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A precise distance to IRAS 00420+5530 via H_2O maser parallax with the VLBA

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Abstract. We have used the VLBA to measure the annual parallax of the H_2O masers in the star-forming region IRAS 00420+5530 ($l = 122.0°, b = -7.1°$). This measurement yields a direct distance estimate of 2.17 ± 0.05 kpc, which disagrees substantially with most other published estimates (a range from 1.7 to 7.7 kpc). This distance is consistent with recent parallax-based distances reported for W3(OH) (Xu *et al.* 2006, Hachisuka *et al.* 2006), lending additional support to the conclusion that the Perseus Spiral Arm of the Milky Way is a factor of at least two closer than kinematic distance estimates imply at galactic longitude ∼130 degrees.

1. Introduction

Very Long Baseline Interferometry extends the range of the direct distance measuring technique of annual parallax from ∼100 pc optically, to ∼10 kpc with radio telescopes such as the VLBA of the National Radio Astronomy Observatory†. Compact radio-emitting objects such as pulsars and masers are thus choice beacons for distance measurements across the Galaxy (e.g., van Langevelde *et al.* 2000, Brisken *et al.* 2002, Chatterjee *et al.* 2004). Such distance measurements will enable enormous improvements in our understanding of Galactic structure and the physics of individual objects.

IRAS 00420+5530 is a star formation region with a high-velocity outflow (Zhang *et al.* 2005), 3.6 cm and 3 mm continuum emission (Molinari *et al.* 2002), and H_2O masers (e.g., Brand *et al.* 1994). Distances of 4.3 to 7.7 kpc (usually kinematic) have been reported and used in these and other recent papers (e.g., Kumar *et al.* 2006, Brand *et al.* 2001), in substantial disagreement with an early photometric distance of 1.7 kpc (Neckel & Staude 1984). Clearly, a better distance estimate is desirable for this object.

2. VLBA parallax observations of IRAS 00420+5530

To resolve this distance uncertainty, we have conducted 12 four-hour VLBA observations (2005 Nov–2006 Sep) of the 22 GHz H_2O masers in IRAS 00420+5530. Two point-like radio-loud background quasars were observed alternately with the target: J0042+5708 (∼190 mJy) for phase-referencing calibration and position registration and J0047+5657 (∼85 mJy) to check astrometric precision. Additionally, seven strong (>1 Jy) calibrators distributed in zenith angle were observed to enable correction for errors in the VLBA correlator's coarse macroscopic tropospheric delay model. The resulting images of the IRAS 00420+5530 reveal the Earth-relative motion of the maser sources on the plane of the sky. The corresponding images of J0047+5708 show that it is stationary to within ∼40 microarcseconds, indicating a per-epoch phase-referencing astrometric precision of this magnitude.

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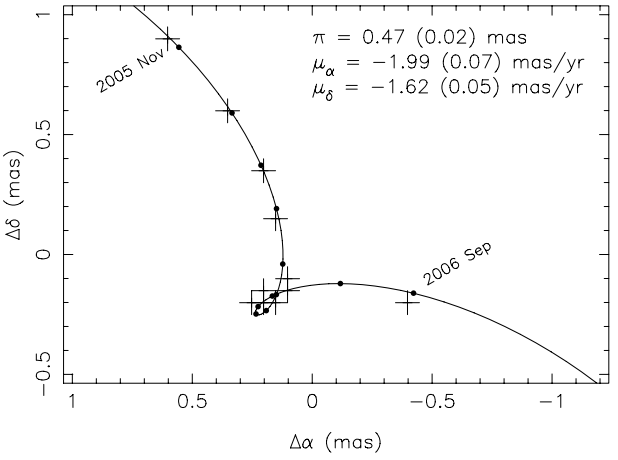

Figure 1. The motion of a maser spot in IRAS 00420+5530 at $V_{lsr} = -44.1$ km/s. Crosses: observations, Dots and curve: proper motion and parallax fit. Ten such fits were combined to form the mean parallax estimate described in the text.

We have fitted the sequence of peak positions for four maser spot regions (in 19 channels, $\Delta V_{lsr} = 0.21$km/s/channel) in IRAS 00420+5530 for linear proper motion and annual parallax. An example of one such fit (for the $V_{lsr} = -44.1$ km/s) is shown in Figure 1. The accuracy of these fits is limited not by the phase-referencing accuracy, but rather by systematic spatial and velocity variability in the maser spots, which make it difficult to identify the same *physical* source components from epoch to epoch to better than ∼50 microarcseconds, in the best cases. Two of the maser spot groups were excluded on this basis. The parallax fits for the remaining two groups (10 channels) are statistically indistinguishable (though their proper motions differ significantly), and have been combined to yield a net parallax estimate of $\pi = 0.46 \pm 0.01$ milliarcseconds.

3. The distance to IRAS 00420+5530

Our parallax yields a distance for IRAS 00420+5530 of $d = 2.17 \pm 0.05$ kpc. This 3% distance disagrees by at least a factor of two compared to kinematic estimates. It is consistent with similarly-measured distances reported for W3(OH) (Xu *et al.* 2006, Hachisuka *et al.* 2006), supporting the conclusion that the Perseus Spiral Arm of the Milky Way is a factor of at least two closer than kinematic distance estimates imply at galactic longitude ∼130°.

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