII. Other elements – like MgII or SiII – have only few, but strong transitions. In the spectra of the CP2 star α2CVn a remarkable number of ions with $Z < 20$ is not well pronounced. This is most obvious in the case of neutral and ionized carbon.

As far as the Rare Earth elements are concerned there are identifications for some second spectra (e.g. HoII, GdII, ...) in the tracings of HD 101065 – Przybylski's star. The spectra of the somewhat hotter HR 465, however, show only marginal contributions from this group of elements. IUE spectra are well suited to show the definite presence of heavy elements like platinum and mercury, as well as the overabundances proposed from optical spectra. Additionally, absorption lines of BiII are observable. There is also strong evidence for transitions due to gold (AuII).

In the *visible*, Gerbaldi and Faraggiana have been extending the investigation of abundances to elements not easily observable with photographic plates. They have derived intriguing results from observations of the neutral lithium resonance line at λ 6707 now easily accessible with modern detectors. The first observations made by them at ESO with CES and Reticon of the LiI 6707 line in cool Ap stars, raised several problems since the feature at this wavelength shows an asymmetric profile different from star to star and an intensity which is not related to the atmospheric parameters of the stars. Surprisingly, the only rough relation detected was that between the equivalent width of λ 6707 and the number of other, mainly unidentified lines present in this spectral range (Gerbaldi, Faraggiana, 1986). Subsequent observations at the Observatoire de Haute-Provence, complementary to those performed at ESO, indicate that a line of another element, so far unidentified, is present at a wavelength very close to the Li line.

Spectroscopic studies of HgMn (CP3) stars were carried out by Schneider (1986), who showed that more than 60 per cent of these stars are binaries. Using new observations he raises this value to more than 70 per cent. This fact puts the CP3 group close to the CP1 (Am) stars, in contrast to the CP2 stars with a binary frequency of only about 30 per cent. The CP3 stars show a concentration towards circular orbits for short periods and a lack of periods less than two days. Stars with periods less than 10 days tend to synchronized rotation. They are all slow rotators with *v·sini* of about 30 km/s.

Abundance analysis of some CP3 stars were carried out by Ansari who carefully studied the effect of rotational broadening of spectral lines on the derived abundance values.

References

Abt, H.A.: 1979, *Astrophys. J.* **230,** 485.
Baade, D., Weiss, W.W.: 1987, *Astron. Astrophys. Suppl.* **67,** 147.
Bidelman, W.P., MacConnell, D.J.: 1973, *Astron. J.* **78,** 687.
Catalano, F.A., Renson, P.: 1984, *Astron. Astrophys. Suppl. Ser.* **55,** 371.
Catalano, F.A., Renson, P.: 1988, *Astron. Astrophys. Suppl. Ser.* **72,** 1.
Didelon, P.: 1987, *The Messenger* **49,** 5.
Gerbaldi, M., Faraggiana, R.: 1986, *Astron. Astrophys.* **158,** 200.
Maitzen, H.M.: 1976, *Astron. Astrophys.* **51,** 223.
Maitzen, H.M.: 1981, *Astron. Astrophys.* **96,** 151.
Maitzen, H.M., Schneider, H., Weiss, W.W.: 1988, *Astron. Astrophys. Suppl. Ser.* **75,** 391.
Maitzen, H.M., Vogt, N.: 1983, *Astron. Astrophys.* **123,** 48.
Manfroid, J., Mathys, G.: 1985, *Astron. Astrophys. Suppl. Ser.* **59,** 429.
Manfroid, J., Mathys, G.: 1986, *Astron. Astrophys. Suppl. Ser.* **64,** 9.
Mathys, G., Manfroid, J.: 1986, *Astron. Astrophys. Suppl. Ser.* **60,** 17.
Mathys, G., Manfroid, J., Renson, P.: 1986, *Astron. Astrophys. Suppl. Ser.* **63,** 403.
North, P.: 1984, *Astron. Astrophys. Suppl. Ser.* **55,** 259.
North, P.: 1987, *Astron. Astrophys. Suppl. Ser.* **69,** 371.
Robinson, R.D.: 1980, *Astrophys. J.* **239,** 961.
Schneider, H.: 1981, *Astron. Astrophys. Suppl. Ser.* **44,** 137.
Schneider, H.: 1986, "Upper Main Sequence Stars with Anomalous Abundances", IAU-Coll. No. 90, eds. C.R. Cowley et al., p. 205.
Schneider, H.: 1987, *Hvar Obs. Bull.* **11,** 29.
Schneider, H., Weiss, W.W.: 1986, *Mon. Not. Roy. Astr. Soc.* **215,** 77.
Schneider, H., Weiss, W.W.: 1989, *Astron. Astrophys.*, in press.
Weiss, W.W., Kreidl, T.J.: 1980, *Astron. Astrophys.* **81,** 59.
Weiss, W.W., Schneider, H.: 1984, *Astron. Astrophys.* **135,** 148.
Waelkens, Ch., Rufener, F.: 1985, *Astron. Astrophys.* **152,** 6.

