

**PHYSICS AND ASTRONOMY  
COLLOQUIUM**

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**The Emergence of Structure in the  
Early Universe: Massive Galaxy  
Protoclusters Discovered with the  
South Pole Telescope**

Abstract

The sub-millimeter galaxy (SMG) population represent the most intense stellar nurseries in the Universe. Their high star formation rates of 200-2000 Msun/yr (compared to the Milky Way's 1 Msun/yr) pose a unique challenge for cosmological simulations of how galaxies form and evolve, particularly in the first few billion years after the Big Bang. They are 1000 times more prevalent 10 billion years ago than today, highlighting a peak epoch of galaxy building, and contributing significantly to the buildup of the Universe's stars.

SMGs are ubiquitous in distant, massive galaxy "protoclusters", the precursors of rich galaxy clusters -- the most massive gravitationally bound objects in the Universe. As such