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Watching Binary Systems with Be Components with the GI2T-REGAIN[1] Spectro-Interferometer

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Abstract. Our program aims at observing selected bright multiple Be stars using the technique of long-baseline optical spectro-interferometry with the GI2T-REGAIN interferometer. These observations - combined with spectral and photometric observations and with appropriate modelling - will bring new constraints on the nature and evolutionary stage of multiple Be stars through an accurate determination of their basic physical properties.

1. Introduction

The previous instrumentation of the GI2T did not permit to calibrate accurately the visibility measurements. This seriously limited any astrophysical application. REGAIN has been designed in order to overcome this problem. This new instrumentation (Mourard et al. 1998, 1999) is divided into two main levels: an interferometric bonnette and a visual-region spectrograph. Considerable effort has been put also into the control system of the interferometer and into the data reduction package. The new visibility estimators have been successfully applied to the data obtained with the previous beam combiner, leading to a new finding about the long-term variability of the Be star γ Cas (Berio et al. 1999).
The capabilities of the GI2T-REGAIN interferometer are well suited for studying the morphology and physical processes of multiple Be systems. We are now elaborating a new program to select the most suitable target stars and to define the optimal observing strategy.

2. The GI2T-REGAIN Spectro-Interferometer

The GI2T comprises of two 1.5-m telescopes on a N-S baseline, which can be varied between 10 and 65 m, and the beam combiner REGAIN, which forms the interferometric focal plane. Different functions are realised in this interferometric bonnette:

[1]Grand Interféromètre à **2** Télescopes-**RE**combinateur du **GrAnd** **IN**terféromètre

- Pupil planes stabilisation: ICCD sends information on the transversal positions of the sub-pupils to stabilisers to keep them on predefined positions;
- Image plane stabilisation: ICCD images are real-time processed to obtain the photocenters positions and send corrections to the telescopes (f≈5Hz);
- OPD compensation: with a 3m-stroke delay line;
- Correction of field rotation;
- Atmospheric dispersion compensation.

The expected astrophysical programs have shaped the instrumental concept of the new REGAIN visual-region spectrograph. It has two parallel cameras equipped with photon counting detectors, operating at wavelength regions around 570 nm and 700 nm, respectively. Three different gratings provide a spectral resolution of up to 30000. The spectrograph can work in two different modes selected by the choice of the entrance focal plane optic:

- The dispersed-fringes mode, having an entrance slit of 4.8″ height and a 1 speckle width.
- The multichromatic "Courtès" mode which provides full-size spectrally filtered images.

In the dispersed fringe mode, a polarimetric device allows visibility measurements in the different polarisations. GI2T-REGAIN will be a suitable tool to obtain 2-D spatial information on the structure of the observed sources using the earth-rotation synthesis effect, differential visibility phase measurements and interfero-polarimetric data (Chesneau et al. 1999).

3. GI2T-REGAIN Observing Program

The first targets of this program have been selected from the list of accessible Be stars for the GI2T-REGAIN interferometry (Hirata 1994). The candidates have to fulfill brightness, size, position and orientation criteria. Among the 18 selected bright stars, well studied by spectroscopy, photometry and polarimetry, some are known to be members of multiple systems with distances determined by Hipparcos. Two possible configurations are found among these systems:

- Widely separated binaries, where the duplicity should have little or no impact on the observed properties of the Be components; and
- interacting binaries, where the nearby companion may directly affect the observed properties and variability patterns of the Be component through the effects of mass transfer, tidal interaction and reflection.

The spectro-interferometric visibility measurements carried out with the GI2T through narrow spectral bands in the continuum and spectral lines will be combined with high-SNR spectral and photometric observations of the same object at the same orbital phase. It will provide direct information on the morphology of the star and its circumstellar environment. These observational results will give new constraints on the nature and evolutionary stage of Be stars through an accurate determination of their basic physical properties like masses and angular sizes, therefore also system dimensions in cases where accurate distances could be derived by independent techniques.

