Precision Low-Frequency Radio Sky Brightness Measurement

Luke McKay *(1), Ravi Subrahmanyan (1), Aaron Chippendale (1), Pietro Bolli (2), Georgios Kyriakou (2), and Ronald E Ekers (1)
(1) CSIRO Space and Astronomy, 26 Pembroke Road, Marsfield NSW 2122, Australia, e-mail: luke.mckay@csiro.au, ravi.subrahmanyan@csiro.au, aaron.chippendale@csiro.au and ron.ekers@csiro.au
(2) National Institute for Astrophysics, Arcetri Astrophysical Observatory, Largo E. Fermi 5, 50125 Firenze, Italy, email: pietro.bolli@inaf.it, georgios.kyriakou@inaf.it

A precision measurement of the low-frequency radio sky brightness is of significant interest for the astronomical community. It can constrain diverse astrophysical phenomena including observations of highly energetic cosmic rays, neutrinos, and models of extragalactic emission [1]. The radio sky brightness dominates the system temperature of low-frequency radio telescopes and must be accurately accounted for when calibrating sensitive total-power measurements to detect cosmic dawn and reionisation via the redshifted 21 cm line. Further, accurately measured radio sky brightness could serve as a stable flux-scale reference for calibrating the SKA Low telescope. The flux scale for cm and longer wavelengths is based primarily on observations of some of the brightest objects in the radio sky using well-defined antennas that can be easily modelled [2]. Modern systems have improved in accuracy but are still based on these early measurements.

In this work, a precision measurement was taken of the low frequency radio sky from 75 MHz to 350 MHz using a single wideband log-periodic SKALA4.1 antenna [3]. The antenna was placed on a 40 m ground mesh at Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory. The antenna was connected to a receiver that continuously and in-situ self-calibrates for receiver noise, impedance mismatch and bandpass [4]. The new improved measurements have been compared to the Global Sky Model (GSM) that was constructed as a fit to previous all-sky images made in this band [5]. We developed a correction to apply to the GSM consisting of a scaling and offset factor to improve the absolute calibration of the model. The work represents a significant improvement in the measurement accuracy of the diffuse sky brightness in the SKA Low band. Below, the uncorrected GSM is plotted against the calibrated measurements at different UTC times. Sky models scaled to our measurements serve as a stable reference for calibration of SKA Low stations. As a result, these measurements serve to define the absolute flux density scale of the SKA Low telescope. We would like to thank the staff at SKAO for their assistance.

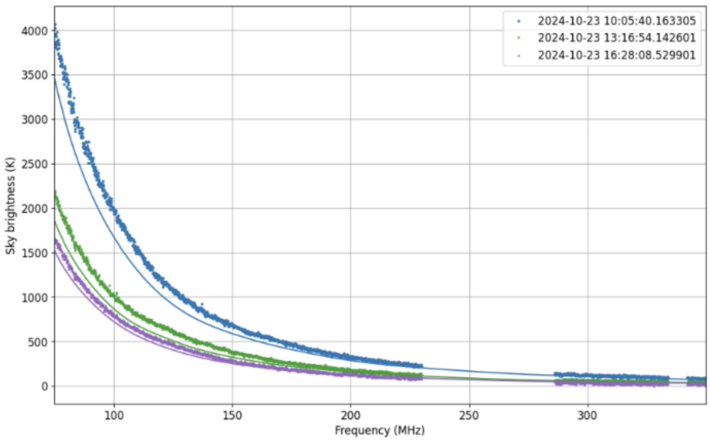

Figure 1. Uncorrected GSM (thin trace) and calibrated radiometer measurements (thick trace) at different UTC times [5].

1. M. Büsken, et al. "Uncertainties of the 30–408 MHz Galactic emission as a calibration source for radio detectors in astroparticle physics," in *A&A*, vol. 679, pp. A50, 2023.
2. Baars, J. et al. “The absolute spectrum of Cas A: an accurate flux density scale and a set of secondary calibrators.”, Astronomy and Astrophysics, vol. 61, EDP, pp. 99–106, 1977.
3. P. Bolli *et al*., "Test-Driven Design of an Active Dual-Polarized Log-Periodic Antenna for the Square Kilometre Array," in *IEEE Open Journal of Antennas and Propagation*, vol. 1, pp. 253-263, 2020,
4. McKay, L., et al, "Continuously field-calibrated radiometer for the detection of the cosmic dawn," in *Proceedings of the XXXVth URSI General Assembly and Scientific Symposium – GASS 2023*, 2023.
5. Zheng, H., et al, “An improved model of diffuse galactic radio emission from 10 MHz to 5 THz”, *Monthly Notices of the Royal Astronomical Society*, Volume 464, Issue 3, January 2017, Pages 3486–3497,