Photon Statistics for Space Terahertz Astronomy

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Photon counting technology in terahertz frequency region will open a new field in astronomy that used photon statistics as an observational tool. Electromagnetic wave has been treated as either stream of independent photons in shorter wavelengths or as radio wave in longer wavelengths. However in far-infrared wavelengths or terahertz frequencies, both characteristics of the photon and the wave appear. Photons in this wavelength region are usually bunched, whose photon statistics tell us the physical states of emission sources, such as thermodynamic temperature when the source is in equilibrium.

When one make use of the bunched photon measurements on two telescopes, one can measure their intensity correlation, as demonstrated by the Hanbury-Brown and Twiss (HBT) experiment for the intensity interferometry. Photon counting detectors would further improve the interferometer technology and realize high sensitivity aperture synthesis interferometry for future space programs, which can be named as Photon Counting Terahertz Interferometry (PCTI).

The technology is based on the intensity correlation which is the same as in HBT, and by using fast photon counting detector, it would be possible to achieve high time resolution better than one wavelength passing, which can be used as the phase information of intensity fluctuation. Furthermore, the element telescopes can be independent and number of elements is not limited and very long baseline interferometry could be realized.

Detector technology based on superconducting tunnel junction detector is proposed. Their fast quantum response to terahertz photons enables wide bandwidth measurements to be used to obtain the phase information of the intensity fluctuation. Series connected junctions coupled with high-impedance and low noise amplifiers can be use to count each photon signal with enough signal-to-noise ratio when leakage current of junction is less than an order of pico-ampere.

With the ultimate sensitivity under low-background condition in space, PCTI would image a few hundred Kelvin sources with micro-arcseconds angular resolution using baseline length of several thousand kilometers in far-infrared wavelengths.

References

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