The Characteristics of the Cool Component of the Cataclysmic Variable AE Aquarii From HIPPARCOS Observations

Michael Friedjung
Institut d'Astrophysique (CNRS), 98 bis Boulevard Arago, 75014 Paris, France

Abstract The parallax of the cataclysmic binary AE Aquarii, found using the HIPPARCOS satellite, is combined with published infrared observations. Indications are obtained that the cool component is somewhat above the main sequence. However, this result is not absolute because of the errors and uncertainties.

1. Introduction

I present results based on a HIPPARCOS program of mine to determine the parallaxes of five cataclysmic binaries. Such objects are generally faint and often at large distances, leading to large errors in the parallax determinations. It is because of this that the results for the old novae V603 Aql and RR Pic, and the novalike cataclysmic RW Sex, were unusable. Observations of the dwarf nova SS Cyg were also planned, but unfortunately the satellite observed another star instead of it. When I tried to calculate properties of the cool component of SS Cyg from the HIPPARCOS observations before being informed about what had happened, I obtained some extremely peculiar results. Thus, the only usable observations were those of AE Aqr, that is, for 20% of the sample of stars.

Cataclysmic binaries are generally understood as consisting of a white dwarf accreting mass lost by a cool companion, which in most cases appears to have similar properties to those of a cool main sequence star. AE Aqr is a nova-like cataclysmic variable of the DQ Herculis class, which has been very much studied (see, for instance, Welsh *et al.*1993, Reinsch and Beuermann 1994, and Echeverria 2006). The white dwarf components of cataclysmic binaries of this type are thought to have a strong magnetic field, which is, however, not strong enough to lock the white dwarf rotation period to the orbital period. In the case of AE Aqr, the white dwarf rotation period is believed to be equal to a 33-second period seen in the optical and x-ray light curves. This object also shows time-variable radio emissions and optical flares.

2. Observations and calculations

Observations with the HIPPARCOS satellite give a trigonometric parallax of 9.80 milliarcseconds (mas) with an error of 2.84 mas. This parallax corresponds to a distance of 102 pc, the error indicating that the value is probably between 79 and 144 pc. The large error in parallax is due to the relative faintness of the object (11th magnitude).

This parallax can be combined with other information in order to determine certain properties of the binary. If we look at the infrared radiation which comes almost exclusively from the cool companion, we can study its nature without being disturbed by radiation from other sources and in particular due to accretion onto the white dwarf. Dhillon and Marsh (1995) studied the infrared spectrum and found a spectral type of K5 from the strength of absorption features in the wavelength region of the K-band (near 2.2 μm). They confirm that almost all light at this wavelength comes from the cool component, the K magnitude of the latter being not more than 0.01 greater than the *K* magnitude of the binary. The reddening can probably be neglected, as La Dous (1991) found an E(*B–V*) of 0.0 from the weakness of the 2,200Å absorption feature in the ultraviolet spectrum.

It is not so easy to find the correct value of the *K* magnitude to use in calculations, because of the variations found by Tanzi *et al.* (1981). The variations may be related to the orbital phase, but the observations by Tanzi *et al.* are not complete enough for this to be certain. Taking account also of other *K* magnitude determinations, a mean *K* of 8.92 is used in this work.

A value for the surface brightness parameter for the cool component defined by Bailey (1981) can then be found. The value of *V–K* is required for this; the value directly observed for AE Aqr clearly cannot be used, because *V* is affected by sources of light other than the cool component. The spectral type of the latter is available for estimating *V–K*, however. The cool component effective temperature corresponding to the spectral type gives a *V–K* of 2.54, according to Veeder (1974), and the *B–V* for this type gives a *V–K* of 2.72, according to Mould and Hyland (1976). Taking a mean *V–K* of 2.63, equation (1) of Bailey (1981) combined with the HIPPARCOS parallax gives a cool component radius of 1.01 $R_{\odot}$. The maximum and minimum values for the distances give corresponding radii of 1.43 and 0.78 $R_{\odot}$. The uncertainty in the value of *K* leads to an uncertainty of about 10% in the radius.

Other parameters can then be determined for the binary. The HIPPARCOS radius, combined with the condition that the cool component fills its Roche lobe, and Kepler's third law, gives, according to equation (4) of Echeverria (1983), a cool component mass of 0.76 $M_{\odot}$. However, the mass found is proportional to the cube of the assumed radius of this component, and so is very sensitive to the exact value assumed for the cool component radius; it is for this reason that the maximum and minimum radii lead to a very large range of possible white dwarf masses—between 2.17 and 0.35 $M_{\odot}$. The upper limit obtained in this way is in fact not very interesting, being well above the Chanderasekhar limiting mass for a white dwarf of 1.4 $M_{\odot}$. In a similar way, the inclination of the orbit of the binary is not at all well constrained, when the mass of the cool component derived from the radius is combined with a condition of Reinsch and Beuermann based on the radial velocity amplitudes. However, the best mass gives an inclination of 54° which is close to that of 58 ± 6° determined using other methods by Casares *et al.* (1996).

3. Discussion

The luminosity and effective temperature of a K5 main sequence star given by Schmidt-Kaler (1982) correspond to a cool component radius of only 0.68 $R_{\odot}$. The difference with the radius found from the HIPPARCOS parallax appears to be on the order of the probable maximum value for the combined errors, and may therefore be significant. It suggests that the cool component lies to the right of the main sequence. However, if the spectral type is overlooked, a cataclysmic binary period radius relation valid for main sequence cool components (Echevarria 1983; Warner 1995), when extrapolated somewhat outside its range of validity, shows no disagreement with the radius derived from HIPPARCOS.

A number of previous authors have found that the spectral types of the cool components of cataclysmic binaries are later than expected for their mass, supposing them to be on the main sequence. Echeverria (1983) found such a result, the radii also being larger. Similar conclusions were reached by Friend *et al.* (1990) for cataclysmic binaries in general, and for AE Aqr in particular by Bruch (1991), Chincarini and Walker (1981), and Patterson (1979). However, according to Warner (1995), Echeverria (1983) obtained an invalid linear squares relation between secondary mass and spectral type. Nevertheless, Warner's figure 2 shows that AE Aqr at least has a spectral type too late for its orbital period when compared with other cataclysmic binaries. This agrees with the present result. Let it finally be noted that the disagreement between the observed and predicted secondary component spectral type would be increased if one were to attempt to correct this spectral type for possible heating by radiation coming from regions near the compact component of the binary.

4. Acknowledgements

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