Committee on Radio Astronomy Frequencies

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To: Radio Spectrum Policy Group

Questionnaire on Long-term vision for the upper 6 GHz band

To whom it may concern,

On behalf of the Committee on Radio Astronomy Frequencies (CRAF) of the European Science Foundation (ESF) I would like to respond to your survey about the current and future uses of the upper 6-GHz band.

CRAF is an expert committee of the ESF and is funded by major European radio astronomy observatories and research institutes. Its aim is the preservation of the Quiet Sky for radio astronomy and other basic sciences, focussing on European activities. To achieve that goal, CRAF participates in meetings of national, regional and international spectrum organisations, such as the International Telecommunication Union (ITU) or the European Conference of Postal and Telecommunication Administrations (CEPT). CRAF's work not only entails advocating for scientific use of spectrum, but it also contributes directly to the regulatory processes of the ITU-R and CEPT with input documents. These documents cover regulatory topics as well as compatibility studies, which are a key ingredient towards successful coordination and co-existence of the many different active and our passive radio service.

Attached to this letter is a list of CRAF's answers to your *Questionnaire on Long-term vision for the upper 6 GHz band.*

Should you have any questions, please do not hesitate to contact us.

Yours faithfully,

B. Winkel

Benjamin Winkel

Answers to questionnaire

1. Current and future spectrum needs

Radio astronomy uses parts of the upper 6-GHz spectrum for observations of the methanol spectral line in the band 6650.0–6675.2 MHz, which is addressed in the ITU-R Radio Regulations footnote 5.149. In Europe, there is a large number of radio telescopes, which are equipped with state-of-the-art receivers to perform measurements of this spectral line and a fair share of the total observing time is invested, both with single dishes but also with telescope networks. In Europe, the band is used by stations in Belgium, Finland, Germany, Italy, Latvia, The Netherlands, Norway, Poland, Spain, Sweden, Switzerland and the UK. Furthermore, the frequency is of interest for geodetic measurements with VGOS stations and the Square Kilometre Array Observatory in South Africa, which receives significant funding from several European countries. A full list of European RAS stations utilising the band can be provided on request.

The 6.6685192 GHz methanol maser line is essential to study the formation of massive stars. These stars form deeply embedded in dense, dusty molecular clouds and, despite being less than 1% of total stellar population, they shape the structure and evolution of galaxies. How these stars form is an important and still unanswered science question; observations require very high angular resolution but precisely locating these formation sites is difficult. The 6.7 GHz methanol maser is by far the best signpost astronomers have, to pinpoint a forming massive star[1] [1,2,3]. The 6.7 GHz methanol maser is observed in many large-scale single-dish and interferometric surveys to identify massive star formation in the Milky Way disk [5,6,7,8]. Methanol maser emission is compact (emitted from a small area on the sky). This also makes it an ideal target for very long baseline interferometry (VLBI), using large networks of antennas such as the Very Long Baseline Array in the US or the European VLBI Network (EVN). Through international collaborations, the EVN covers three continents in ITU-R Regions 1 and 3. Thanks to the milli-arcsecond resolution of VLBI, astronomers can measure the distances and proper motions of massive young stars through methanol masers and unravel the structure and the rotation of the Milky Way[2] [9]; see Fig. 1.

With VLBI, also the maser cloudlet distribution, motions, and the magnetic fields around the forming stars can be measured. No other spectral line can be used for this. Such observations also allow us to study the mechanisms through which the star grows [10,11].

Methanol maser observations have increased world-wide. Many radio antennas, single dish as well as telescope arrays, observe the methanol line for 1000s of hours every year. Astronomers have joined forces in the Maser Monitoring Organisation[3] where they share information and collaborate. Particularly interesting sources are often followed up with multi-epoch VLBI observations to investigate the accretion mechanism in detail [12]. Losing access to the 6.7 GHz frequency would heavily obstruct the present rapid progress in our understanding of high-mass star formation.

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[1] There are about 1200 high-mass star-forming regions with methanol maser detections, see the maser database at https://maserdb.net/stats.pl?molecule=CH3OH_II&.

[2] The Bar and Spiral Structure Legacy survey website is available at http://bessel.vlbi-astrometry.org/.

[3] The Maser Monitoring Organisation website is available at https://www.masermonitoring.com/.

