

## Research Note

# Discovery of a new bright close double star<sup>\*</sup>

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**Abstract.** We report in this note the discovery of a close double star. The binarity of the bright star SAO 12917 is determined from visible speckle interferometry with the Bernard Lyot telescope. The separation and the position angle of the binary system are measured together with a relative photometry in the three visible spectral bands B, V and R. The data reduction is performed making use of a cross-correlation technique, derived from the speckle masking technique. We discuss the nature of the components and roughly estimate that the period of this double star system is about 13 years.

**Key words:** techniques: interferometric – methods: data analysis – binaries: visual – stars: individual: SAO 12917

## 1. Introduction

We firstly observed the bright star SAO 12917 on December 11th 1995. This star was detected as double by us using visible speckle interferometry at the 2m Bernard Lyot telescope. The discovery was fortuitous: the goal of the observing run was indeed to confirm the binarity of some suspected double stars. SAO 12917 has been chosen in fact for calibration purpose and supposed to be an unresolved object.

The publications available related to SAO 12917 (HIC 17891, HD 23523, HR 1158) mainly concern some photometric measurements (Hersh & Heck 1980, Heck 1977, Abt & Moyd 1973, Danziger & Faber 1972, Grygar & Kvizova 1961).

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<sup>\*</sup> Based on observations obtained at Bernard Lyot telescope, Pic du Midi de Bigorre, France.

The spectral type is A5V and the visual magnitude  $m_v$  is equal to 6.03.

The night following the discovery was dedicated to photometric measurements of SAO 12917 in three spectral bands in order to get some information about this binary system.

The cross-correlation technique used here to reconstruct the system belongs to the speckle imaging technique created by Labeyrie (1970). It uses a statistical analysis to recover images in spite of atmospheric turbulence. It is derived from speckle masking technique (Weigelt 1977) and is currently developed (Lyon 1993) by the Probability Imaging group of Département d'Astrophysique, Nice.

The paper is organized as follows. We describe the way the observations were carried out in Sect. 2. The procedure to derive the parameters of the binary is exposed in Sect. 3, together with the results obtained: separation, position angle and relative photometry of the components. The nature of the system is then discussed in the last section, including an estimation of the orbital period of the system.

## 2. Observations

The instrumentation used consists of the specklegraph (André *et al.* 1994, André 1995) developed by the Aperture Synthesis group of Observatoire Midi-Pyrénées, coupled to an intensified camera and an acquisition system belonging to the Probability Imaging group of Département d'Astrophysique, Nice. This instrumentation was mounted at the Cassegrain focus of the Bernard Lyot telescope ( $D = 2$  m,  $F = 50$  m).

The observations were performed during the nights of December 11th and 12th 1995. Three filters were used: B ( $\lambda = 450$  nm,  $\Delta\lambda = 70$  nm), V ( $\lambda = 550$  nm,  $\Delta\lambda = 70$  nm) and R ( $\lambda = 650$  nm,  $\Delta\lambda = 70$  nm). As speckle imaging require, some

**Table 1.** Conditions of observations in the three spectral bands B, V and R. The number of frames for SAO 12917 and its reference star are given, together with the associated average value of the Fried parameter  $r_0$  and the epoch.

| Spectral band                    | $n_o$ | $n_r$ | $\langle r_0 \rangle$ | epoch    |
|----------------------------------|-------|-------|-----------------------|----------|
| B ( $\lambda = (450 \pm 70)$ nm) | 3266  | 3258  | 13 cm                 | 1995.948 |
| V ( $\lambda = (550 \pm 70)$ nm) | 3842  | 3638  | 7 cm                  | 1995.945 |
| R ( $\lambda = (650 \pm 70)$ nm) | 2619  | 2617  | 30 cm                 | 1995.948 |

thousands of short exposure ( $\Delta t = 20$  ms) frames were recorded for each spectral band. A nearby point-like source taken as a reference star was observed consecutively under identical conditions. The reference star SAO 12929 has a 6.24 visual magnitude and a spectral type B9VI. Table 1 gives the conditions of observation for each set of data (corresponding to each spectral band) with the associated averaged value of the Fried parameter  $r_0$ .

The field of view of each frame used is about  $4'' \times 4''$ , sampled by  $128 \times 128$  pixels, the exact pixel size being ( $0''.0308 \pm 0''.0006$ ).

### 3. Data processing

For each set of observations at a given spectral band, the quality of each short exposure frame is estimated by calculating the Fried parameter  $r_0$  associated to each frame. This parameter is then used as a criterion to select the frames.

#### 3.1. Technique

The data reduction method applied here derives from the triple correlation method (speckle masking). The cross-correlation between one image and the square of it is calculated, this is a slice of the average triple correlation of the image. Averaging this quantity over a large amount of frames, one obtains the cross-correlation  $K_I(\rho)$  associated to the image formed at the focus of the telescope:

$$K_I(\rho) = \langle \int I^2(r)I(r+\rho)dr \rangle \quad (1)$$

where  $r$  and  $\rho$  are vectors in the focal plane,  $I(r)$  being the intensity in the image. This technique can be applied here as written in Eq. 1 because  $I(r)$  is defined on many levels (precisely 256). This could not be possible for data obtained with a photon counting camera coupled with a photon centroiding algorithm. In this last case, the dynamic is lost and  $I(r) = I^2(r)$  (one should then use the alternative quantity  $I(r)I(r+\epsilon)I(r+\rho)$  instead of  $I^2(r)I(r+\rho)$ , with  $\epsilon \ll r$ ). Making use of the convolution relation between the triple correlation of the image ( $K_I(\rho)$ ), of the object ( $K_O(\rho)$ ), and of the point-spread function ( $K_S(\rho)$ ), we can write:

$$K_I(\rho) = K_O(\rho) * K_S(\rho) \quad (2)$$

**Table 2.** Intensity ratio  $\alpha$  found with the two methods used (cross-correlation and fork algorithm) and for the three spectral bands B, V and R. The corresponding approximate difference of magnitude  $\Delta m$  is also given. The positive values of  $\Delta m$  show that the brightest star is down and right in the frames (i.e. North and East, see also Fig. 1).

