High noon for cosmic giants: SPT2349-56

beacons for massive galaxy formation from the South Pole Telescope

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Hubs in the emerging cosmic web

Giant elliptical galaxies in the local Universe are typically located in the centers of galaxy clusters, surrounded by quiescent satellites and a hot, chemically enriched intracluster medium. While cluster environments are well studied out to z = 1-2, the formation process in the first two billion years remain enshrouded in cosmic history. Challenging the successful hierarchical formation scenario, giant elliptical precursors are observed in compact groups of vigorously star-forming, extremely submm-bright, dusty galaxies[6]. These protocluster (PC) cores are the main candidates for the first stages of cluster formation. Yet, it is unknown whether all cores will grow into massive clusters by z = 0, or remain isolated as massive galaxies in the field[5]. To distinguish these two modes, a statistical sample of PC cores is required. *ALMA* continuum and line observations, with unparalleld submm sensitivity and resolution, offer the best tools to understand the nature of PC cores at z>3.[9,10]

Publications

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[2] Chapman, S.C. et al., 2023, arXiv:2301.01375
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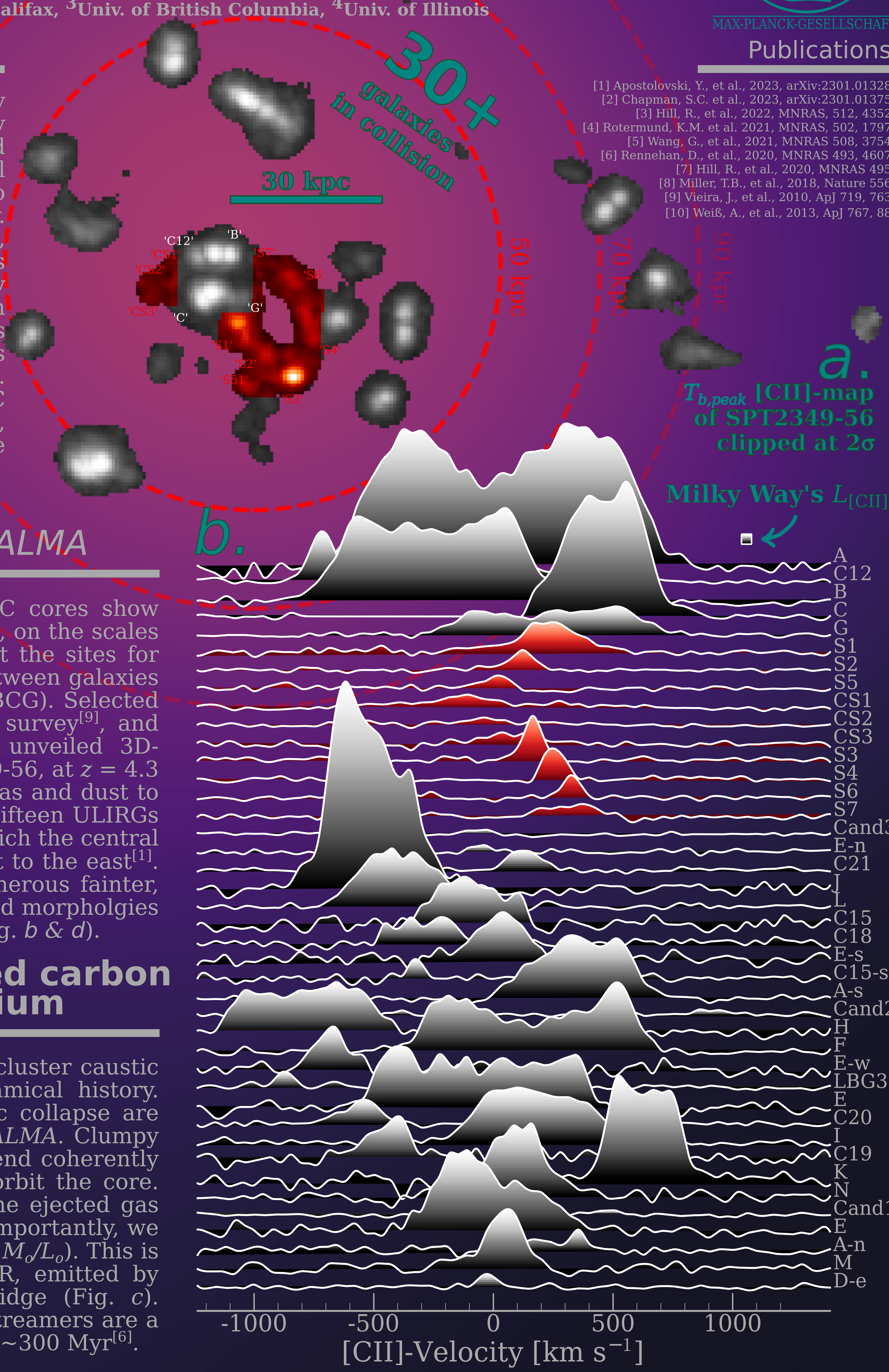
[4] Rotermund, K.M. et al. 2021, MNRAS, 502, 1797
[5] Wang, G., et al., 2021, MNRAS 508, 3754
[6] Rennehan, D., et al., 2020, MNRAS 493, 4607
[7] Hill, R., et al., 2020, MNRAS 495
[8] Miller, T.B., et al., 2018, Nature 556
[9] Vieira, J., et al., 2010, ApJ 719, 763
[10] Weiß, A., et al., 2013, ApJ 767, 88

