PROCEEDINGS OF SCIENCE

A preliminary distance to W 75N in the Cygnus X star-forming region

Kazi L. J. Rygl[∗a,b†], **Andreas Brunthaler**[a], **Karl M. Menten**[a], **Mark J. Reid**[c], **Huib-Jan van Langevelde**[d,e], **Mareki Honma**[f], **Karl J. E. Torstensson**[e,d], **Kenta Fujisawa**[g] and **Alberto Sanna**[a‡]

[a] *Max-Planck-Institut für Radioastronomie (MPIfR), Auf dem Hügel 69, 53121 Bonn, Germany*
[b] *Istituto di Fisica dello Spazio Interplanetario (IFSI-INAF), Via del Fosso del Cavaliere 100, 00133 Roma, Italy*
[c] *Harvard Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA*
[d] *Joint Institute for VLBI in Europe, Postbus 2, 7990 AA Dwingeloo, the Netherlands*
[e] *Sterrewacht Leiden, Leiden University, Postbus 9513, 2300 RA Leiden, the Netherlands*
[f] *Mizusawa VLBI Observatory, National Astronomical Observatory of Japan, 2-21-1, Osawa, Mitaka, Tokio 181-85588,Japan*
[g] *Faculty of Science, Yamaguchi University, 1677-1 Yoshida,Yamaguchi 753-8512, Japan*
E-mail: kazi.rygl@ifsi-roma.inaf.it, brunthal@mpifr-bonn.mpg.de, kmenten@mpifr-bonn.mpg.de, reid@cfa.harvard.edu, langevelde@jive.nl, mareki.honma@nao.ac.jp, kalle@strw.leidenuniv.nl, kenta@yamaguchi-u.ac.jp, asanna@mpifr-bonn.mpg.de

Cygnus X is one of the closest giant molecular cloud complexes and therefore an extensively studied region of ongoing high mass star formation. However, the distance to this region has been a long-standing issue, since sources at galactic longitude of 80° could be in the Local Arm nearby (1–2 kpc), in the Perseus Arm at 5 kpc, or even in the outer arm (10 kpc). We use combined observations of the EVN plus two Japanese stations to measure very accurate parallaxes of methanol masers in five star-forming regions in Cygnus X to understand if they belong to one large star-forming complex or if they are separate entities located at different distances. Here we report our preliminary result for W 75N based on six epochs of VLBI observations: we find that W 75N is at a distance of $1.32^{+0.11}_{-0.09}$ kpc, which is significantly closer than the reported values in the literature (1.5–2 kpc).

10th European VLBI Network Symposium and EVN Users Meeting: VLBI and the new generation of radio arrays
September 20-24, 2010
Manchester Uk

∗Speaker.
†Current affiliation IFSI-INAF.
‡This work was partially funded by the ERC Advanced Investigator Grant GLOSTAR (247078).

PoS(10th EVN Symposium)103

1. Introduction

In the early days of radio astronomy, a conspicuously strong, extended source of radio emission was found around Galactic longitude $\sim 80^{\circ}$ and named the Cygnus X region [13]. It stands out equally remarkably in infrared (IR) surveys of the Galaxy ([11]; see e.g., the spectacular Spitzer imaging [8]). Its associated Giant Molecular Cloud complex (e.g., [17]) is harboring many dense, dusty, hot cores with embedded protostars [10]. This and the presence of several OB associations and a superbubble driven by the O-stars' stellar winds as well as the famous Cygnus Loop supernova remnant give testament to intense and widespread star formation happening over (at least) the past few millions of years (see, e.g., [5]; [1]; [19]). Since it is also thought to be relatively near to the Sun, many of the above phenomena can be studied here in detail. The distance to this remarkable "mini-starburst" region has been a long-standing issue. It is still not clear whether all clouds are at the same distance or whether we see a projection of several clouds at different distances (see [17] and [18] for a detailed discussion). For example, three OB associations have distance estimates between 1.2 and 1.7 kpc, a difference of more than 30%. This uncertainty of 500 pc is almost 10 times larger than the extent of the Cygnus X region on the sky – 2 by 3° or 50 by 80 pc at a distance of 1.5 kpc. Thus, important physical parameters of objects in this region such as luminosities and masses are uncertain by a factor of $\sim$2. The situation is further complicated by the fact that sources at a galactic longitude of $\sim 80^{\circ}$ could be in the Local Arm and nearby ($\sim 1-2$ kpc), in the Perseus Arm at $\sim$5 kpc, or even in the outer arm at distances of $\sim$10 kpc (e.g. the Cygnus X-3 microquasar). Fortunately, several 6.7 GHz methanol masers are known in the Cygnus X region [20]. One can use this maser line for astrometry; in [16] we have measured the parallax and proper motions of five star-forming regions (SFRs) and reached accuracies as good as 22 μas. These were the first parallax measurements performed with the European VLBI Network (EVN) .