AK Scorpii: A New Pre-Main-Sequence Spectroscopic Binary

J. ANDERSEN, Copenhagen University Observatory, Denmark, and Center for Astrophysics, Cambridge, Mass., USA
H. LINDGREN, ESO
M.L. HAZEN, Center for Astrophysics, Cambridge, Mass., USA
M. MAYOR, Observatoire de Genève, Switzerland

While we know that perhaps ~25% of normal main-sequence stars are spectroscopic binaries, very few of their progenitor systems have yet been detected among (low-mass) pre-main-sequence stars: Mathieu's (1988) review at the recent IAU General Assembly lists only 11, and for only three had orbits been published at that time. This meagre yield must be due mainly to selection effects mitigating against the discovery of pre-main-sequence binaries. These stars are intrinsically faint and generally found in highly obscured regions, so systematic and accurate radial-velocity observations were impossible until the advent of efficient cross-correlation techniques. Due to their importance for the understanding of star formation processes in general, pre-main-sequence binaries are now being searched for very actively, and the sample will no doubt increase sharply over the next few years. We would like

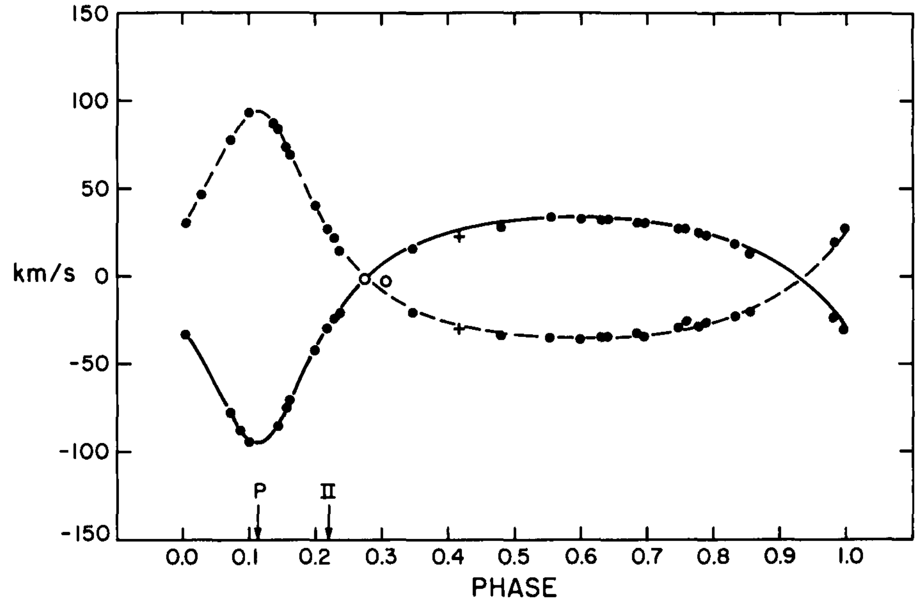

Figure 1: *Spectroscopic orbits for AK Sco. Phases are counted from a hypothetical primary eclipse; the phases of secondary eclipse (II) and periastron (P) are indicated. Cross: coudé spectrum; dots: CORAVEL observations; circles: single-lined CORAVEL observations, not used in the solution.*

to share with readers some of the fun we have had with one of these new systems, AK Sco (full details will appear in *Astron. Astrophys.*).