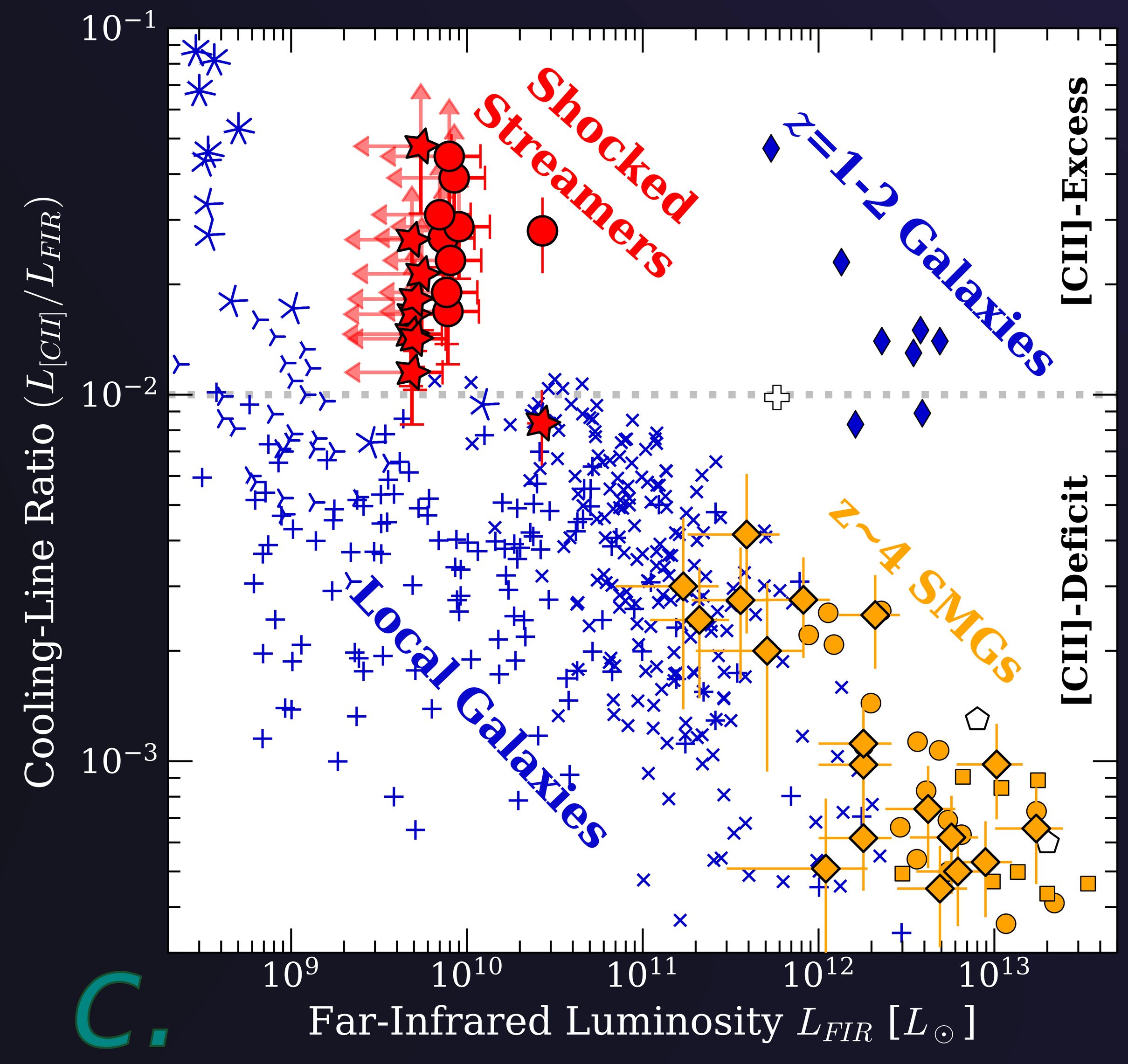


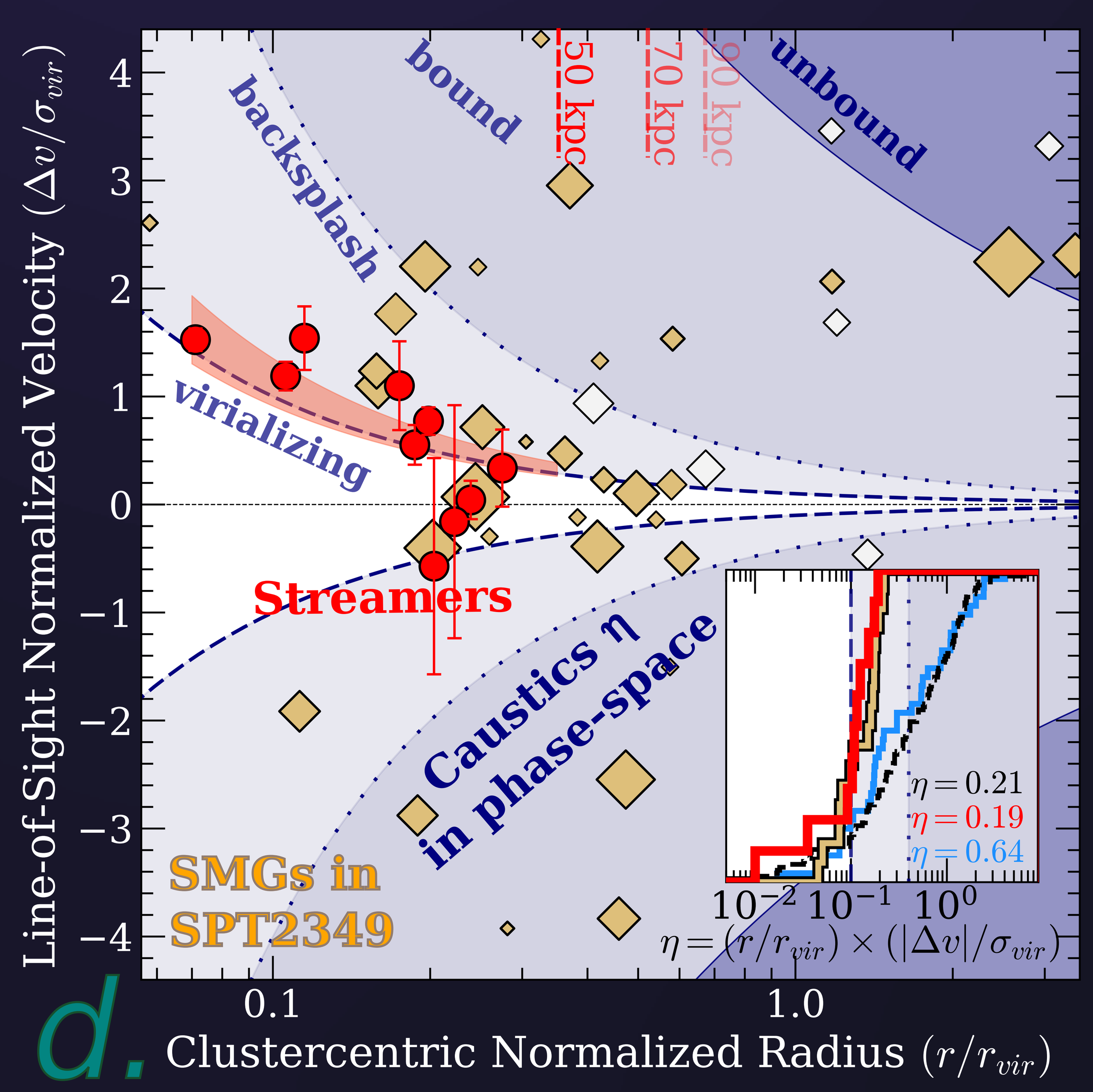
Monolithic collapse at z=4.3 of a protocluster core as seen by *ALMA*

