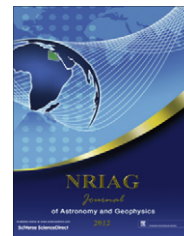




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An overview investigation of Be/Shell stars

S.M. Saad ^{*}, M.A. Hamdy, M.S. Abolazm

National Research Institute of Astronomy and Geophysics, Helwan, Egypt

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Abstract Be/Shell stars as hot massive type stars are one of the most important stellar groups through the global universe contents. They are important sources of UV photons, so they are playing an important role in the heating and ionizing the interstellar environment up to few hundred parsecs. We here represent an overview investigation of the Be/Shell stars using the last decades “ground and space” observations with high sensitivity, high signal to noise ratio and the new applied techniques in addition to the recent developments of advanced models.

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Introduction

The emission line stars has been defined phenomenologically. Their defining property is the presence of Balmer emission, observed at least once during their documented history. The first distinct group of hot emission-line stars were Be stars. Be/Shell stars are a subgroup of B type stars. The optical spectra of B-type stars predominantly contain absorption lines of hydrogen and neutral helium (HeI), which means that they have an effective temperature range of between 10,000 K and 30,000 K. Main sequence luminosities are between 10^2 and $10^4 L_{\odot}$, with respective masses and radii of between $3.4\text{--}17.5 M_{\odot}$ and $2.8\text{--}7.7 R_{\odot}$ Schmidt-Kaler (1982). Other spectral features may include lines from CaII, CII, CIII, NII, NIII, OII, SiII, SiIV, and MgII species.

The variability nature of the Be phenomenon or at least some of the observed variations of Be stars still remain myste-

rious. Studies of Be stars in each of the accessible wavelength domains have revealed unique information: UV studies have emphasized the duality between Balmer emission line and the star's radiative wind flux. X-ray analysis have drawn a distinction between the high energy flux emitted from interacting binaries and most isolated Be stars. Infrared and polarimetric studies have explored the shape and extent of circumstellar disks. Optical studies have spatially imaged their disks, while temporal studies have suggested the non-radial pulsation modes probably exist in some stars. They have also established the reality of very rapid changes in spectra and light which so far have eluded interpretation, Balona (2000).

Early observations of Be and Shell stars

The early spectroscopic observations of H α with objective-prism plates resulted in the discovery of hundreds of new Be stars and led to Mount Wilson Catalog of Be stars published in four parts. All available studies led to the conclusion that except in the binary stars and perhaps in close groups and a few galactic clusters the orientation of the rotational axis have a random distribution, hence, ever though it is impossible to derive the equatorial velocity of rotation of a particular star but only its projection, $v \sin i$. Statistical study for that values indicate that the Be stars tend to be rapidly rotating objects

^{*} Corresponding author. Tel.: +20 02 2556 0046.

E-mail address: somaya11@yahoo.com (S.M. Saad).

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whose and their equatorial velocity may be of the order of 200 km s^{-1} , or in few cases in excess of this value.

For the Be stars that possess shell spectra of the absorption type, most of them would lie in velocity range of $150\text{--}200 \text{ km s}^{-1}$. The probable mechanism of emission ring formation has been described by Struve as follows: “It is tempting to suggest that the rapidly rotating B stars are unstable at their equators and that they are losing mass through rotational breakup.

In 1950 Merrill turn the attention to a subclass of Be stars known as shell stars. Term shell stars has special meaning when applied to B-type stars, they are stars with spectra showing emission wings in one or more of hydrogen lines, sharp hydrogen absorption cores plus narrow absorption lines of ionized metals, and weak diffuse absorption lines of neutral helium. Bright examples of shell stars defined in this way include γ Cas, ϕ Per, ψ Per Pleione (28 Tauri), ζ Tau and 48 Lib. It should be emphasized that shell stars just represent one phase of the Be phenomenon, so shell stars are nothing else than Be stars viewed under specific inclination angle. The shell phenomenon is produced most probably by equatorial gaseous disks or rings whose planes are oriented approximately close to the line of sight as shown in Fig. 1. While all B-type shell stars are Be stars, not all Be stars show shell spectra as defined above. Some Be stars never show shell spectra (because of the inclination of the rotation axis), while the shell spectrum comes and goes in others like Pleione, Nemravová et al. (2010). Fig. 2 displays a series of the $H\alpha$ profiles over the time interval of the formation of a new shell.

Early work of Merrill and Struve during the last decades led to better understanding of the physics of the shells, which were recognized to be analogous to the atmospheres of supergiant stars, they are cooler and less dense than the atmosphere of the underlying B-type stars.

Variability with different time scales

The most important feature of Be stars is its variability, they are spectral and photometric variables on timescales that may range from minutes to years. The Be stars in which very little or no variations have been observed yet are suspected to be variable on much longer timescales. Lastly, the variations may be periodic or episodically, and more types of them may occur superimposed at the same time. This is what makes mod-

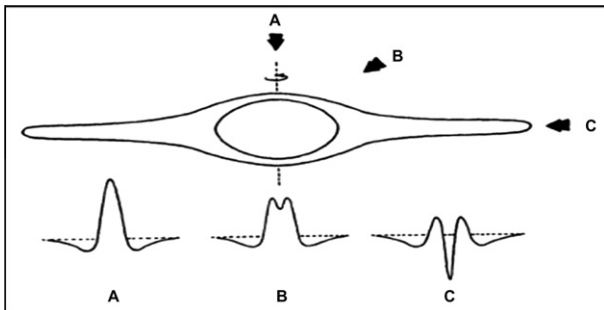


Fig. 1 Struve (1931) proposed a Be star model envelope, showing how the observed line profiles depended on viewing angle. The three position are, Pole on (A), with inclination angle on line of sight (B) and equator on (C).

