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# THE DETECTION OF NARROW ABSORPTION COMPONENTS (NACS) IN FX Lib = 48 Lib[1]

We report on observations of optical shell lines in FX Lib = 48 Lib = HR 5941 (B3IV e-sh, $v \sin i$ = 400 km s$^{-1}$), a well-known equatorial shell star studied since decades (see Guo 1994 for further references). We have detected in some of these shell lines satellite absorption features which, though quite conspicuous at sufficiently high resolution, apparently have never been observed before.

The observations were carried out in three runs in 1995: March 07–10 (period I) at the 1.4m Coudé Auxiliary Telescope of ESO at La Silla/Chile (observer: RWH). Attached to the telescope was the Coudé Echelle Spectrograph CES, operated with the Long Camera, and a UV-coated LORAL 2048 × 2048 CCD with 15$\mu$ pixel size. The effective resolving power as determined from the width of thorium emission lines was $R = 50\,000 - 120\,000$.

The second run (period II) was on April 10–18 (observer: RWH) at the 1.52m telescope of the Observatoire de Haute Provence at St. Michel/France, equipped with the Coudé spectrograph *Aurélie* and a one-column CCD (double barette Thomson) with 2048 pixels of 13 $\mu$ size each. The effective resolving power was $R \approx 45\,000$.

The third run (period III) was on April 26 – May 01, 1995 (observer: MV), again at the OHP 1.52m telescope with the same instrumentation.

All data were reduced in the standard way and binned on a heliocentric radial velocity scale ($V_{\rm hc}$).

We have measured the spectral region of three important shell lines in 48 Lib: H$\alpha$, Fe II $\lambda$5317 (together with several other fainter Fe II lines including the $\lambda$5276 feature), and Na I$-D_1, D_2$ including the He I $\lambda$5876 line.

We have covered by our extensive spectroscopic survey timescales between hours (in series of integrations with a single exposure time of 15–30 minutes) and two months (gap between periods I and III).

The H$\alpha$ profile (Figure 1a) consists of two asymmetric emission humps with ratio $V/R$ = (2.65−1)/(4.22−1) = 0.51 (ratio of continuum-subtracted fluxes in violet peak and red peak, resp.), separated by a deep central shell trough of residual intensity $0.08F_{\rm c}$. There is no evidence for any small-scale fine-structure in the line profile, contrary to the observation of Guo (1994) who reported moving bumps at H$\alpha$ in April 1994.

The Fe II lines offer a completely different picture. One such $\lambda$5317 measurement from period I is shown in Figure 1b, a larger subset on an extended scale in Figure 1c. The line structure is dominated by an asymmetric blueshifted shell feature of typical width (FWHM) = 90 km s$^{-1}$, centred at $V_{\rm hc}$ = −52 km s$^{-1}$. This dominant absorption feature is flanked by faint extended emission on its red side. More conspicuous, however, are

[1]Based on observations obtained at the European Southern Observatory, La Silla, Chile, and at the Observatoire de Haute-Provence (CNRS), St. Michel, France

