Contribution ID: **7** Type: **not specified**

Dynamics and Emissions of Accreting Axion Clouds

Tuesday, 12 May 2026 16:10 (15 minutes)

Ultralight axion fields can form gravitational atoms around compact objects, in which self-interactions drive the relaxation of axion waves into bound states that grow exponentially. Once the field amplitude approaches the axion decay constant, nonlinear dynamics become essential. We identify two distinct regimes of late-time evolution, determined by the gravitational fine-structure constant and the cloud growth rate: a Bosenova regime, characterized by collapse accompanied by explosive axion bursts, and a weak-saturation regime, in which the outward axion flux induced by self-interactions balances the relaxation pump. In the saturation regime, the resulting axion radiation exhibits discrete spectral lines at odd multiples of the bound-state energy, directly reflecting the structure of the axion self-interaction potential. We show that axions with a pure cosine potential and those with a QCD axion-like potential predict distinct emission spectra, enabling terrestrial detection of the axion flux to discriminate between ultraviolet axion models.

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Session Classification: DM+Axion+early universe