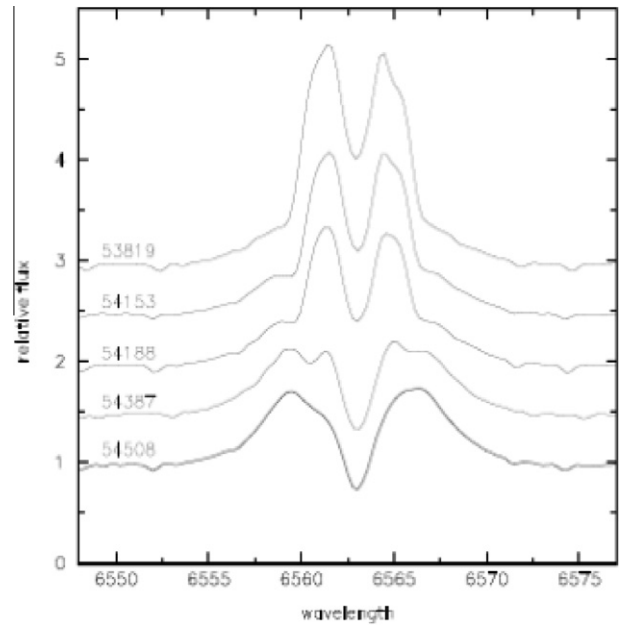


Fig. 2 A series of the $H\alpha$ profiles over the time interval of the formation of a new shell. Spectra are shown and the time runs from the top to the bottom. One can see how the new broad emission gradually rises in intensity and how its blending with the decaying previous double (but narrower) emission creates a profile with four emission peaks for some time. Then the new emission gets so strong that it merges with the original one (after Nemravová et al., 2010).

eling of processes in Be stars so difficult, and why many questions have not been solved yet. Periodicity of phenomena in Be stars is hard to define. In some cases the variations reach from fast to very slow, that a repetition of the occurrence hasn't been observed yet, thus it is impossible to determine if the phenomenon is periodic or not.

The violet-to-red peak intensity ratio (V/R) is one of the most striking features of the emission lines, which give a measure of the line asymmetry. Usually, the V/R ratio behaves quasi-periodic in terms of years. Be stars may change from stable $V = R$ to V/R variability and back Porter and Rivinius (2003). Hanuschik et al. (1996) supposed that the majority of Be stars have emission lines with stable and equal V and R peaks, compared to one-third of them which show cyclic variation of V/R.

On average, periods of V/R variations are usually about 7 years (Mennickent and Vogt (1991) and are connected with long-term variations. In some particular cases they display different successive phases of activity, as reported about 59 Cyg by Harmanec et al. (2002) or about ζ Tau by Hubert et al. (1982). For several other stars, V/R variations are quasi-periodic on a long-time scale, like e.g., γ Cas with a period of 25 years and κ CMa with a period of 22 years, Mennickent and Vogt (1991). Using high time-resolution spectra, V/R are also found to vary on a rapid scale they found erratic or quasi-periodic variations, as reported also for β CMi, Mennickent and Vogt (1991). In most cases with V/R variations, long-term variations are found to be superimposed with a short ones, which is sometimes misinterpreted as irregular variations. In a particular case of 59 Cyg, two significant periods have been