AK Scorpii: Classical or "Naked" T Tauri Star?

AK Scorpii is an 8th magnitude mid-F type variable star projected on the southern outskirts of the Sco-Cen association. Herbig and Rao (1972) found it to have a strong Li*I* line at 6707 Å as well as strong Hα emission with a central reversal, showing it to be very young. It shares its large-amplitude light variations and infrared excess with the "classical" T Tauri stars, but the absence of emission lines other than Hα makes its optical spectrum more similar to those of the "naked" T Tauri stars (Walter et al. 1988), which may owe their lack of conspicuous circumstellar matter to the presence of a binary companion.

A coudé spectrum of AK Sco taken with the ESO 1.5-m telescope in May 1986 showed it to be a double-lined spectroscopic binary with approximately equal components. As AK Sco had once been considered to be an eclipsing binary, we hoped that it would be possible to determine the masses, radii, luminosities, and composition of its components. Comparing them with stellar evolution models, age, helium abundance, and other interesting parameters might then be determined.

Orbital Parameters

We therefore observed AK Sco in 1986–87 with CORAVEL on the Danish 1.5-m telescope on La Silla and determined its spectroscopic orbit as shown in Figure 1. The orbital eccentricity is $e = 0.47$, the period is 13.6093 days, both minimum masses ($m\sin^3 i$) are 1.06 ± 0.01 solar masses, and the orbital semi-axis major is about 31 solar radii. The origin of the phases plotted in Figure 1 is where a primary eclipse would occur; the phases of a possible secondary eclipse and of periastron passage are also indicated.

Unless we can determine the inclination of the orbit, we cannot find the absolute masses of its components, and unless the system eclipses, we cannot directly determine their radii either. Now that we know when to look for eclipses in AK Sco, do they in fact occur? We searched for the answer in a nearby "gold mine", the vast Harvard plate collection going back about a century. And yes indeed, it holds more than 2,000 plates on which AK Sco can be measured! The period 1910–12 had a particularly dense coverage of plates (83), so we estimated the brightness of AK Sco on these plates and plotted the resulting magnitudes against spectroscopic phase. Alas – no correlation whatever! So, while shallow eclipses might still be discovered by careful photoelectric photometry, most of the ~1-magnitude variations we do see must have some other origin, probably in nearby dust clouds.

A Model of the Binary

If we cannot actually determine the masses and radii of AK Sco, what might they reasonably be? Spectroscopically, the components of AK Sco look just like F5 main-sequence stars. Popper's (1980) review indicates that reasonable ZAMS masses and radii are 1.3 $M_\odot$ and 1.26 $R_\odot$; the orbital inclination is then $i \approx 69°$. If the orbital and axial rotation periods are equal, we expect to measure rotational velocities of $v\sin i \approx 4$ km s^{-1}. However, due to tidal effects, convective stars in eccentric systems are expected to rotate faster than this, about 2.5 times faster for the orbital parameters of AK Sco. This revises our prediction to $v\sin i \approx 11$ km s^{-1} for both stars.

What we actually measure from the width of the CORAVEL cross-correlation profiles is $v\sin i = 19 \pm 1$ km s^{-1}, so the stars either spin faster or have larger radii than first assumed. Consideration of the time-scales for synchronization suggests that the former is unlikely, especially since the stars were probably even larger and easier to synchronize when they were younger. Hence, the stars in AK Sco are probably well above the ZAMS.