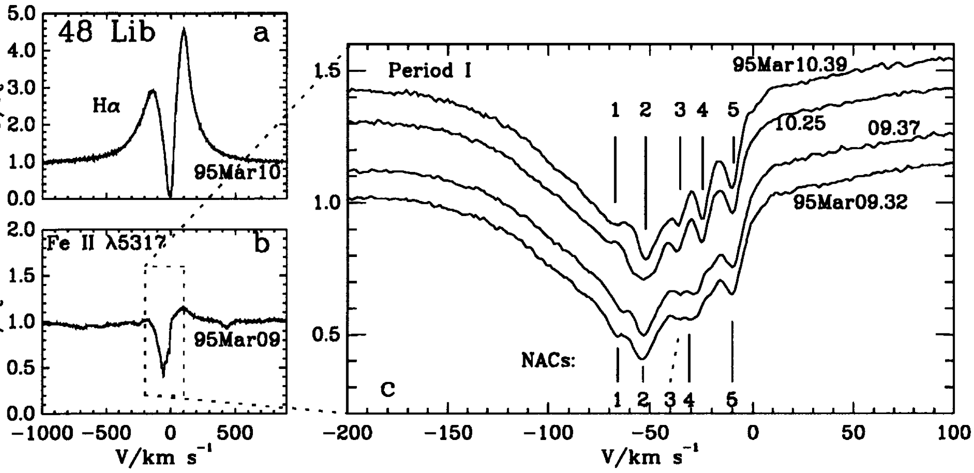


**Figure 1a**. Hα profile of 48 Lib. **1b**: Fe II λ5317 profile. **1c**: Close-up of some Fe II profiles. The NACs are numbered 1...5. We show four spectra out of 9 measured in period I.

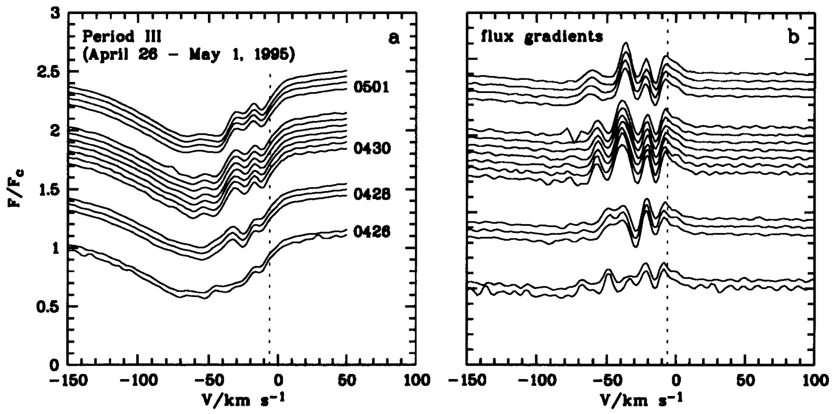


**Figure 2**. Close-up of our Fe II λ5317 data from period III. **2a**: Line profiles. **2b**: normalized flux gradients $(\Delta F/\Delta v)/F$ (where $F$ denotes the flux and $v$ the radial velocity), chosen to enhance the visibility of the NACs. The dotted line marks the stellar rest velocity.

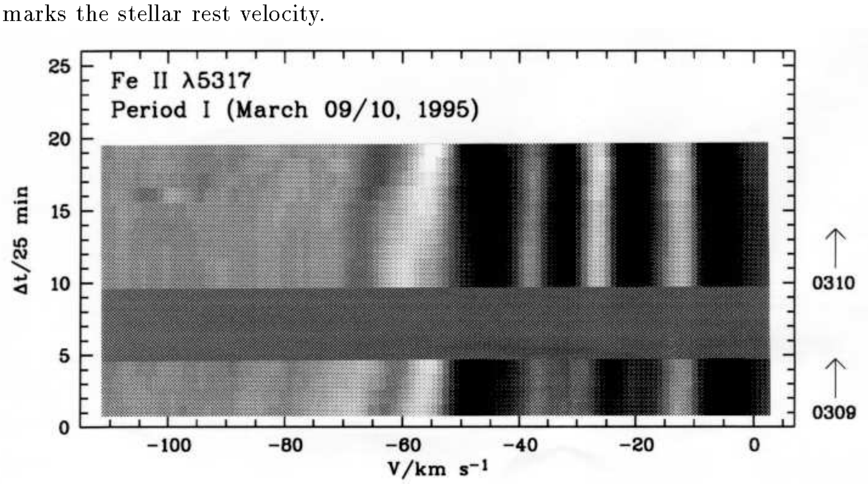


**Figure 3**. Gray-scaled plot of the NAC evolution during period I. We show the flux gradient on a linear timescale with one time-step $\Delta t$ equivalent to 25 minutes. Lags between actual measurements are filled by interpolation. The total time interval represented here is 100 min for March 9, and about 3 hours for March 10.

several subordinate absorptions embedded into the central part of the shell trough and its low-velocity flank (Figure 1c). These will be called *narrow absorption components* (NACs) in the following.