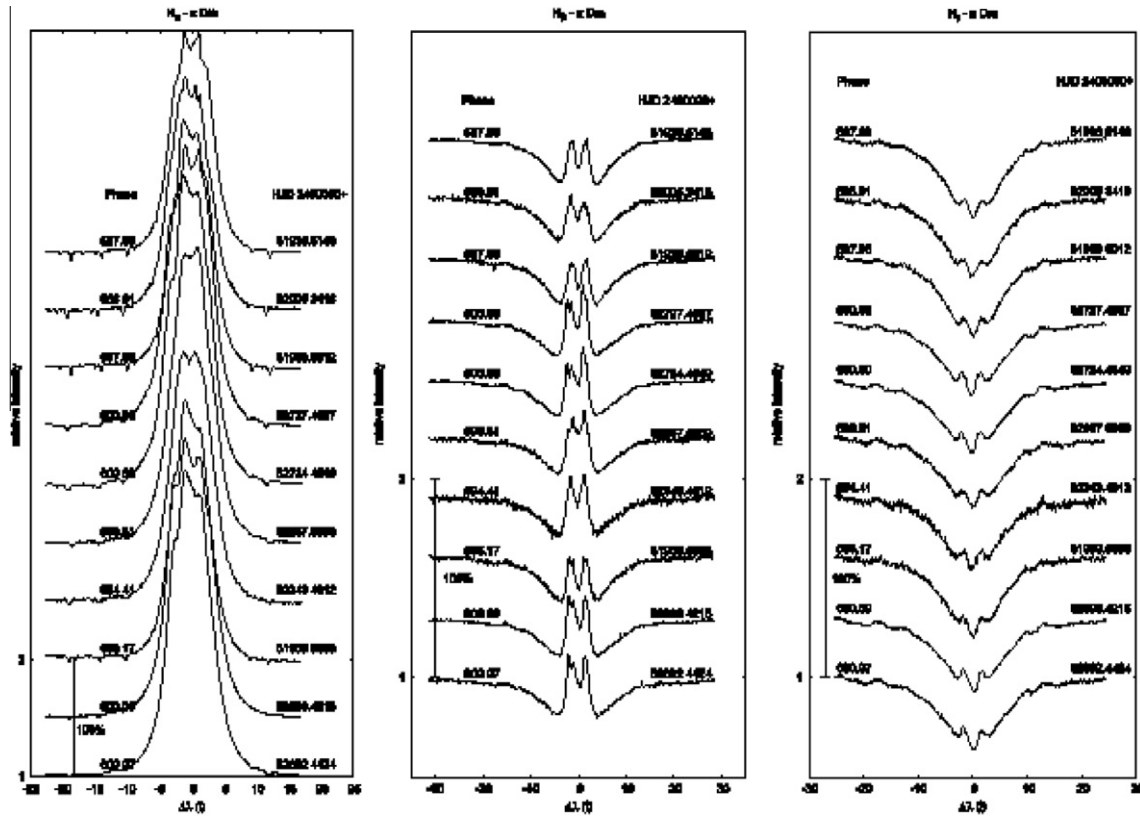


Fig. 3 K Dra, variations of the double-emission peaks for different phases during one period. Left panel: for H α , middle panel: for H β , and right panel: for H γ (Saad and Kubat, 2010).

obtained. The first one, 28.1971d, which follows the orbital period of the binary system, and another long one of 2-years, which is connected with the formation of the new Be envelope, Harmanec et al. (2002).

Saad et al. (2004) analyzed more than 100 spectra around H α region and concluded that for κ Dra, V/R variations is folded with a 61.51d period (orbital period), and behave independently of its long-term variation. Other similar systems, like 4 Her, where V/R variations follow its orbital ones with a 46.1921d period, Koubsky et al. (1997), 88 Her, which varies with a 86.7221d period, Doazan et al. (1985), and Φ Per with a period 126.696d Poeckert (1981) are denoted as V/R phase locked with their orbital period. With respect to the H α , V/R asymmetry of κ Dra, Arsenijevic et al. (1994) noted that, according to the polarization results, the internal layers of the envelope have an axial symmetry, but the outer H α emitting region, affected by the presence of the companion, is probably associated with non-axi symmetric external layers. Various postulations and models have been devoted to explain long-term V/R variations. Struve (1931) suggested an elliptical-ring model (which is the geometrical one) which was elaborated by McLaughlin (1961). Further modifications were done by Huang (1973, 1975), who attributed the V/R variations to the apsidal motion of an elliptical ring in which emitting atoms revolve around the star according to the Kepler law. The binary model proposed by Kriz and Harmanec (1975) is another view, where the companion star deforms the disk into the elliptical one through tidal interactions.

More recently, Kato (1983) and Okazaki (1991) explained the long-term V/R variations by one-armed global oscillations,

where a thin non-self graviton Keplerian disk is distorted through a density wave. Let us consider once more this view in κ Dra, the emission structure is originating in the envelope, however the binary star is sitting somewhere inside. Therefore, it affects the innermost parts of the surrounding structure. This part of the disk rotates most rapidly. Due to the Roche lobe geometry, there is a high asymmetry in the outer parts of the disk, which therefore reflect an asymmetry between the red and blue components (i.e. V/R variations), alternating around the orbit. In κ Dra, binarity seems to play the most important role in the line asymmetry, which explores the V/R changes and more further explain its phase locked variations with $p = 61.5549$ d period, Saad and Kubat (2010). Fig. 3 illustrates the variations of the double-emission peaks for different phases during one period, for H α , H β , and H γ . While Fig. 4 represents the long-term distribution of the RVs of V and R peaks, the periodogram of the RVs residuals of violet and red peak after prewhitening for long term variations.

Be/Shell investigation with old and new techniques

The observations of Be/Shell stars and long time monitoring even with old techniques left us a great legacy of photometric, spectroscopic observations and huge amount of information through different archives and libraries. With the technical revolution in the second half of the twenties century, the study of Be/Shell stars has blossomed in a variety of ways in the last decades. Every part of electromagnetic spectrum has seen a revolution in observing techniques. While much of this has been on the ground, recently space-based observations

provided high level of sensitivity and clarity that have revolutionized all fields in astronomy. These observational developments have been supplemented by massive improvements in computing power, allowing for the processing of large amount of astronomical data and theoretical modeling.

Photographic/photometric photometry

Observations of stellar objects using broad band photometry (b.b.p.) started at 1850 without any knowledge of the intensity distribution, because it started 50 years earlier than the spectrophotometry. Human eye was the only means that was known at that time, and visual magnitude covered only one section of the spectrum. Therefore the b.b.p. measurements are called “one color photometry”. With knowing visual magnitudes, very limited information were available.

With the advent of the photographic plate, the photographic methods lead to the two color photometry, because the photographic plate at that time only sensitive in blue and not in yellow as the eye, it was first regarded the observed difference between visual and photographic magnitudes of stars as systematic error in the photographic method.

After many years it was found that the difference was a real physical quantity “Colour Index”. Estimation of the difference in two color were found to be related to the color temperature of the stars. With limitation, the system of two color photometry were used at that time to develop the studies of the individual stars, binaries and star clusters with this methods.

Due to the limitation of the BV system, an urgent need for a new fundamental system arises. The three color photometry was the logical development of two color photometry. It was found that the intensity distribution in stellar spectra differ very much from one region to the other. [Johnson and Morgan \(1953\)](#), were proposed a new fundamental photometric system in ultraviolet, blue and yellow, (UBV) with effective wavelengths 3500 Å, 4350 Å and 5550 Å respectively, known later on as the standard international system.

