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Dear GAVRT Teachers and Students;

January 11, 2007

Best wishes for a great 2007.

There have been two recent scientific meetings and I would like to share with you some of the experiences, science, and excitement from them. Scientific meetings like these highlight the international nature of science in general, and astronomy and astrophysics in particular. The scientists attending the meetings came from across the astronomical world including Australia, Brazil, Canada, Chile, China, Denmark, Finland, France, Germany, Hungary, India, Italy, Mexico, the Netherlands, New Zealand, Poland, Russia, South Africa, Spain, Switzerland, the United Kingdom and the USA, almost the entire alphabet.

The first was the Fifth Stromlo Symposium, "*Disks, Winds & Jets – From Planets to Quasars*", which was held in Canberra at the Mount Stromlo Observatory of the Research School of Astronomy and Astrophysics. The second was the "*23rd Texas Symposium on Relativistic Astrophysics*", again in Australia, this time at the University of Melbourne. In this letter I will talk about the Stromlo Symposium, and leave the Texas Symposium until later. I have listed the web addresses of the meetings at the end of my letter.

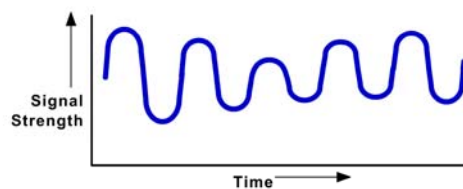
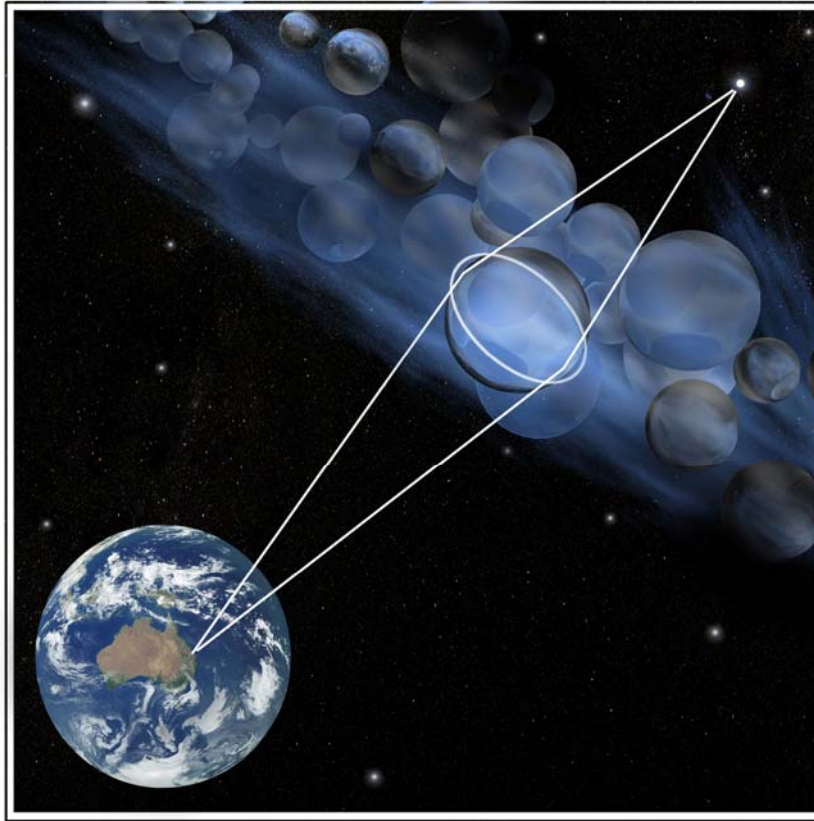
At the Stromlo Symposium, I presented a paper on the QVS source the GAVRT Program has been monitoring, "*Inter-Stellar Scintillation, Scattered Size and Microarcsecond Structure of the Unusual Source B0059+581*". Included in the presentation were the 2005 GAVRT 2.3 GHz QVS data, which shows the clear annual cycle of the variability pattern.

The authorship also emphasises the international nature of astronomy and the international extent of the GAVRT Collaboration; Jim Lovell and myself from Australia, Alan Fey, Ken Johnston and Roopesh Ojha from the US Naval Observatory, Jean-Pierre (J.-P.) Macquart who holds a joint position at the US National Radio Astronomy Observatory and Caltech, Yasuhiro Koyama from Japan, Hayley Bignall from the Netherlands, and the GAVRT Team from across the world! The paper will be published in the journal *Astrophysics and Space Science* and a draft will be distributed to you next month.