| Spectral band          | B               | V               | R                 |
|------------------------|-----------------|-----------------|-------------------|
| $\alpha$ (cross-corr.) | $1.09 \pm 0.18$ | $1.02 \pm 0.12$ | $1.109 \pm 0.020$ |
| $\alpha$ (fork algo.)  | $1.06 \pm 0.19$ | $1.12 \pm 0.21$ | $1.14 \pm 0.12$   |
| $\Delta m$             | +0.08           | +0.07           | +0.13             |

In practice the computation is performed in the Fourier plane where the above relation becomes:

$$\hat{K}_I(u) = \hat{K}_S(u)\hat{K}_O(u) \quad (3)$$

and:

$$\hat{K}_I(u) = \langle \hat{I}^2(u)\hat{I}^*(u) \rangle \quad (4)$$

$\hat{K}_S(u)$  is estimated by calculating the cross-spectrum for the unresolved reference star thus allowing the determination of  $\hat{K}_O(u)$ .

Hence, if  $O(r) = a\delta(r)+b\delta(r+d)$  is the double star separated by  $d$  and of intensity  $a$  and  $b$  for its components, we expect that:

$$K_O(\rho) = (a^3 + b^3)\delta(\rho) + ab^2\delta(\rho - d) + a^2b\delta(\rho + d) \quad (5)$$

$K_O(\rho)$  is then composed of a central peack and two disymmetric lobes.

The main interest of the cross-correlation method, compared to the classical autocorrelation often performed for the study of double stars, is that it gives without ambiguity the orientation of the components. The drawback is that it is more sensitive to the noise than the classical speckle interferometry technique. Anyway, a more detailed description of this method will be published in a next publication.

As an alternative to this method, we also made use of the folk algorithm (Baguolo 1988) to evaluate the intensity ratio  $\alpha = b/a$ .

#### 3.2. Results

Fig. 1 displays the aspect of  $K_O(\rho)$  in the R spectral band. We made use of this quantity to determine the angular separation  $\rho$ , the position angle  $\theta$  and the oriented relative intensity ratio  $\alpha$  between the components for the different spectral bands.

The separation  $\rho$  and the position angle  $\theta$  were determined from the best set of frames (spectral band R). We found:

$$\begin{cases} \rho = 0''.1100 \pm 0''.0033 \\ \theta = 213^\circ \pm 1^\circ \end{cases} \quad (6)$$

Table 2 gives the results found in the three different bands for the intensity ratio  $\alpha$  (and then the difference of magnitude  $\Delta m$ ).

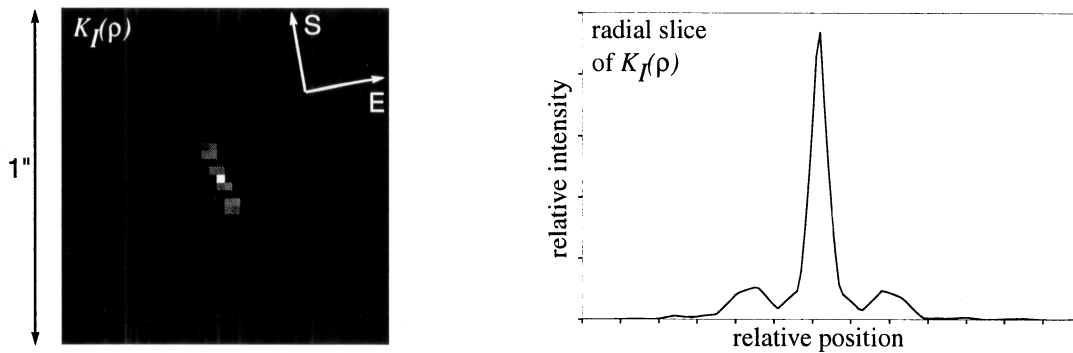


Fig. 1. Cross-correlation (enlarged to  $1'' \times 1''$ ) and the radial slice of it, for the spectral band R.

#### 4. Discussion

Since the differences of magnitude at distinct visible wavelengths are approximately equal, both components are more or less of same spectral type. The components are also more or less of same magnitude in the B, V and R bands ( $m_v$  per component =  $6.03 + 2 \log 2$ ). The known classification of the whole system being A5V, one may reasonably suppose that the components belong both to the main sequence and thus that the total mass of the system is about  $(2.2 + 2.2)M_\odot$  (Allen 1962). The modulus distance of the stars ( $m_v - M_{v,A5V \text{ star}}$ ) is equal to 4.8 and corresponds to about 90 pc of distance.

Assuming that the binary separation is close to the semi-major axis of the orbit (which is a reasonable assumption since this bright binary has not been detected before) and according to the third Kepler's law:

$$M_{\text{system}}/M_\odot = (a/1UA)^3 (P/yr)^{-2} \quad (7)$$

then:

$$P \approx 13 \text{ years} \quad (8)$$

We conclude that regular observations of this new bright system must lead soon to the determination of some orbital elements. We had chosen to nickname this binary Moai 1. The word 'moai' means image in the Easter Island idiom.

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