Then the photoelectric photometry (based on photomultiplier tubes technology) was introduced and were used widely for stellar photometry instead of the photographic plate. Using the calibrated filters sensitive to different specific wavelength regions, many photometric system were created and used in various studies.

Stellar spectroscopy

Due to the low/limited spectral resolution in the first generation of spectrographs, the spectroscopic studies of stars generally and of Be/Shell stars in particular was concentrated in general studies of stellar energy distribution (based on the continuum energy distribution), stellar classification and the measurements of the radial velocity for binaries.

Although several difficulties related to the old observational techniques as well as the low resolution and limited wave length ranges the Astronomers in the first half of the 20th century could obtained and left a very large legacy of recorded data and catalogs. Both the available photometric and spectroscopic observations was used to draw the most important information concerned the characteristics, the variability and the peculiarity of the Be/Shell stars. Planning of long time monitoring of Be/Shell both photometrically and spectroscopically in different

range of spectra keep the variability history for a large number of these stars and still nowadays used.

CCD camera

The development of semiconductor technologies in the second half of the 20th century led to exciting new detector technologies such as photomultiplier tubes and charged-couple devices (CCDs). These devices utilize the photoelectric effect to convert incident photons into a charge that can then be measured and recorded. CCDs have revolutionized astronomy in the last two decades, virtually replacing photography in professional astronomy. The sensitivity and power of CCDs has been adopted to image objects once only obtainable on long photographic exposures on the world's largest telescopes. The peak quantum efficiencies of greater than 90% means that they are much “faster” than photographic emulsions so that the same length exposure will reveal far fainter sources than a photograph. Shorter exposures therefore can often be used so that many more fields can be imaged in a single observing session. Digital read out, low noise and stability helped to obtain high time resolution exposures.

High resolution and long wave range spectrographs

The progress in the investigation of Be/Shell stars during the past decade was enabled using mainly the high-resolution Echelle spectrographs. Such instruments made possible to carry out multi-line studies of line profile (due to the wide wavelength covered range) variations and to search for correlations between photospheric and circumstellar phenomena. Among the most important ones we can list, HEROS (Landessternwarte K onigstuhl, Heidelberg/ESO), FEROS (ESO), MUSCOS (Haute Province Observatory) or GIRAFFE (South African Astronomical Observatory). The broad spectral range, for some of the above listed instruments reaching from the atmospheric UV limit up to the near-IR, and at the same time their medium to high spectral resolution permitted to study phenomena on a basis not possible with high-resolution long-slit spectrographs. At least two new main directions were explored:

- Multi-line studies of line-profile variations (lpv). After the first monitoring of lpv in eighties it was assumed that the variations follow the same variability pattern in all spectral lines. The echelle spectrographs played a decisive role in disproving this assumption and subsequently in explaining the nature of rapid lpv, [Rivinius et al. \(1998, 2003\)](#).
- Correlations between characteristics of absorption lpv and emission-line parameters confirmed a close link between photospheric processes and the formation of circumstellar disks.

Interferometric technique

The first interferometric observations of a Be star were obtained by [Dougherty and Taylor \(1992\)](#). The radio study of ω Per using the very large array “VLA” confirmed that the geometry of the emitting circumstellar region was not spherically symmetric and ω Per's radio emission has an axial ratio

