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letters

Hanbury Brown and Twiss: Important, anti-weird, beautiful

Daniel Kleppner's Reference Frame entitled "Hanbury Brown's Steamroller" (PHYSICS TODAY, August 2008, page 8) provided much insight into the correlation of photon counts from separate detectors. However, more than just demonstrating an interesting physical phenomenon, the technique was important for astronomy. In combination with radiant fluxes at Earth's surface, the angular diameters of 32 hot stars measured with the intensity interferometer near Narrabri, Australia,[1] gave empirical absolute surface fluxes in erg cm^{-2} s^{-1} Hz^{-1} for the stars. With the UV flux measurements from the *Orbiting Astronomical Observatory-2* and the longer-wavelength data from the ground, the angular diameters gave the stellar surface temperatures.[2] Previously, astronomers depended on fitting flux distributions to imperfect model atmospheres.

References

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I read with interest Daniel Kleppner's lucid column on Hanbury Brown's "steamroller." Kleppner mentions an aspect of the Hanbury Brown and Twiss (HBT) effect that at first seemingly defied a quantum interpretation; he terms it "anti-weird," since in certain cases a completely classical understanding is possible. Other aspects of the Hanbury Brown physics are truly weird in the sense that they violate a Bell inequality.

I and collaborators Peter Samuelsson and Eugene Sukhorukov have proposed an interferometry experiment with fermions in an electrical conductor. Carriers are injected into the conductor from two contacts, and the cross correlation of the electrical current is measured at two other contacts along the conductor.[1] In that arrangement, it is possible to investigate the Aharonov–Bohm effect in the fermionic HBT interferometer. Our initial discussions of such an effect date back to the early 1990s.[2] My collaborators and I found a geometry in which the conductance (intensity) shows no Aharonov–Bohm signature, but the current correlation (intensity correlation) is nevertheless a periodic function of the Aharonov–Bohm flux.[1]

We termed our finding the two-particle Aharonov–Bohm effect. The effect was recently observed by a group headed by Moty Heiblum at the Weizmann Institute of Science. His team cooled a mesoscopic conductor to tens of millikelvin and measured its conductance and noise correlations.[3] Theoretical work by Carlo Beenakker at Leiden University has shown that due to orbital quasiparticle entanglement,[4] the two-particle effect is equivalent at zero temperature to a violation of a Bell inequality.[1] The case of nonzero temperature is more complicated and is still a subject of research.[5] The possibility of observing truly weird quantum physics is certain to increase interest in Hanbury Brown's physics.

References

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I found Daniel Kleppner's Reference Frame concerning the Hanbury Brown and Twiss (HBT) effect and its applications very interesting. In particular, Kleppner mentions recent beautiful experiments using the HBT effect to explore the physics of quantum gases. The applications have been even more important than it would appear from Kleppner's piece, if one considers the role that time-dependent intensity correlations of scattered light have played in dynamical studies of critical phenomena and, more generally, of phase transitions in fluids, liquid crystals, and soft matter. Early contributions to such studies came from George Benedek (an MIT colleague of Kleppner's) in the 1960s. Herman Cummins, working in those days at the Johns Hopkins University, also made relevant contributions. In the past 40 years, thousands of papers have described the applications of intensity-correlation spectroscopy not only to statistical physics but also to physical chemistry and biology.

Concerning spatial intensity correlations, I agree with Kleppner that until a few years ago no important applications had appeared, mainly because they simply reflect, in the far field, the geometric properties of the volume from which the light is collected. However, in addition to what Kleppner describes, recent work by Marzio Giglio and coworkers (University of Milan) on near-field scattering from colloidal particles[1] promises exciting new developments.

Reference

1. See, for instance, M. Giglio, M. Carpineti, A. Vailati, *Phys. Rev. Lett.* **85**, 1416 (2000).

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Kleppner replies: I thank Donald Morton for calling to my attention the measurements of a number of hot stars in the 1970s. My comment that the Hanbury Brown and Twiss (HBT) effect was never "particularly important" for astronomy reflected Hanbury Brown's own assessment of his accomplishment. I believe that my comment is defensible if the impact of intensity interferometry on astronomy is compared with, for instance, the impact of very long baseline interferometry. Vittorio Degiorgio quite correctly points out that intensity correlations have long been a tool for studying critical phenomena. The early