PROCEEDINGS OF SCIENCE

A VLBI antenna for the island of Madeira

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It was almost exactly 12 years ago, at the 4th EVN Symposium, that we first presented our project of placing a VLBI antenna at Madeira, ideally linked to the EVN. Now, the 10th EVN Symposium has already passed. Twelve years ago there were 10 antennas on the EVN, now we have 18. A lot of things have changed during these 12 yrs, the EVN now growing to become e-EVN with all antennas linked via fibre cable in order to do real time data acquisition and processing. On our side, we have selected and completed all tasks required to inspect in detail the best sites in Madeira: weather, RFI, horizon profiling, etc. And rather than having a stalled or stopped project we have now become more ambitious. We are keeping two sites at Madeira as candidate locations, since they both fit all requirements for placing a top-class radio astronomical instrument.

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1. Background

Madeira has been known as an excellent optical astronomical site (McInnes 1981). As regards the Radio Astronomy perspective, published interest has been (a lot) more discrete. In the late 70s "Madeira was considered as a possible location for a VLBA antenna." (Ken Kellermann, Priv. Commun.). It was, then, about 20 years later (in 1998) that the matter was put again to the attention of this community. More precisely, this was done at the EVN/JIVE Symposium No.4, on 22-24/10/1998, at JIVE. An (never published) oral account was given to the nine tens of participants on the plans to install a VLBI antenna at Madeira; that would (ideally) be a 25m, 43 GHz system. Those were very early stages. But the project got a good start: Richard Schilizzi suggested three names for a site selection committee (also fairly pointing out that money would always be something we would have to find on our own); almost all present at the Symposium in 1998 signed a declaration stating the interest in the radio observatory. These were vital information to persuade funding agents (the Universidade da Madeira, the portuguese National Science Foundation — FCT) to support the process that lead into the measurements described in Sections 3 and 4. And we now know what we have: two excellent sites.

2. Motivation

Why Madeira? Well, geographical location is really the main reason, by far. In fact, other Atlantic islands have been thought about for a number of years now (Cabo Verde, Açores, etc.) although no formal communication was ever presented to this community[1], to our best knowledge. The idea is to fill-in, as much as possible, the uv-plane 'mid-Atlantic gap' that has not yet gone out of the uv-coverage in VLBI observations, despite the fact that e-EVN can cover it a bit more due to the recent amazing increase in bandwidth (hence, sensitivity). Furthermore, Madeira is among the most seismically stable and hurricane free islands in the Atlantic.

When considering the EVN only (or, better, the e-EVN nowadays), the perspective for an antenna at Madeira has now quite different implications. In 1998 the EVN had only 10 antennas and Madeira would be south and west of them all, increasing the resolution of the EVN in a way that would make it better than the VLBA (by then, as now, the maximum baseline of the VLBA was 8600km while the EVN would jump from 8476km to 9950km). Of course, now this is no longer the case, since the EVN has 18 antennas and goes all the way from Arecibo (in Puerto Rico, USA) to Shangai and to South Africa, almost reaching the Earth diameter. However, Madeira would be crucial in another way: precisely because of these distant antennas at Arecibo, South Africa and Shangai, Madeira would fill the uv-plane close to the longest baselines in the array, where it is most needed, in order to increase the sensitivity in radio maps for features with sizes of the order of the size of the EVN beam. And just by looking at the worlwide EVN map (Figure 1) we do get how crucial would an antenna at Madeira be. Especially when our current plans involve a mm-wave large antenna ($\sim$50 m, 86 GHz).

Finally, it is also obvious from Figure 1 that, as a whole on the planet, the EVN has an east-west configuration. Madeira would help 'approaching' the southern hemisphere by pushing up the

[1]The astronomical community. In fact, there are on-going plans for placing two geodetic antennas at the Açores islands — Gómez-González et al. (2010).

