The Mass of the Classical Cepheid V350 Sgr

Nancy Remage Evans

Smithsonian Astrophysical Observatory, Cambridge, MA 02138, USA

Erika Böhm-Vitense and Bernhard Beck-Winchatz

Astronomy Department, University of Washington, Seattle, WA 98195, USA

Kenneth Carpenter

Laboratory for Astronomy and Solar Physics, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

Richard Robinson

Computer Sciences Corporation, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

Abstract. Two medium-resolution spectra of the hot (B9.0 V) companion of the Cepheid V350 Sgr have been obtained in the wavelength range 1840 to 1880 Å using the GHRS. These spectra are very similar to the spectra of the A0 V standard α Lyr convolved with a rotational-broadening function of 150 km s\(^{-1}\), indicating that V350 Sgr B has a high rotational velocity. The velocity difference between the spectra of V350 Sgr B at two orbital phases is measured to be 22.1 ± 8 km s\(^{-1}\). The large error results primarily from the high rotational velocity.

The orbital velocity of the Cepheid at the same two phases is known from the ground-based orbit determined by Evans & Sugars (1997). The spectral type of the companion was determined from comparing IUE low-resolution spectra with spectral standard stars. V350 Sgr B is an excellent match with the B9 V standard. Using the new data on the masses of eclipsing binaries from Andersen (1991), this corresponds to a mass of 2.5 ± 0.1 \(M_\odot\). Combining this mass with the orbital-velocity amplitude ratio of the Cepheid and the companion, a mass of 5.0 ± 2.0 \(M_\odot\) is derived for the Cepheid. A Cepheid mass, together with its luminosity, is a good test of evolutionary calculations. Specifically, main-sequence core convective overshoot is a parameter that affects the later stages of evolution strongly, but is still uncertain. Unfortunately, because of the large error in the mass determination of V350 Sgr A, it is only a weak discriminant between overshoot values.
Figure 1. The GHR S G200M spectra of $\alpha$ Lyr and the second observation of V350 Sgr. In order to separate the two spectra, $6 \times 10^{-14}$ ergs cm$^{-2}$ s$^{-1}$ Å$^{-1}$ has been added to the $\alpha$ Lyr spectrum, which had been scaled to the flux of the V350 Sgr spectrum. The vertical lines on the far left indicate the continuum and zero level of each of the spectra. Both spectra have been smoothed with a 10 point boxcar. In all figures, wavelength is in Å and flux is in ergs cm$^{-2}$ s$^{-1}$ Å$^{-1}$.

1. Introduction

In addition to their use as primary distance indicators, classical Cepheids are a key test of stellar-evolutionary calculations. Because the instability strip provides a fiducial in the region containing evolved stars in the HR diagram, an observed mass can be linked with a precise luminosity for comparison with theoretical calculations. Concern about the theoretical predictions was raised more than two decades ago when masses derived from pulsation calculations differed substantially from those from evolutionary calculations. In addition, the treatment of convective overshoot at the boundary of the core of main-sequence B stars (Cepheid progenitors) has a large effect on main-sequence lifetimes as well as the luminosity of a given mass in the blue loop (Cepheid) region.

For these reasons, determination of dynamical Cepheid masses was undertaken in this project. Since the orbit of a binary Cepheid can be measured from the ground, only two carefully timed satellite observations are needed to measure the velocity amplitude of a hot companion. The results for the Cepheid V350 Sgr are described below.
2. Observations

Observations of V350 Sgr B were carried out on 1994 May 2 and 1995 September 23 (near orbital-velocity maximum and minimum) with the GHRS. Because of the faintness of V350 Sgr B (\(V = 11.5\) mag), the medium-resolution grating G200M was used. The wavelength region from 1840 to 1880 Å was observed. As a comparison star, \(\alpha\) Lyr was also observed. The observing procedure included a PEAKUP for accurate centering in the Small Science Aperture, and a wavelength-calibration observation at the beginning and end of each orbit. These allowed us to correct for thermal drifts and interaction with the earth's magnetic field. For full details see Evans et al. (1997). With these precautions, we estimate the uncertainty of the velocities is 2.7 km s\(^{-1}\) (Heap et al. 1995).

Figure 1 shows the comparison between the second spectrum of V350 Sgr B and \(\alpha\) Lyr. Clearly V350 Sgr B has a large rotational broadening. Figure 2 shows both V350 Sgr B spectra as well as the \(\alpha\) Lyr spectrum convolved with a rotational-broadening function of 150 km s\(^{-1}\), which is a much better match to the V350 Sgr B spectra. Because of the high rotational broadening of the Cepheid companion, the line contrast is much reduced, resulting in a large uncertainty when the two V350 Sgr B spectra are cross-correlated. The velocity difference between the two spectra is 22.1 km s\(^{-1}\). The uncertainty of the center of the Gaussian fit to the correlation peak is 8 km s\(^{-1}\). While this is only a single source of error, it completely dominates other errors, such as the wavelength uncertainty (2.7 km s\(^{-1}\) as discussed above), and we adopt it as the error estimate of the velocity difference.
3. Discussion

The orbital velocity difference for the Cepheid at the same two phases (10.9 km s\(^{-1}\)) is taken from the orbit determined by Evans & Sugars (1997). The spectrum of the companion is found in the same study to be B9.0 V. This corresponds to a mass of $2.5 \pm 0.1 \, M_\odot$. We note that in a system such as V350 Sgr where the B star is linked with a more massive star, the uncertainty in the mass of the B star is reduced because it must be close to the zero-age main sequence.

The mass we derive for the Cepheid V350 Sgr A is thus $5.0 \pm 2.0 \, M_\odot$. The large uncertainty in the mass results from the velocity uncertainty due to the high rotational velocity of the companion. Unfortunately the \(1\sigma\) error bar easily includes all values of overshoot currently in use, so the V350 Sgr system is not a good discriminant between them.

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References