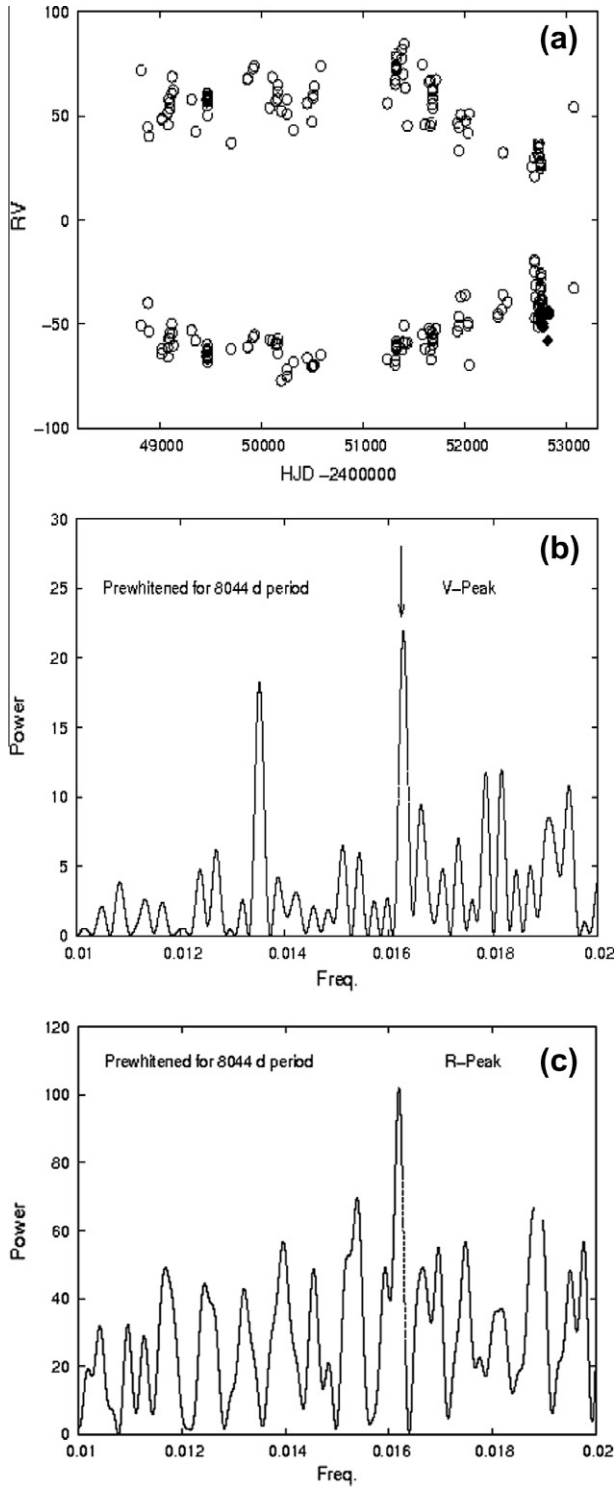


Fig. 4 K Dra, violet and red peaks variations of $H\alpha$ (a): the long-term distribution of the RVs of V and R peaks, (b): the periodogram of the RVs residuals of V peak after prewhitening for long term variations, (c): similar to (b) but for the R peak. The arrow indicates the peaks of the predicted frequencies (Saad and Kubat, 2010).

of < 2 . More recently, optical interferometry has begun to produce results for Be stars, particularly from the (several) groups at Mount Wilson and Observatoire de la Côte d'Azur. The re-

sults from these groups have confirmed the aspherical geometry of the circumstellar emission Quirrenbach et al. (1994, 1997), Stee (1995). Fig. 5 shows $H\alpha$ intensity map of z Tauri, showing the high axial ratio of the circumstellar environment of this shell star. The polarization angle (denoted by the arrow) is perpendicular to the plane of the disk.

Indeed, for those stars that have had the position angle of the disk measured, it lies normally to the continuum polarization angle (Quirrenbach et al., 1997), as expected for scattering models e.g., Brown and McLean (1977) and Wood et al. (1996a, 1996b). Also, the available axial ratio determinations of the envelopes agree well with the inclination estimates from the emission shape.

Several attempts have been made at determining the opening angle of the disk directly from the data: values of 5 and 13 from the statistical studies of Be-shell stars were determined by Porter (1996) and Hanuschik et al. (1996), respectively, and an upper limit of 20 was determined from interferometric observations and spectropolarimetry by Quirrenbach et al. (1997), while Wood et al. (1997) calculate an opening angle of 2.5 for z Tauri from polarization (this technique is sensitive to the inner regions only, which, if the disk flares, may account for the apparent inconsistency with the statistical studies that probe larger disk radii). Hanuschik also finds that the disk flares at large radii; i.e., the opening angle is an increasing function of radius. Yudin (2001) concludes from his statistical analysis that the half-opening angles lie in the range 10–40°.

In summary, interferometric studies have confirmed that the geometry of the circumstellar gas is disk-like and that statistical estimates of opening angles point to a relatively thin disk. The polarization angle is perpendicular to the outer disk plane, which also strongly suggests a disk structure in the inner parts (since these densest regions affect the polarization most), and the observed variation properties are modeled best with a homologous structure from the near-photospheric regions

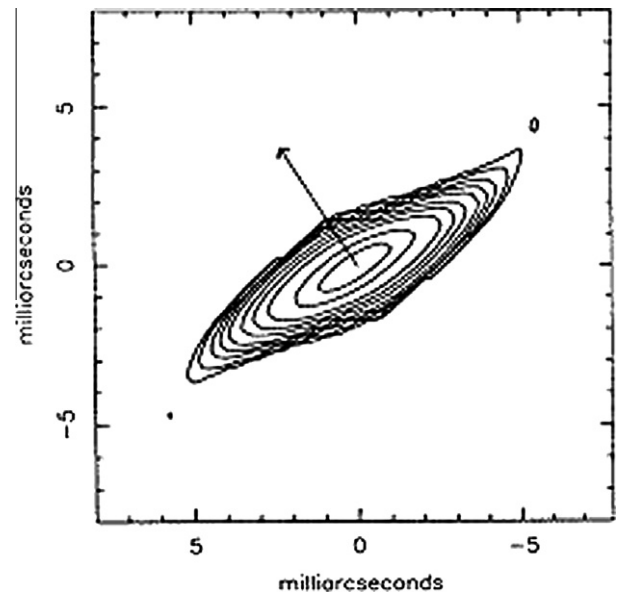


Fig. 5 Reconstructed $H\alpha$ intensity map of z Tauri, showing the high axial ratio of the circumstellar environment of this shell star. The polarization angle (denoted by the arrow) is perpendicular to the plane of the disk (after Quirrenbach et al., 1994).

outward, Rivinius et al. (2001). Fig. 6 displays the distribution of the disk around some Be/Shell stars.

High spectral resolution interferometry

It is the most recent applied technique for the study of Be stars. Circumstellar disks and outflows play a fundamental role in star formation. The study of the disk and emitting region of Be with high spatial and spectral resolution using the high spectro-interferometry allows the probing stellar photospheres for fundamental parameters and the inner accretion-ejection region to be resolved.

Long-baseline interferometry at optical and near-IR bands provides not only the angular sizes and mean effective temperatures of stars but also the means to probe temperature variations across and within stellar photospheres. Such measurements are critical for testing models of stellar atmospheres and interiors.