Published models of pre-main-sequence evolution are relatively old and still largely untested, so we searched instead in Popper's (1980) review for a real, suitably evolved binary as a "role model" for AK Sco. The F5-type system RZ Cha (1.5 $M_\odot$, 2.2 $R_\odot$), an old friend of ours from early days on La Silla, seems to fit the bill (and the rotation) for an inclination of $i \approx 63°$. In this model, the stars still narrowly fail to eclipse. Assuming an effective temperature of 6,500 K, AK Sco is about 200 pc distant, consistent with membership in the Sco-Cen association.

The Environment of AK Sco

Although, spectroscopically, AK Sco itself looks rather ordinary, it appears to live in quite a lively place, judging by its irregular variability, which seems too large (≈1 mag) to be reasonably explained by star spot activity. The UBVRI photometry of Kilkenny et al. (1985) shows that the star gets redder as it gets fainter, with a ratio of total to selective absorption $R = A_v\, E(B-V) \approx 4.6$. This is much higher than in ordinary interstellar matter (R = 3), as often occurs in circumstellar dust and is usually considered due to a relatively large grain size.

There is additional evidence for circumstellar dust from infrared photometry of AK Sco: Figure 2 shows the energy distribution derived from the UBVRIJHKL photometry by Kilkenny et al. (1985) and the 12, 25, and 60 μm IRAS fluxes. The fluxes have been corrected for an average amount of extinction. Three black-body curves have been fit to the data. In addition to the flux from AK Sco itself, they show the

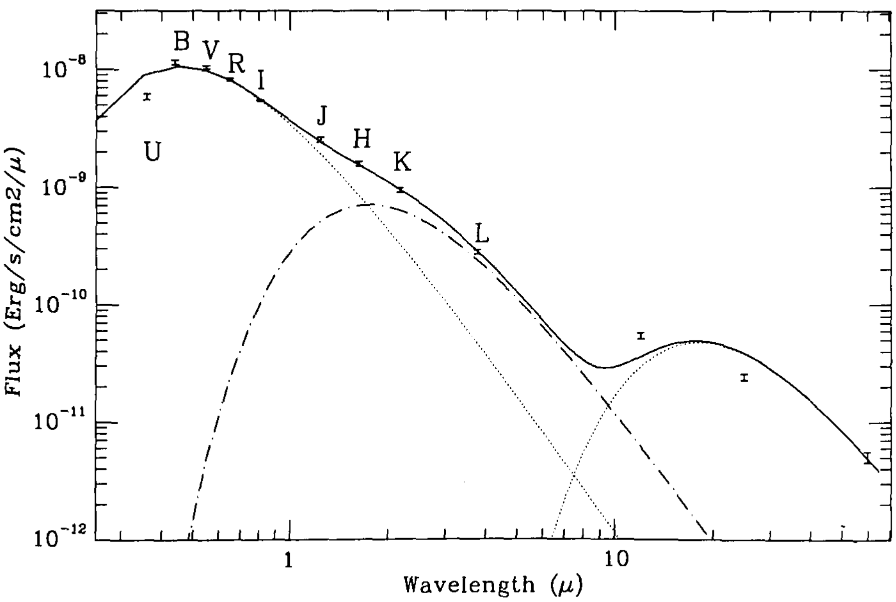

Figure 2: *Blackbody fit to the optical-infrared energy distribution of AK Sco. The three curves correspond to temperatures of 6,500, 1,600, and 160 K.*