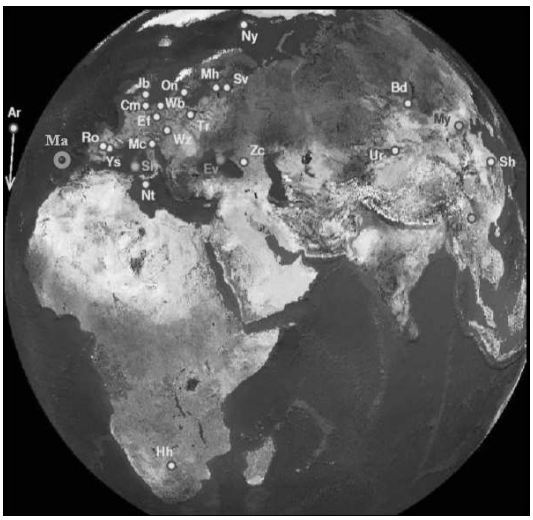

Figure 1: The EVN with Madeira (Ma).

sensitivity of the EVN for lower declination sources: the southern hemisphere is the region on the sky where most action will take place in the next few decades (via ALMA, SKA and E-ELT, for now). In fact, the current move south of the largest astronomical instruments skyrockets all Atlantic islands as particularly relevant places for VLBI radio antennas. Madeira might open the way for radio astronomical observations being made from new antennas at Açores[2], Cabo Verde, Fernando de Noronha (Brasil), etc.

3. Site surveying

The ideal site for a radio telescope is a shallow valley protected from man made interference. Ideally, the site should not be exposed to frequently gusty or very strong winds (under the risk of compromising most days in the year). Seven sites (A-G) were initially selected in Madeira for on-site inspection, after a careful study of military survey maps. After the visits, three were deemed as the best (A, D and F/G, the latter a combination of the 6th and 7th). It was then decided that extensive measurements should be made at all these three sites: i) meteorology; ii) RFI; iii) horizon profiling. Later, we have actually added precipitable water vapour estimates.

1. We got funding for only one automatic weather station so we had to circulate it through the three sites: one full year of measurements was conducted at each site (from late 2003 to 2007). Then, these would be correlated with the measurements at six other stations in the island that had climate normals (at least 30 years of data collection). The main variable to be measured was wind, although some other might have relevant implications (at least as regards on deciding which of the last three sites is really the best): relative air humidity, number of clear hours and precipitation, for example.

[2]The persuasion to increase the astronomical time at the future geodetic antennas in Açores would, therefore, be much stronger. See previous footnote.

2. In September 2005 we got borrowed equipment to measure RFI at the three sites during three random working days (one at each site). A total of 30 sweeps were done, from 80 MHz to 2 GHz in steps of 0.1 MHz. The total duration of each sweep was 64 mins.

3. Using a theodolite we measured the horizon profile at all three sites at ground level (in January 2005).

4. Results

4.1 Meteorology

Not a single day, over the full year sampled, had gusts stronger than 36 km/h. In fact, since the weather station is still gathering data today at the last site studied (D) we have an even stronger case for wind at the latter: in just over 4.5 yrs, not in a single day did we get gusts stronger than 36 km/h The average wind was well below this value at all sites. All three sites are quite humid (about 90% relative air humidity all year) and wet (it rains about 2.0–2.5 m per year) but with clear skies most of the time. The three can also get very dry at times (below 10% of relative air humidity).

4.2 RFI

At site A, in general, we measured $<$-80 dBm; a few peaks reached -40 dBm. At D and F/G the results are even better since, in general, we got $<$-90 dBm, with a few peaks reaching no more than -60 dBm. Hence, the D and F/G sites are radio quieter than the IAU recommendations for a radio site by a factor of, at least, 20! The A site is a bit noisier, but still below the IAU recommendations.

4.3 Horizon profiling

The three sites had their ground horizons established and all are excellent. D and F/G have it always below 10°, while A reached 15° but only at Azimuth 60°.

4.4 The two sites left

Mainly because of the RFI results, site A was removed from the site list. We are now left with two excellent sites (D and F/G) and it is not yet clear which one is the very best. The first sits at an elevation of 1300m, while F/G sits at 1000-1100 m (this is a gentle westlooking slope). The two sites D and F/G are presented in Figure 2, as located on a Madeira map, and in Figure 3 as Google Earth sees them... both reside in remote areas, at the heart of the Madeira Natural Park and, hence, hardly any development is expected in the coming years meaning that RFI should remain about the same.