They are characterized by the following properties:

*Number.* In the spectra from period I, we count 5 NACs, while in the later periods only 4 are visible at any time with certainty (Figure 2). They only show up in the subrange $V_{\rm hc}$ = –80 and –10 km s$^{-1}$ of the shell trough.

*Width.* Their width decreases from the bluemost NAC to the that one with the smallest velocity. Typical values are about 10 km s$^{-1}$ for the bluemost NAC. The NAC with lowest velocity has width $\Delta V$= 4 km s$^{-1}$ (FWHM) in the CAT spectra with highest resolution (period I, $R$ = 120 000 or instrumental FWHM = 2.5 km s$^{-1}$) and are well resolved. In periods II and III, we measure $\Delta V\approx$ 7 km s$^{-1}$ which corresponds to the instrumental FWHM, i.e. the NACs are unresolved then.

*Depth.* The depth of the deepest resolved NACs from period I is about 0.11–0.13 continuum units.

*Time variability.* In those nights with multiple exposure we find slow variability of the NAC features both in RV and depth on a timescale of hours (see Figure 3). RV changes, if present, are always such that a feature moves *from larger to smaller blueshifted velocities.* The bluemost NACs move fastest, while those with smallest radial velocity are stationary. Most rapid changes observed occur in period I, with $\geq$ 20 km s$^{-1}$ per day. “Acceleration” is generally lower at later times. This rate is large enough to modify the overall appearance of the NACs from night to night considerably.

Beyond any doubt, the NACs are true spectroscopic structures rather than noise since their depth is considerable. Moreover we find the same features, with the same RV and relative depths, in the Fe II $\lambda$5276 line, as well as at Na I. In the latter line, the NACs are even deeper than at Fe II.

In the stellar He I profile, neither broad shell feature nor NACs are visible.

Due to their depth and to the fact that no small-scale structure is visible in He I, we conclude that the NACs have nothing to do with profile fluctuations induced by non-radial pulsations (e.g., Baade & Balona, 1994). Furthermore their relatively small radial velocity, their drift to *smaller* velocities, their extreme narrowness and their occurrence in optical lines of species with low ionization degree (rather than in UV lines of high ionization stages) clearly distinguishes them from the well-known DACs in stellar wind lines (Prinja 1994, Henrichs et al. 1994).

There are only a few earlier observations of 48 Lib which show related behaviour: Aydin & Faraggiana (1978) report night-to-night variability in the Na I-D lines in 1970–74. Their photographic material, however, has much lower S/N quality than ours. Guo (1994) reports H$\alpha$ variability in 1994, with not fully resolved spectra of unknown reliability. Our own overview of earlier H$\alpha$ and Fe II data in 48 Lib (Hanuschik et al., 1995) does not show any such fine structure in 1987–1993. In absence of any reliable previous observation of NACs we believe that we have found a new spectroscopic phenomenon in Be star disks which occurs only rarely and transiently.

The NACs are likely to be caused by regions of higher density, or lower temperature, as compared to the surrounding gas. These regions must be very small in comparison to the disk dimensions, $\Delta R/R_{\rm d} \ll 1$, since their observed RV width of 4–10 km s$^{-1}$ is only slightly more than the *thermal width* of iron at 10$^4$ K (2.9 km s$^{-1}$ FWHM), and much less than the RV width of the shell volume (about 90 km s$^{-1}$).

However, if the NACs were simply caused by local clumps moving across the stellar disk in elliptical Keplerian orbits, their observed RV change during a night would be too small (typical time scale for crossing the shell volume at 5 stellar radii is half a day). It seems more likely that they are due to higher-order components of the density wave which causes the cyclically changing line profile asymmetries in 48 Lib (see Hanuschik et al. 1995).

The shell volume mainly traces the *radial component* of the velocity field in a small part of the circumstellar disk (Hanuschik, 1995). The detection of NACs in 48 Lib therefore provides highly valuable, otherwise unaccessible information about the structure of the disk in 48 Lib. We strongly urge other observers with access to a medium-sized telescope with Coudé spectrograph equipment to continue observations of these conspicuous features, which are best observable at Fe II $\lambda$5317.

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