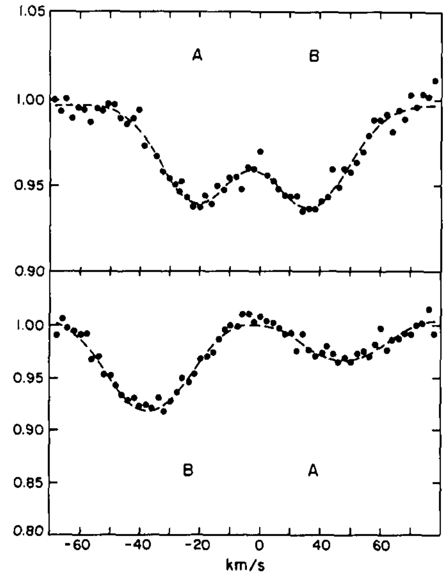

Figure 3: *Cross-correlation profiles for two CORAVEL observations (phases 0^P.23 and 0^P.48), separated by only 1.2 orbital cycles.*

presence of two dust components at approximate temperatures of 1,600 K and 160 K. The total energy emitted in these components amount to about half of that received from AK Sco, roughly consistent with the light loss at intermediate brightness levels.

Size of the Dust Clouds

We can obtain an order-of-magnitude estimate of the sizes of the two dust clouds by requiring that the energy emitted by a grain be equal to that it absorbs from the star. The resulting distance from AK Sco is then 25–50 solar radii for the hot dust, and about 10 AU – the orbital radius of Saturn – for the cool component. Thus, the hot dust cloud has essentially the same size as the binary orbit and presumably consists of material left over from its formation, while the cool dust cloud has the size of a typical planetary system (assuming that the one in which we live is typical!).

The CORAVEL data contain one striking piece of information supporting this picture: The luminosity ratio between the two components, as measured by the equivalent widths of their cross-correlation dips, changes up or down by up to a factor two from one orbital cycle to the next (Fig. 3). Again, star spots are unlikely to cause such large variations; even if they did, they should significantly distort the profiles, which is not seen. Moreover, the variations are largest when the stars are farthest apart.

The simplest interpretation appears to be that we are seeing the effect of inhomogeneities in the hot dust cloud not only *in front of,* but probably also *between* the stars. This opens an exciting possibility for mapping out the dust clouds near the system, in the following way: At any given time, we know the precise position of both stars in their orbit. Photometry tells us the *total* obscuration in front of the two stars, and a simultaneous CORAVEL or other spectroscopic observation can give us the *ratio* of the light losses for each component. We can therefore compute, point by point, the amount of dust in front of each star as it goes through an orbital cycle, and draw a map of the dust clouds and eventually of their motions. Perhaps one could even measure the velocities of circumstellar lines at high resolution?

Thus, AK Sco no doubt has lots more fun in store for the observers: There are eclipses to look for and dust clouds to map. Spectroscopically, one can investigate the Li and other element abundances, indicators of chromospheric activity, and signatures of possible magnetic fields: AK Sco is within reach of the CES. And perhaps, one day, it will be possible to resolve the system interferometrically (with the VLT?), although the angular separation is only of the order of 1 mas; its absolute masses and distance could then be determined even if eclipses should not occur.

References

Herbig, G.H., Rao, N.K.: 1972, *Astrophys. J.* **174,** 401.
Kilkenny, D., et al.: 1985, *South Afr. Astron. Obs. Circ.* No. **9,** 55.
Mathieu, R.D.: 1988, *Highlights of Astronomy,* Vol. **8,** in press.
Popper, D.M.: 1980, *Ann. Rev. Astron. Astrophys.* **18,** 115.
Walter, F.M., et al.: 1988, *Astron. J.,* **96,** 297.

Supershells and Galactic Fountains

B. M. SHUSTOV[1]*, Astronomical Council, Moscow, USSR*

In the gaseous disk of our Galaxy as well as in other galaxies, HI structures (shells, bubbles, holes, etc.) on scales of 0.1–1 kpc are recognized to be common features; see e.g. the comprehensive review by Tenorio-Tagle and Bodenheimer (1988). The larger ones are usually named with the prefix "super". The estimated energies which are required to produce such large objects are high – up to some 10^{54} erg. These energetic events must exert a significant influence upon the gaseous galactic disk and corona.

In our Galaxy, the disk and the corona are believed to be evolutionarily coupled in a recycling process, although there is no common opinion about details of the

[1] Visiting astronomer, ESO – Garching.