Recent interferometric images of rapid rotators like Be/Shell stars attest to the short-comings of standard models of rotating stars. In low-gravity photospheres, where changes in optical depth correspond to physical depths which are a significant fraction of a star's radius, interferometry at high-spectral resolution uniquely probes the angular size of a star through individual spectral bands. Such measurements enable the ability to map out the extended vertical structures of these photospheres and reveal the limitations of hydrostatic stellar atmosphere models.

The application of High Spectral Resolution Interferometry technique in the study of some Be stars, Stefl et al. (2011) revealed in general that:

- Scheme of the interferometric appearance of circumstellar disks results from simple uniform or Gaussian disk models and consists of a single central reversal (similar to spectral flux profile with a stellar absorption line) in the visibility and a smooth *S*-shaped phase profile.
- The results reveal much complex structure.
- Broadened, double or multiple-peak profiles commonly appear in the visibilities. In phase, a third peak is sometimes seen superimposed to the center of the expected *S*-shaped profile.

- In some cases, this phase reversal merely is a small perturbation of the *S*-shaped profile, but in others it reaches an amplitude comparable to the one of the main peaks. Both visibility and phase profiles are very strongly dependent on the projected position angle of the baseline used for the observations.

The key role of the high spectral resolution for interferometry of Be stars is demonstrated in Fig. 7. The double peak visibility and phase profile, showing a strong phase reversal, are compared with medium and highest resolution. The fine structure both in visibility and phase is lost already in the both resolutions and these characteristics appear as single reversals of reduced amplitude. Obviously, high spectral resolution adds a new and essential dimension to interferometry of objects with significant internal motions. This is demonstrated by the here presented observations of classical Be stars.

Polarimetric technique

While it has been accepted for many years that Be stars have circumstellar gas, its geometry and kinematics have remained a hotly contested subject. Recently, a consensus has been emerging about the geometric distribution of the gas. It has long been suspected that the circumstellar gas is in the form of a disk, Struve (1931). Polarization studies e.g., McLean and Brown (1978) have indicated that the circumstellar gas is not spherically symmetric.

One of the difficult aspects of trying to study the nature of stellar winds and circumstellar envelopes is that the radiation from the star itself dominates the observed spectrum. Furthermore, the circumstellar environment is rarely directly resolvable with current instruments and techniques. However, polarimetry, and particularly spectropolarimetry, provides a means of probing the disk directly. The polarization in hot stars is produced primarily by electron scattering in the circumstellar environment. This polarized flux is affected by passage through the circumstellar material, via pre- and post-scattering attenuation of the flux. The measured polarization is the ratio of the polarized flux to the total flux (which is dominated by the direct starlight). Because of this, in the ratio the

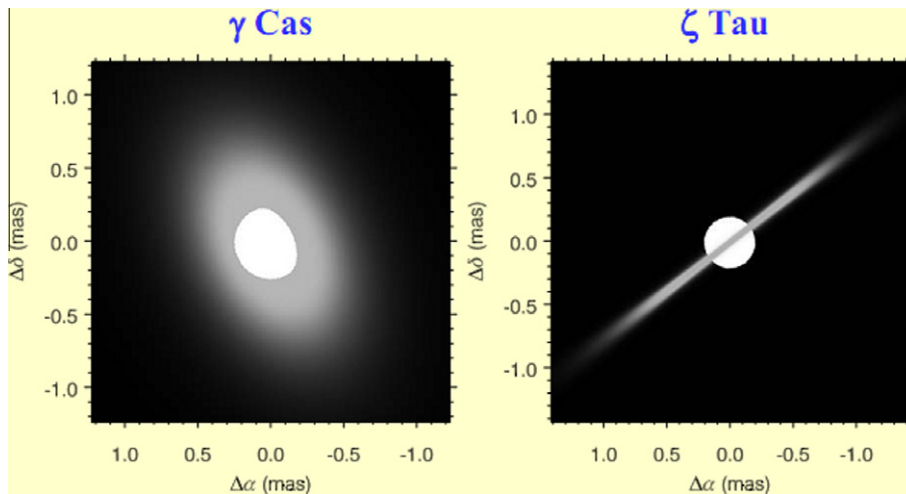


Fig. 6 Disk around Be stars (after Gies et al., 2007).

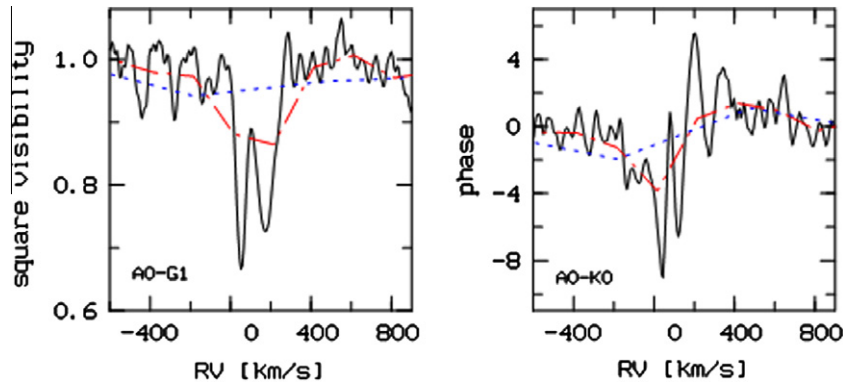


Fig. 7 The effect of the spectral resolution demonstrated on observations of δ Sco obtained on May 10, 2010. Visibility and phases are shown. The full black line represents high-resolution interferometric observations, compared with medium resolution $R = 1500$ (overplotted as the long dashed line) and the low resolution $R = 450$ (short dotted line) (after, Stefl et al., 2011).

wavelength dependence of the stellar spectrum cancels out. Thus, any residual wavelength dependence of the polarization level is determined by the opacity within the circumstellar envelope. So observations of the polarization (as opposed to the total flux) give insights into the physical conditions of the circumstellar material.