3.1. β Lyrae

β Lyr (HD 174638) is a 12.9-d spectroscopic and eclipsing binary which consists of a massive early B star which is (almost?) completely hidden from view by a thick accretion disk fed by the gas inflow from its brighter B6-8II companion. Questions about the true geometrical structure of the components of circumstellar matter around β Lyr, secular stability of the light curve and of the accuracy of the basic physical elements of the binary are clearly important for the understanding of the system and its evolutionary stage.
Systematic observations of β Lyr were carried out in 1994, with a 51-m N-S baseline, γ Lyr being the reference star (Harmanec et al. 1996). The analysis of the visibilities in the continuum light indicated that the binary β Lyr was not resolved by GI2T at any orbital phase. It implies that the orientation of the orbital plane must be close to the E-W direction, in agreement with its polarimetric determination (Hoffman et al. 1998). The visibilities in the Hα and He lines clearly show that the source of the emission is resolved at all orbital phases. Analysis of these interferometric results combined with spectroscopic, photometric and polarimetric data have led to the conclusion that the bulk of the Hα and the He I 6678 emission originates from jet-like gaseous structures perpendicular to the orbital plane. The future observations planned with GI2T-REGAIN will help to confirm and improve this morphological scheme. If the bulk of the Hα emission indeed comes from "jets" of gas expanding along the N-S direction, then a wavelength-dependent variation of the phase of the complex visibility function across Hα (relative to the nearby continuum) should be observed. These relative-phase measurements will bring direct information on the position of iso-velocity region of the jets. One can also benefit from the earth-rotation synthesis effect to obtain information on the structures along the E-W direction.

3.2. ϕ Per and o And

These two stars have been selected as new program candidates.
ϕ Per (HD 10516) is a spectroscopic binary with a 126.7-d period. The brighter and a more massive star is an early-B emission line star, the secondary is a sdO hot compact star (Božić et al. 1995, Gies et al. 1998). From the observations carried out with the Mark III interferometer, no signature of binarity has been detected, leading to the conclusion that $\Delta m_V \geq 2.5$ (Quirrenbach et al. 1997). An approximate geometrical model of ϕ Per was used to compute the expected visibility curves and their wavelength dependence, base length or hour angle as illustrated by Fig. 1.

Comparison of the visibility curves with and without a detectable secondary component shows that there *are* observable time variations due to the presence of the secondary. Even for a $\Delta m_{H_\alpha} = 4$, the amplitude of these variations of about 5% should be detectable with GI2T-REGAIN.
The next step will be to study the differential phase variation between the lines and continuum. The observing strategy will be to use the GI2T-REGAIN simulator (Berio 1999) that enables one to calculate the expected SNR vs. instrumental parameters and observing conditions.
o And (HD 217675) is a quadruple system (Hartkopf et al. 1996, Hill et al. 1988). The primary A is a variable Be star. There are two speckle-interferometric com-

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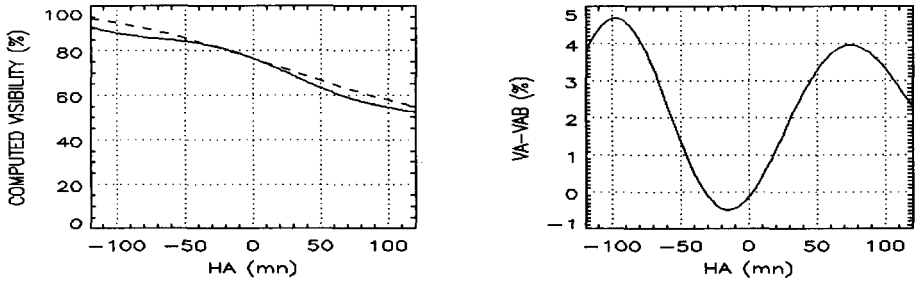

Figure 1. (left) Computed visibility for ϕ Per vs. hour angle, λ=6563Å, baseline=50m, dashed line: for the primary alone V_A (disk+central star), solid line: for the binary system V_{AB}, $\Delta m = 4$, maximum elongation. (right) $V_A - V_{AB}$ vs. hour angle

panions: a closer one, a, at about 0.05″ and a more distant one, B, orbiting with P=68.6 yrs and a=0.277″. B itself is a double-line 33-d spectroscopic binary. Interferometric measurements may help to derive the basic properties of the Aa pair and its possible relation to the cyclic long-term variations of the Be star.

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