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Large Satellite Constellations and the Next-Generation Ground-Based Cosmic Microwave Background Survey, CMB-S4

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The accelerating deployment of large satellite constellations in LEO, with the aim of providing ubiquitous worldwide telecommunications and internet access, challenges the existing coexistence regime for active and passive use of the radio spectrum.[1] At present, radio astronomy is enabled by three modes of protection—first, by primary or shared spectral allocations in the ITU Radio Regulations and comparable allocations within individual administrations; second, by statutory geographic separation measures such as radio quiet zones; and third, by the de-facto geographic protection afforded by the remote locations of many observatories. Of these, the second and especially third modes of protection are in danger of being rendered obsolete by tens of thousands of orbiting transmitters. This is critical, because while spectral protection will remain effective for an important part of radio astronomy, leading-edge science that depends on access to broad spectral bandwidths including spectrum allocated to active services will only remain possible through coordinated protection from active transmitters.

One such class of advanced science now at risk is observational cosmology surveys targeting the cosmic microwave background (CMB). Measurements of this primordial black body radiation and the radiation associated with the intervening universe and its interaction with the CMB enable studies of the physics governing the origin and subsequent evolution of the Universe. These surveys focus on the degree to arc-minute scale angular brightness fluctuations of the intensity and polarization of the CMB, and must utilize the full available bandwidth in the atmospheric transmission windows across the millimeter-wave band. Historically, CMB instruments have operated from remote, dry, high-altitude sites that minimize foreground radiation from the Earth's atmosphere and afford isolation from terrestrial transmitters, including the South Pole and the Atacama desert in Chile.

These challenging measurements have advanced through decades of technology development. The detectors employed in these experiments are large arrays of background-limited polarization-sensitive bolometers cooled to sub-Kelvin temperatures that require years of integration time on the sky to reach their sensitivity goals. The CMB Stage 4 (CMB-S4) project will achieve the next leap in sensitivity of CMB surveys.[2] The experiment will deploy some 500,000 detectors on telescopes installed at the South Pole and in the Atacama desert, covering all atmospheric windows from 20 – 315 GHz. This unprecedented sky coverage and sensitivity will also open a new window on the time-variable universe at millimeter-wave frequencies. In recognition of its significant potential scientific impact, CMB-S4 was recognized as a priority large project by the Astro2020 decadal survey of astronomy and astrophysics.[3]

In this presentation, we will assess the potential effect of future large satellite constellations on the ability of CMB-S4 to achieve its scientific aims, and possible modes of coordinating with satellite operators to minimize their impact. Engagement and communication will be essential, both through the regulatory process and directly with system operators. We will discuss our efforts towards that end, including field testing and a recently-completed ITU report on technical and operational characteristics of CMB detectors.[4]

References

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[4] International Telecommunication Union, "Technical and operational characteristics of broadband, background-limited detectors operating in the millimetre-wave regime," Report ITU-R RA.2512-0, October 2022.