It is important to note that such international collaboration is an immensely important aspect, not only for science, but also for society. In a world that is often fragmented, as it seems to be at the moment, it is essential that communication between humans all across the planet remain active and above politics.

The beautiful 2.3 GHz GAVRT data collected on B0059+581 during 2005, lies at the heart of our paper. We are looking at the changes in the flux density of the target source B0059+581 that are caused by Inter-Stellar Scintillation or ISS. ISS is a result of the

turbulent, ionized structures in the inter-stellar medium, ISM, of our Galaxy, which act on the radio waves very much like lenses. The ISM is in motion throughout the Galaxy and as it moves past the Earth, these fluctuations cause alternate focusing and de-focusing of the radio waves from a distant quasar on to our radio telescopes. This causes the flux density of the source, in our case B0059+581, to vary. The following shows this graphically for a radio telescope in Australia.

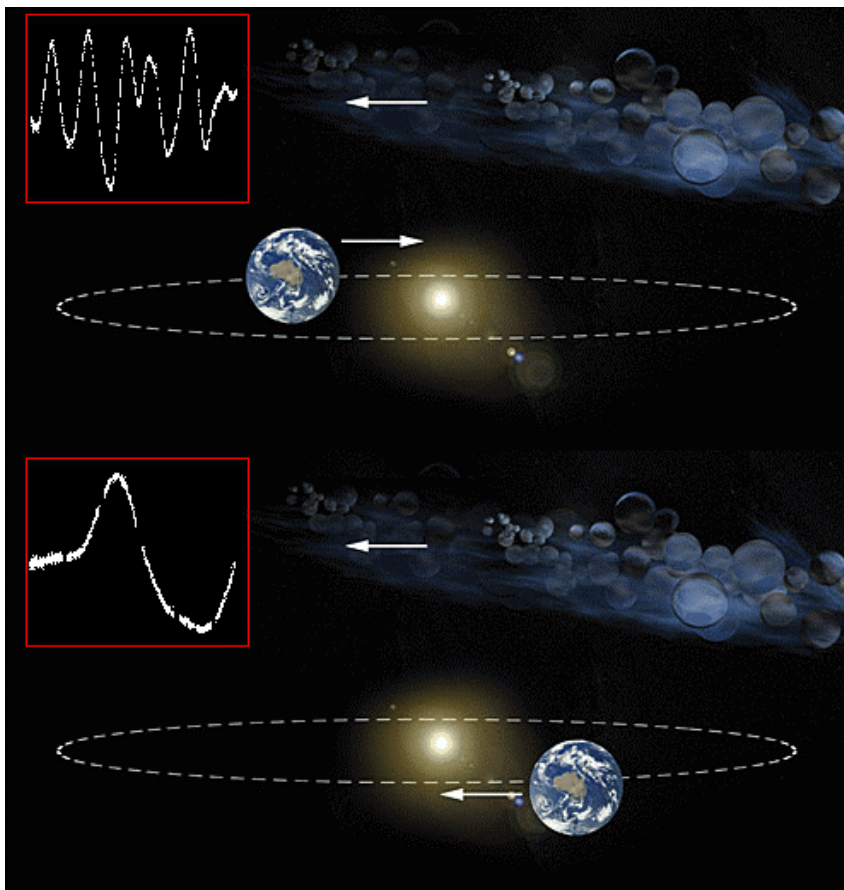


This phenomenon is the same as we see on a clear night when we look at the stars above us with our eyes. The stars *twinkle* due to the turbulent motion of the air around us as the young poets Jane and Ann Taylor wrote in 1806:

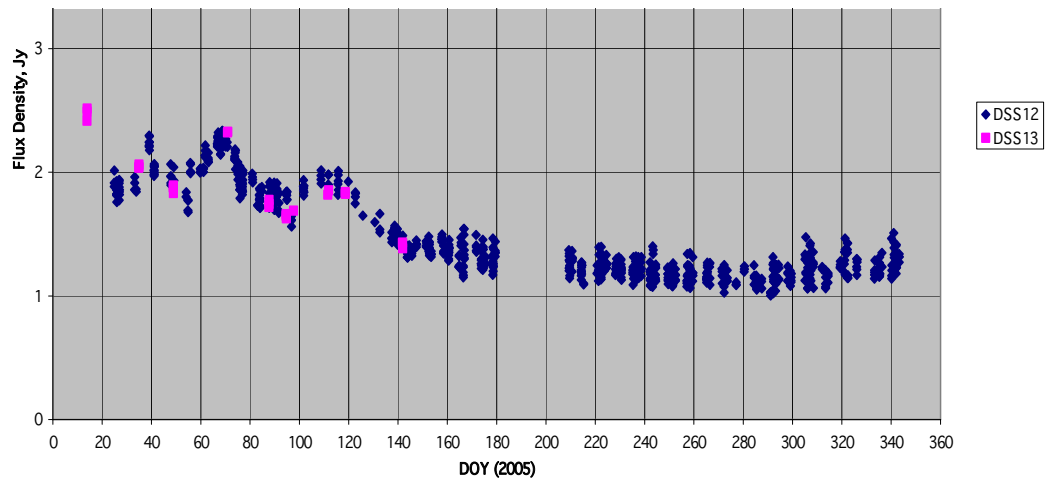
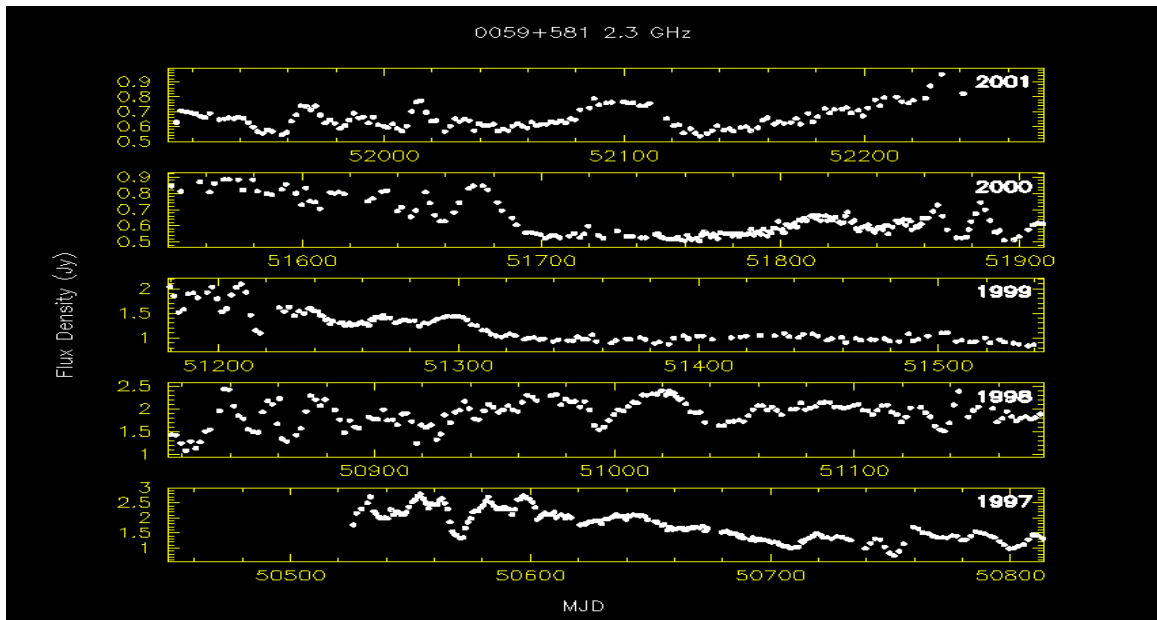
*“Twinkle, twinkle, little star,
How I wonder what you are.
Up above the world so high,
Like a diamond in the sky.
Twinkle, twinkle, little star,
How I wonder what you are!”*

When you've looked closely at the twinkling stars, you may have also noticed that the stars twinkle but the planets do not. The stars have a very small angular size because they are far, far away, but the nearby planets have a large angular size. Something very similar applies with the radio sources. Only the smallest, most compact radio sources are found to actually twinkle. The value of observing interstellar scintillation is that it allows us to find the smallest, most compact radio quasars and study them in detail. At the same time we are also learning about the inter-stellar medium, ISM, which is the *stuff* in between the stars in our Galaxy. Actually, the ionized inter-stellar medium gives us access to something akin to a radio telescope several hundred thousand kilometres in diameter. So, when you're observing with QVS you're not just using a 34-m diameter radio telescope, you're actually observing with a 200,000-km diameter radio telescope!