5. The future

The future is bright. As it must be. The first step will be to produce a full dossier containing the case for a Radio Telescope at Madeira. This should be already done with the help of an initial consortium of national/international radio astronomers. Then, their home institutes and others are expected to join in the venture. Finally, a formal proposal for *any* suitable funding agency (all hypothesis considered) will be submitted. It might take five years. It might take another 12 or

Figure 2: The two best sites at Madeira (only the western half of the island is shown): D and F/G. Any of these is great for radio astronomy (see text and Figure 3).

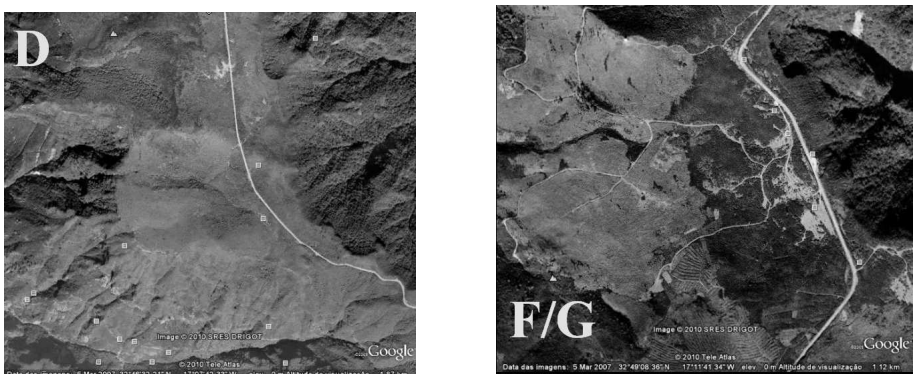

Figure 3: The two best sites at Madeira as seen by Google Earth. They are both inside the Madeira Natural Park. See also Figure 2.

more. It might even only be included in a 2040-50 decadal summary report like the Porcas (2011) summary. But it will be there, eventually...

Our optimism is well supported. In fact, while preparing this presentation, it was very gratifying to remind ourselves of what we presented in a poster way back into 1998 (at the EVN Symposium nr.4)[3]. In it, a single page in A4 listed all the items in the plan to develop Astronomy in general at Madeira. By then, not one of the items was done, but all were hoped: from hiring more astronomers, to supervising thesis, and communicating science to the public, a total of 13 items were listed. After 12 years, it was encouraging to find out that only *two* of the items in the list were not accomplished! And these relate to building a major optical or radio telescope at

[3]The scientific part of it actually got published in Augusto et al. (1999).

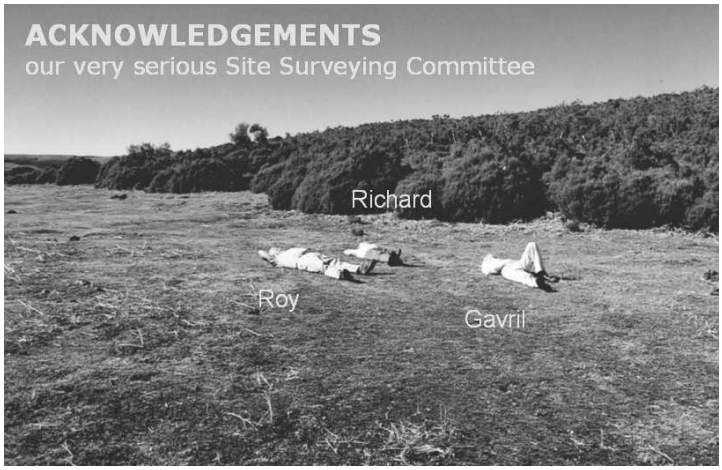

Figure 4: The three-expert committee for site selection at Madeira. The photo was taken at site D, on the 13th of May 1999. See Figures 2 and 3.

Madeira and a planetarium/museum for the Public. Hopefully, it will not take many more years to check these two out as well...

Acknowledgments

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