A further look at stellar parallax measurements in astronomy

Parallax measurements are one of the first rungs of the cosmic distance ladder – astronomy's network of methods for distance measurements. Each of these methods is valid for a range of distances, with methods for greater distances being calibrated using those for smaller ones. Parallax measurements are a crucial rung in the distance ladder: they provide astronomers with distance mea to the nearest hundred thousand or so stars. The calibration of measurements to more distant stars and galaxies depends on these parallax measurements.

The capability to tell the distances to the nearest stars, and to determine the amount of light they emit, was a key step towards understanding the stars' physical properties, internal constitutions and source of energy. However, the distances to the stars are so large that the accuracy needed for determining stellar parallaxes was beyond the reach of astronomers until the mid-19th century. Even so, the baseline – the distance between the positions of the two observations – needed to be extremely large. Distances on Earth were significantly too small, so astronomers began making observations half a year apart, corresponding to a change in location of 300 million kilometres.

The first widely accepted stellar measurement using parallax was made by Friedrich Wilhelm Bessel in 1838. This was soon followed by more precise measurements, with a jump in accuracy in the early 20th century due to the advent of astrophotography. The current gold standard is set by the ESA space mission Hipparcos, based on measurements taken between 1989 and 1993 and resulting in a catalogue of 100 000 stellar parallaxes with accuracies of less than a milli-arc second, or one 3.6-millionth of a degree. This is the angle subtended by an astronaut sunbathing on the Moon, as seen by an observer on Earth.

The Hipparcos data are due to be replaced by the results of the ongoing ESA mission Gaia, which was launched in late 2013. The mission's key goal is to determine positions and parallax for one billion stars with unprecedented accuracy, extending distance estimates with an accuracy of 10 per cent as far as the centre of our galaxy, and reaching parallax accuracies of 20 micro-arc seconds for the brightest stars, including those only 1/600th as bright as the faintest stars visible to the naked eye.

An overview of the evolution of the accuracy of parallax measurements is shown in figure 1.

Supporting material for:

Pössel M (2017) Parallax: reaching the stars with geometry. *Science in School* **39**: 39–44. www.scienceinschool.org/2017/issue39/parallax

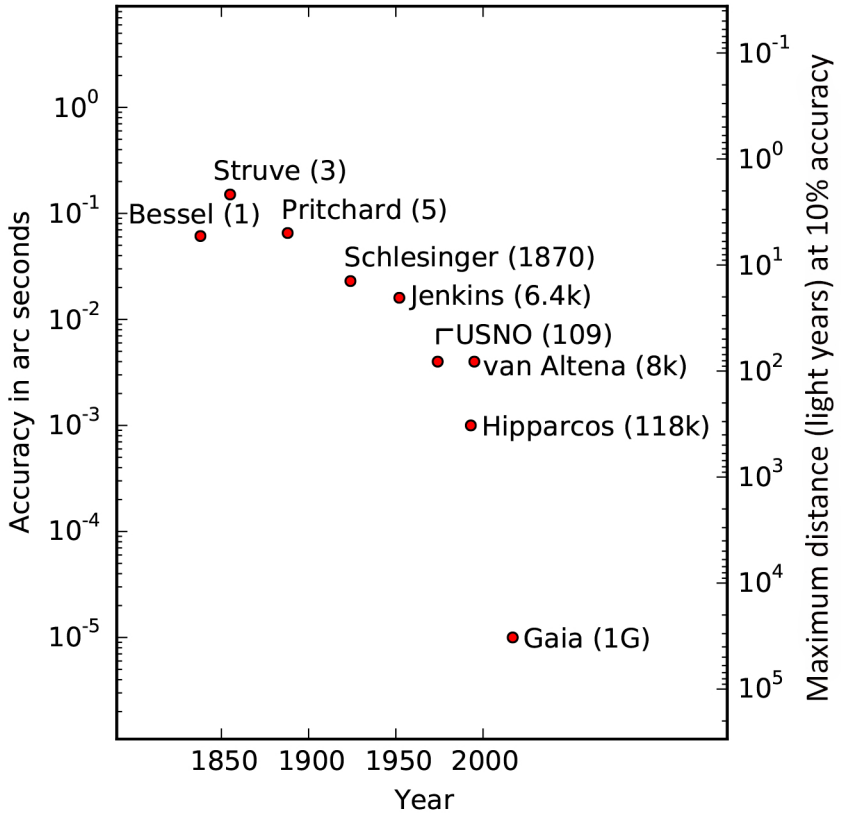

Figure 1: Changes in estimated parallax accuracy measurements over time. The figures in brackets are the number of stars observed for that survey. Image courtesy of Markus Pössel

Resources

To find out more about the history of parallax measurements, see:
Hirshfeld A (2013) *Parallax: The Race to Measure the Cosmos*. Mineola, NY, USA: Dover Publications. ISBN: 9780486490939

For those who can read German, the original stellar parallax story can be read in:
Bessel FW (1838) Bestimmung der Entfernung des 61sten Sterns des Schwans. *Astronomische Nachrichten* **16**: 65-96. doi: 10.1002/asna.18390160502

More information about the cosmic distance ladder can be found in the following two books:

de Grijs R (2011) *An Introduction to Distance Measurement in Astronomy*. Chichester, UK: John Wiley & Sons. ISBN: 9780470511800

Webb S (2008) *Measuring the Universe: The Cosmological Distance Ladder*. London, UK: Springer. ISBN: 9781852331061

For more information about the Hipparcos mission and its results, see:

Supporting material for:

Pössel M (2017) Parallax: reaching the stars with geometry. *Science in School* **39**: 39–44. www.scienceinschool.org/2017/issue39/parallax

Perryman M (2010) *The Making of History's Greatest Star Map*. Heidelberg, Germany: Springer. ISBN: 9783642263033. doi: 10.1007/978-3-642-11602-5

van Leeuwen F (2007) Validation of the new Hipparcos reduction. *Astronomy and Astrophysics* **474**: 653-664. doi: 10.1051/0004-6361:20078357

For more information about the ongoing Gaia mission, see:

de Bruijne JHJ, Rygl KLJ, Antoja T (2014) Gaia Astrometric Science Performance Post-launch Predictions. In Walton NA et al. (eds) *The Milky Way Unravelled by Gaia: GREAT Science from the Gaia Data Releases* pp 23-29. EAS Publications Series 67-68. Les Ulis, France: EDP Sciences. ISBN:. 9782759818266. doi: 10.1051/eas/1567004

Prusti T (2012) The promises of Gaia. *Astronomische Nachrichten* **333**: 454-459. doi: 10.1002/asna.201211688

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Pössel M (2017) Parallax: reaching the stars with geometry. *Science in School* **39**: 39–44. www.scienceinschool.org/2017/issue39/parallax