Furthermore, the combination of spectropolarimetric observations with other techniques, such as high dispersion spectroscopy, optical interferometry, and infrared photometry, can provide strong constraints on models of the circumstellar environment.

Spectropolarimetric observations

In the case of the classical Be stars, which are rapidly rotating near-main-sequence B-type stars, electron scattering of the starlight occurs within a gaseous circumstellar disk. For these stars, there is no dust present in the circumstellar envelope, so only electron scattering is responsible for the observed intrinsic polarization. This provides a useful test case for polarization diagnostics, since one only needs to be concerned with two polarization components: the polarization produced by scattering of starlight within the circumstellar disk, plus the added polarization produced by passage through the intervening interstellar medium along the line of sight to the star.

Polarimetric studies of Be stars, such as those carried out by the Halfwave POLarimeter “HPOL” instrument at the Pine Bluff Observatory (Bjorkman and Meade, 2005), and that obtained by ultraviolet spectropolarimetry from the Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE), flown on space shuttles Astro-1 (1990) and Astro-2 (1995) have provided clinching evidence that the circumstellar envelope is indeed disk-like. From basic polarization data one can derive the disk orientation on the sky, even when the source is unresolved. Fig. 8 shows 15-year polarimetric variability of the Be star π Aqr. The open squares represent the equivalent polarization values for each observation (left axis scale), while the filled circles represent the $H\alpha$ equivalent width (EqW; right axis scale) measured simultaneously (positive EqW values indicate the line in emission, while negative values indicate absorption). Measurement errors are smaller than the sizes of the symbols (after Bjorkman and Meade, 2005).

Diagnostics of circumstellar disks

Recently the spectropolarimetry has been used to diagnose the physical geometry and density of circumstellar disks around

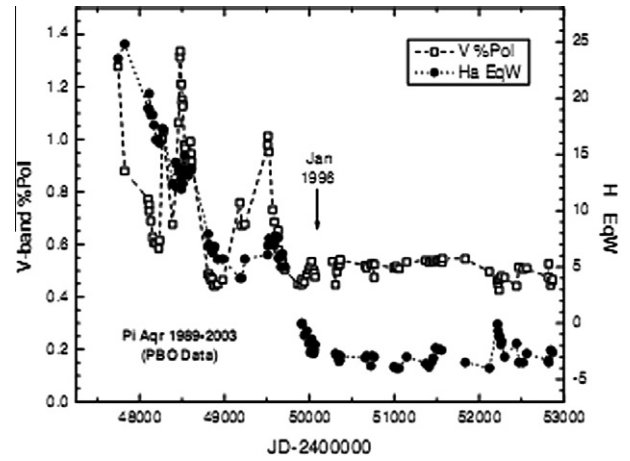


Fig. 8 Fifteen-year polarimetric variability of the Be star π Aqr. The open squares represent the equivalent polarization values for each observation (left axis scale), while the filled circles represent the $H\alpha$ equivalent width (EqW; right axis scale) measured simultaneously (positive EqW values indicate the line in emission, while negative values indicate absorption). Measurement errors are smaller than the sizes of the symbols (after Bjorkman and Meade, 2005).

classical Be stars (Wood et al., 1997; Quirrenbach et al., 1997). As discussed by Wood et al. (1997), one can find that measurement of the peak polarization level observed together with the size of the polarimetric Balmer jump, provides a diagnostic of both the geometrical thickness of the disk (the opening angle) and the optical depth in the disk, which indicates the density of material. For the case of ξ Tau, the study indicate a very thin disk with an opening angle of only 2.5° , which agrees with predictions of either the wind-compressed disk model (Bjorkman and Cassinelli, 1993) or a hydrostatically-supported Keplerian disk. Evidence for the thin nature of the disk is confirmed by a combination of optical interferometry and spectropolarimetry (Quirrenbach et al., 1997). Fig. 9 represents the spectropolarimetric observation of the classical Be star ξ Tau from the ultraviolet to the near-infrared. There is general wavelength dependence, as well as the depolarization across the spectral lines.

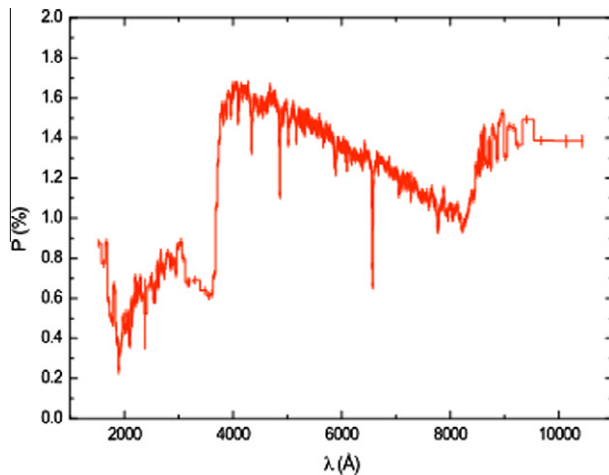


Fig. 9 Example of spectropolarimetric observation of the classical Be star ξ Tau from the ultraviolet to the near-infrared. There is general wavelength dependence, as well as the depolarization across the spectral lines (after Wood et al., 1997).