2. Observations and data reduction

The project EB039 contains eight epochs of observations with the EVN plus two Japanese stations (Yamaguchi and Mizusawa) between March, 2009, and November, 2010, of which six were already correlated and reduced – the results published here are based on these. Each observation lasted 12 hours and made use of *geodetic-like* observations to calibrate the tropospheric zenith delays at each antenna (see [14], [4], [15] for a detailed discussion).

Before we started the parallax observations, we observed several compact NVSS [6] sources within 2° from the maser source at 5 GHz with the EVN in eVLBI mode to obtain their positions with sub-arcsecond accuracy. Finally, we used two extragalactic background sources, J2045+4341 and J2048+4310, within 2° of W 75N and J2029+4636 from the VLBA calibrator survey [3] with a separation of 4.3°. A typical observing run started and ended with $\sim$1 hour of geodetic-like observations and $\sim$10 minutes of observations of fringe finders. The remaining time was spent on maser/background source phase-referencing observations. The masers in Cygnus X and the three background sources were phase referenced to the strongest maser in W 75N, using a switching time of 1.5 minutes.

The observations were performed with eight intermediate frequency bands (IF) of 8 MHz width, each in dual circular polarization and 2 bits sampling, yielding a recording rate of 512 Mbps.

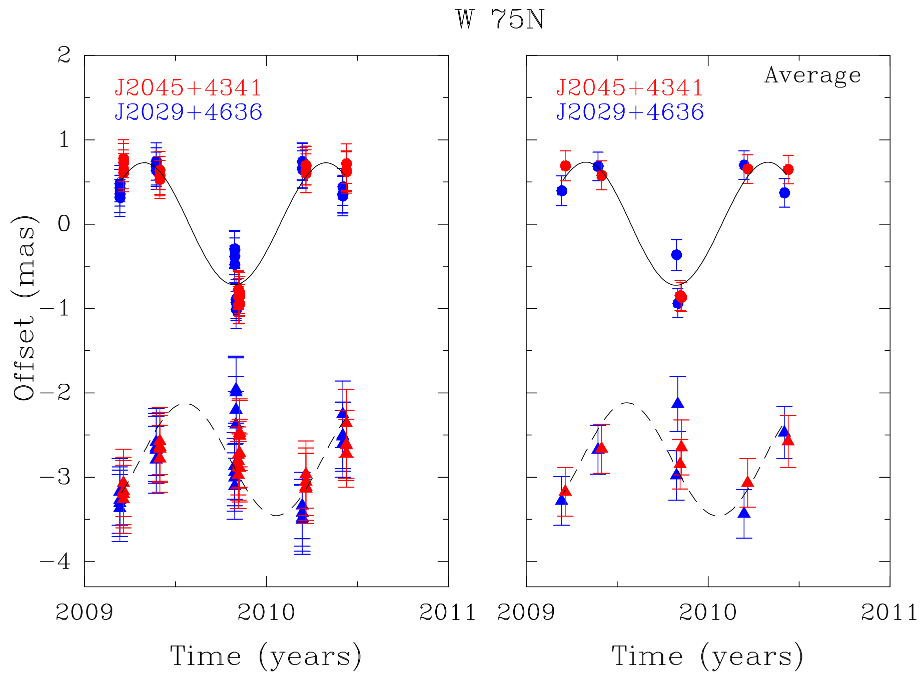

Figure 1: Parallax fit to 4 maser spots using 2 background sources (color coded). The left panel shows a fit to all maser spots, and in the right panel the postions of the masers have been averaged per epoch and background source. The solid line represents the fit to the parallax signal in right ascension, while the dashed line represents the fit in declination. Proper motions have already been removed here.

The data were correlated in two passes at the Joint Institute for VLBI in Europe (JIVE). The maser data were correlated using one 8 MHz IF band with 1024 spectral channels, resulting in a channel separation of 7.81 kHz or 0.41 km s^{-1} at 6.7 GHz. The background sources were correlated in continuum mode with eight IFs of 8 MHz width with a channel separation of 0.25 MHz. The data were reduced using the NRAO Astronomical Image Processing System (AIPS) and ParselTongue [7] following the description in [16].