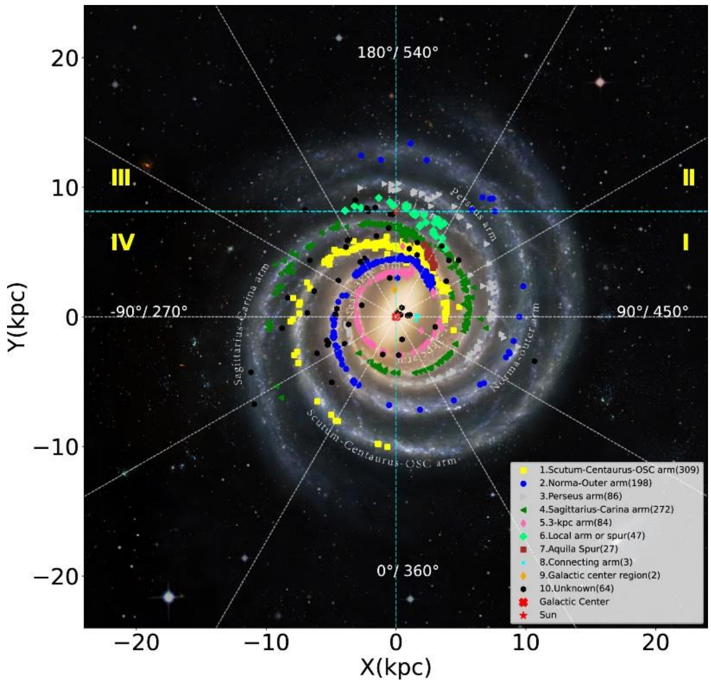

Fig. 1: An example of the science done with 6.7 GHz methanol masers: The detected galactic plane distribution of 6.7 GHz methanol masers (colored dots) overlaid on an artist impression of the Milky Way. The Sun is indicated by a red star. The illustration is borrowed from the article Yang et al. 2024.

With RR 5.149 the ITU-R has recognised the importance of methanol observations in the 6.6 GHz band. RR 5.149 states that "in making assignments to stations of other services to which the bands: [...] 6 650–6 675.2 MHz [...] are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. [...]". At WRC-23, with Resolution 220 this was echoed in *invites administrations 3*: "to take all practical steps to protect the radio astronomy service (RAS) from harmful interference in the frequency band 6 650-6 675.2 MHz, [...]". It is noted that unlike RR 5.149, Resolution 220 does not refer to assignments, only. Therefore, Resolution 220 seems highly relevant for the European harmonisation process.

As the methanol maser frequency is fixed by nature, it is not possible to shift the observing band to some other frequency, which is a solution that was feasible for the EESS.

2. Impact on radio astronomy by introducing MFCN

During the CEPT and ITU-R processes that led to the identification of IMT in the upper 6-GHz band at WRC-23, CRAF demonstrated with detailed compatibility calculations that minimum separation distances, which would be required for the protection of RAS observations, are large. For the in-band sharing scenario, several hundreds of kilometres may be necessary and at least several dozens of kilometres for adjacent frequencies or in the spurious domain. Therefore, any coordination between RAS and MFCN could not be addressed at national level only.

If the protection criteria are not met, this might have severe consequences for the European scientific community. In Europe, we have many of the most relevant radio astronomical facilities in the world. At the same time, owing to the relatively higher population density, protection measures such as radio quiet zones or other types of coordination zones do not exist for most observatories. In the past, this was compensated for by strong support from European spectrum agencies, which maintained good observing conditions for decades, in line with the ITU-R Radio Regulations. Reducing this protection would also mean putting European scientists at a huge disadvantage compared to astronomers in other parts of the world, impacting the European research and education landscape.

3. Potential mitigation measures to improve compatibility

With a recent input document (R23-WP7D-C-0013) to ITU-R Working Party 7D, we analysed the effectiveness of various potential mitigation measures, which could help to improve the coexistence situation between MFCN and radio astronomy. While these deserve further investigation, we can already highlight some key elements:

1. With regards to the required separation distances, it makes a big difference whether the MFCN base stations are fully affected by so-called clutter losses (i.e., when the antennas were installed below the roof-tops) or not. This could potentially reduce the coordination sizes by up to a factor of two. This aspect could also be incorporated into the site planning of the MFCN base stations.
2. In general, radio astronomy observatories should be put in remote locations, ideally with some level of natural terrain shielding. However, in practice this can only apply to new observatories and, unfortunately, some of the already-established European radio astronomy facilities are in rather open terrain.
3. Modern 5G MFCN equipment can utilise beam forming with their active antenna systems, which can be used to minimise the radiated power towards the radio telescopes. First analyses indicate that the overall effect of this mitigation technique would be smaller than that of clutter utilisation. Nevertheless, in combination with other possibilities, it may help to further improve the situation.
4. So far, studies have revealed that base stations have a much higher interference potential than user equipment. Thus, one possibility would be to also limit or coordinate the use of downlink channels in the radio astronomy frequency band 6650.0–6675.2 MHz and manage the deployment of base stations in the vicinity of our observatories.

References

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