



Contribution ID: 169

Type: Plenary/Parallel talk

Photons and Light Propagation in Massive, Non-Linear, Standard-Model Extension Theories for astrophysics and cosmology

Astrophysical observations are largely based on electromagnetic signals still read with the Maxwellian massless and linear theory, possibly an approximation of a larger theory, as Newtonian gravity is for Einsteinian gravity in weak fields. Photons are the sole free massless particles in the Standard-Model (SM). Apart from massive formalisms (de Broglie-Proca, Bopp, Stueckelberg and others), the SM Extension dresses the photon of a mass dependent from the Lorentz-Poincaré symmetry violation. Non-linear theories by Euler-Heisenberg (for second order quantum electrodynamics and strong magnetic fields) and Born-Infeld (to normalise the infinitesimal charge) and followers complete the picture of the Extended Theories of Electromagnetism (ETE). Adopting ETE lead to surprising options for reading the universe: deviations from Maxwell's laws; light dispersion with a bearing on multi-messenger astronomy; birefringence; photon frequency shift in vacuo with a bearing on the red shift and dark energy. Some of the results in theory, observations and experiments from a collaboration (CERN-King's College London, Univ. Napoli, UERJ and CBPF Rio de Janeiro, IAC Tenerife and other institutes) will be addressed. Finally, time permitting, the application of the Heisenberg uncertainty principle to cosmology shall be mentioned with respect to the Hubble tension and the Hubble-Lemaître parameter as quantum measurement.

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Session Classification: Poster session