Multiwavelength observations and long time monitoring

The dense, long-time monitoring permits a better separation of repetitive and ephemeral variations. The broad wavelength coverage includes lines formed under different physical conditions, i.e. different locations in the disk, so that the dynamics can be probed throughout much of the disk. Polarimetry and interferometry constrain the spatial structure. All together, will enable to get a better understand of the dynamics and life cycle of Be/Shell stars disk.

On I Eri (X-ray, UV, and optical; Smith et al., 1997) and γ Cas (X-ray and UV; Smith et al., 1998) led to the picture of magnetic flaring. For γ Cas, Robinson et al. (2002) proposed a magnetic field threading from the star through the disk: the combination of an azimuthal field and a dense disk sets up a magnetic dynamo in the disk that in turn produces cyclic flux changes. In this scenario, the differential rotation between star and disk causes magnetic stresses that may eject high-velocity plasmoids (similar to coronal mass ejections), some of which impact on the stellar surface and may account for the hard X-ray flares.

Space missions and its role in the study of Be/Shell stars

The opening of the space age in 1957 led to the emergence of several new disciplines of science: planetology, extraterrestrial astronomy and space physics. Stellar physics, while also existing before, has also entered a qualitatively new phase with space science. The hundreds or dozens of space missions with some science payload in the past decades have produced an enormous and exponentially increasing quantity of data.

By getting above the atmosphere, astronomers were able to open several new windows on the Universe at different wavelength domains, such as infrared, ultraviolet, X-ray and γ -ray. Equally important has been, however, the possibility of making observations unimpeded by atmospheric seeing in the optical domain. The HIPPARCOS mission and the Hubble Space Telescope are the two most celebrated missions of this kind. In addition to avoiding the problems caused by the

atmosphere, space astronomy also offers another advantage: the possibility of performing interferometric measurements on unprecedented, cosmic scales.

As a consequence a large number of Be/Shell stars were detected by IRAS satellite because of the presence of infrared excesses in their spectral energy distribution. These IR excesses are thought to be due to radiation of circumstellar gas and dust. Studies of their shapes and strengths help to constrain properties of the circumstellar matter and in combination with spectroscopic studies, the evolutionary state of the star Miroshnichenko et al. (2001). For example Be stars with free-free IR excesses are main sequence objects, those with much stronger IR excesses due to dust particles in a wide range of temperatures and moderate luminosities are pre-main-sequence ones, while high-luminosity Be-type stars with dusty IR excesses are usually post-main-sequence.

Ultraviolet observations of Be/Shell stars with IUE indicated the presence of highly ionized spectral lines than normal B type stars, C IV and Si IV are detected. Be/Shell stars ultraviolet spectra show clear short ward shifted velocity reach 1300 km s^{-1} which connected to stellar wind, suggesting the expanding of the circumstellar material away from the stars, Slettebak, 1988.

X-ray observations suggested rapidly rotating Be stars is temporarily surrounded by matter expelled in its equatorial plane, the passage of neutron star through this circumstellar matter and the resultant accretion disk produce an X-ray outburst (Janot-Pacheco et al., 1981). X-ray observations expected thousands of Be/X-ray binaries in our galaxy (Rappaport and van den Heuvel, 1982).

Be/Shell stars models

Long time monitoring of Be stars revealed the inherent complexity of the Be phenomenon, due to the unusual high time variability of the line spectrum, continuous spectrum, radial velocity and brightness on various time scales. It is not clear, whether this variability are only due to very subtle physical and/or geometrical variations in the outer parts of the stars. As consequence of the very complex nature of the stars, as yet there is no one self-consistent model of any Be star. The different scenarios/models that represent the Be phenomenon started with Struve rotational model (1931), then the interacting binary model proposed by Kriz and Harmanec (1975). Baade (1987) suggested non-radial pulsation model for distortions in the line profile of a rapidly rotating, non-radially pulsating stars as underlying cause of Be phenomena. Stellar wind and wind compressed disk model and wind model suggested mass outflow in the form of radiation-driven stellar wind in hot massive stars Owocki (2011). Recently, the Genetic Algorithms were used to develop automated fitting methods to perform the spectral fits. In case of spectral lines fitting, these can be expressed by the fundamental parameters, T_{eff} , $\text{Log } g$, Z , v_{turb} , M , v_{∞} . So, different sets of these fundamental parameters describe so-called individuals, and by “evolving” generations of these individuals the line fits obtained, Mokiem et al. (2005).

Conclusion

From one side we can conclude the remarkable progress in the investigations of Be stars, made use of the new powerful

observing facilities and techniques. Be/Shell spectroscopic investigation with old and new techniques. This implies a major challenge for theoretical calculations and disk modeling of Be stars. From the other side we can say that, Be stars do not form a sufficiently homogeneous class to generalize findings from such detailed studies. We should keep in mind that “a single deviant case is not sufficient to disprove a hypothesis in general”.

- The old observational techniques didn’t contribute too much to the Be/Shell stars studies. This is due to the limitation of photographic, photometric observations (one, two and three color photometry) and early spectroscopic observational techniques.
- Due to the great revolution in Astronomical observational techniques not only in the ground-based observations but also in the space-based observation, a huge quantity of data information covered the whole range of the electromagnetic spectrum were available. Analysis of these data using the more recent powerful computers revealed very important results which throw more light on some Be problems, while other problems still need more efforts (observational and theoretical).

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