3. Results and discussion

We detected 6.7 GHz methanol masers towards five SFRs: W 75N, DR 20, DR 21A, DR 21B, and OB 2. W 75N has 14 different methanol maser features emitting in a velocity range of 3 – 10 km s^{-1}. The parallax of W 75N was based on four maser spots which are compact and have well-behaved proper motions, making them suitable for parallax fitting.

The parallaxes and proper motions were determined from the change in the positions of the maser spot(s) relative to the background source(s). The data were fitted with a parallax and a linear proper motion. We made combined fits with respect to each background source, assuming one parallax but different proper motions for each maser spot. Because the position measurements of different maser spots are not independent, we multiplied the error of the combined fit by $\sqrt{N}$, where N is the number of maser spots. However, this will overestimate the error, if significant random errors are present (e.g., owing to maser blending and structural changes over time), since the latter are not correlated among different maser spots. Following the approach of [2] we calculated the

PoS(10th EVN Symposium)103

average positions with respect to each background source after removing their position offsets and proper motions. Then, we performed a parallax fit on these averaged data sets relative to each individual background source, and on both the background sources combined. This approach has the advantage that we can reduce the random errors, while leaving the systematic errors unaffected.

Figure 1 shows the 6-epoch results for four maser spots in W 75N with respect to two background sources, J2045+4341 and J2029+4636. After averaging the maser spots in each epoch, the combined fit to both background sources yields a parallax of 0.756 ± 0.057 mas, corresponding to a distance of $1.32^{+0.11}_{-0.09}$ kpc. This is significantly closer than the distance range in the literature of 1.7 to 2.1 kpc which is often based on distance estimates to the Cyg OB associations.

For understanding whether Cygnus X consists of several unconnected SFRs the distances toward all the different SFRs must be measured very precisely. With addition of the two epochs observed this November, and one more year of observations in 2011, we intend to reach accuracies of better than 30 μas – which translates to error bars of 50 pc at a distance of 1.3 kpc. In addition to the parallaxes we will publish the three-year proper motions of the methanol masers.

References

[1] Abbott, D. C., Bieging, J. H., & Churchwell, E. 1981, ApJ, 250, 645

[2] Bartkiewicz, A., Brunthaler, A., Szymczak, M., et al. 2008, A&A, 490, 787

[3] Beasley, A. J., Gordon, D., Peck, A. B., et al. 2002, ApJS, 141, 13

[4] Brunthaler, A., Reid, M. J., & Falcke, H. 2005, Future Directions in High Resolution Astronomy, 340, 455

[5] Cash, W., Charles, P., Bowyer, S., et al. 1980, ApJ, 238, L71

[6] Condon, J. J., Cotton, W. D., Greisen, E. W., et al. 1998, AJ, 115, 169

[7] Kettenis, M., van Langevelde, H. J., Reynolds, C., et al. 2006, Astronomical Data Analysis Software and Systems XV, 351, 497

[8] Kumar, M. S. N., Davis, C. J., Grave, J. M. C., et al. 2007, MNRAS, 374, 54

[9] Menten, K. M. 1991, ApJ, 380, L75

[10] Motte, F., Bontemps, S., Schilke, P., et al. 2007, A&A, 476, 1243

[11] Odenwald, S. F., & Schwartz, P. R. 1993, ApJ, 405, 706

[12] Pestalozzi, M. R., Minier, V., & Booth, R. S. 2005, A&A, 432, 737

[13] Piddington, J. H., & Minnett, H. C. 1952, Australian Journal of Scientific Research A Physical Sciences, 5, 17

[14] Reid, M. J., & Brunthaler, A. 2004, ApJ, 616, 872

[15] Reid et al. 2009, ApJ, 693, 397

[16] Rygl, K. L. J., Brunthaler, A., Reid, M. J., et al. 2010, A&A, 511, A2

[17] Schneider, N., Bontemps, S., Simon, et al. 2006, A&A, 458, 855

[18] Uyanıker, B., Fürst, E., Reich, W., et al. 2001, A&A, 371, 675

[19] Walsh, D., & Brown, R. H. 1955, Nature, 175, 808

[20] Xu, Y., Voronkov, M. A., Pandian, J. D., et al. 2009, A&A, 507, 1117

PoS(10th EVN Symposium)103