By measuring changes in the variability characteristics over the course of the year, we can determine how the quasar appears to know when it's a New Year, despite being billions of light years away. These yearly changes, shown in the diagram below, are known as the **annual cycle**. For half of the year, as the Earth revolves around the sun, the Earth and interstellar medium are moving in roughly opposite directions. During this period, their relative speed is rapid, but the variation time-scale is short. Six months later, however, the Earth is on the opposite side of its orbit and is moving roughly in the same general direction as the ISM, therefore making the relative speed slower and the time-scale longer.



The annual cycle in B0059+581 can be seen in our 2005 GAVRT data. It is especially clear if we also include earlier measurements made from 1997 through 2001. Here is the 2.3 GHz data from the Japanese telescopes and, below, is your great GAVRT 2.3 GHz monitoring results from 2005. You will notice that the GAVRT data is *smoother* in the sense that the variations are more easily tracked throughout the year. This is a distinct advantage of using one telescope for the program in which it was designed for. The Koyama et al. observations were taken for another purpose and were originally used for monitoring the crustal activity in the region around Tokyo (Koyama, Kondo, T., & Kurihara, N., 2001, Radio Science, 36, 223).



At the top is the 2.3 GHz data from Koyama et al., (Koyama, Y., Kondo, T., & Kurihara, N., 2001, Radio Science, 36, 223) for 1997 through 2001. Below are the plotted GAVRT 2.3 GHz data for 2005.

In particular, this demonstrates very clearly that the source is still showing the same dramatic variability that was seen back in the late 1990s. Moreover, this variability shows the same clear

annual cycle of a decade earlier, where the variations are strong with a 2 – 3 week time-scale, occurring earlier in the year around May-June and then effectively slowing down. Such a pattern demonstrates, unequivocally, that this variability is caused by *inter-stellar scintillation* and is not intrinsic to the source.

Now, while the GAVRT data is much smoother than the Japanese data, you will see the scatter of the individual measurements is about 0.3 Jy peak-to-peak, which may seem a little large. After all, this is a big 34-meter dish with a world-class, low-noise receiver. We can actually calculate what might be expected due to the known properties of the radio telescope and its receiver. This calculation makes use of the concept of the *thermal noise* of the receiver together with the collecting area of the dish. When we do that, it appears as though the observed scatter is indeed considerably larger than we calculate.

This is a very important point; if the GAVRT Program is to do the best science, then it must make the best measurements that it is capable of. So, just when the QVS campaign has achieved a really nice result for B0059+581, it seems that we're now going to explore how to improve the overall capabilities of the *Michael J. Klein Radio Observatory*, formerly known as DSS-12.

The QVS program is undergoing changes. This year's campaign is entitled "**Just when I'm out, they pull me back in, QVS 2007!**" The QVS program needs to take a leading role not only in monitoring these dramatic variable sources, but also in improving the performance of the dish for all of the GAVRT campaigns. Discussions are already going on with the JPL and Lewis Center engineers and astronomers. We will keep you up to date on the status of the overall effectiveness of our antenna.

The history of the discovery of B0059+581 illustrates the international nature of astronomy too. The source was first discovered in radio surveys of the northern sky made in 1983 and 1987 with the 91-meter (300 foot) telescope at Green Bank in the wilds of West Virginia, by Jim Condon and John Broderick, who worked at Virginia Tech. Unfortunately, while their survey was still in progress, the telescope collapsed on the night of November 15, 1988.

Because it is so compact, B0059+581 is also one of the radio sources that make up the International Celestial Reference Frame, ICRF. It is against this set of fundamental position reference sources that the most precise measurements of the period of rotation of the earth are being made. You may have heard of the occasional *leap-second* that has to be added to our precision clocks; well, these are in part due to B0059+581!

If you wish to follow up those two scientific meetings, their web address are: the Fifth Stromlo Symposium, **Disks, Winds & Jets – From Planets to Quasars**, <http://www.mso.anu.edu.au/5SS/>, and the **23rd Texas Symposium on Relativistic Astrophysics**, <http://www.texas06.com/>.

With very best wishes for 2007,

David Jauncey
Chief Research Scientist
Australia Telescope National Facility, CSIRO



B0059+581 was optically identified as a quasar and the redshift was first measured with the Russian 6-meter telescope near the town of Zelenchukskaya in the north Caucasus Mountains. Here's a neat picture taken in winter; do you recognize the cities that the signs are pointing to?

Moscow, Leningrad, Rostov Don, and Gorky