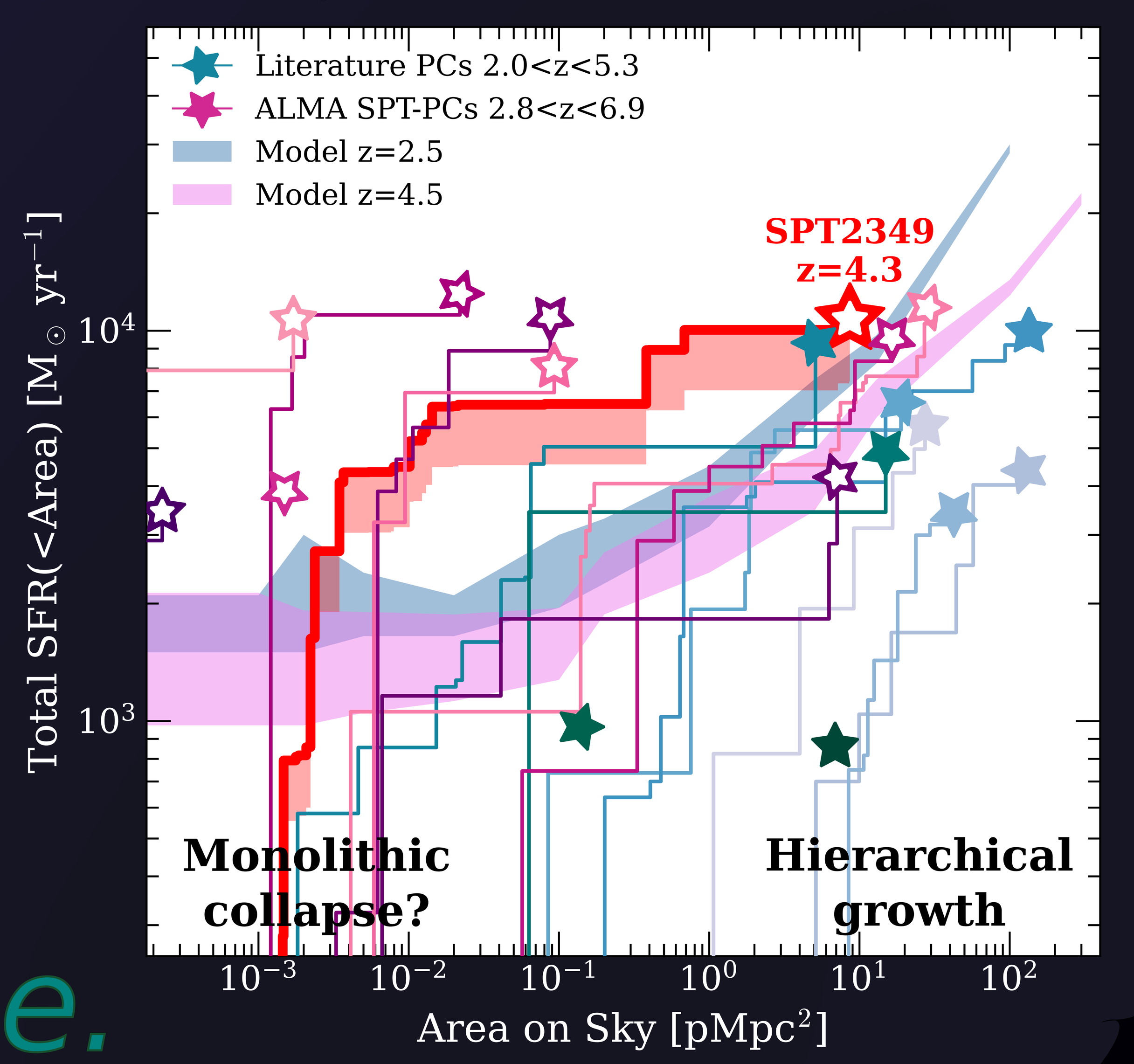
Characterized by enormous molecular gas reservoirs, PC cores show spatially correlated star-formation, totalling 10'000 M$_o$ yr^{-1}, on the scales of the emerging cosmic web[5] (Fig. *a*, *e*). They represent the sites for heat injection and chemical enrichment of the medium between galaxies and around the mass-dominant brightest cluster galaxy (BCG). Selected from the 25'000 deg^2 large South Pole Telescope (SPT) survey[9], and guided by 870μm APEX/LABOCA maps, *ALMA* finally unveiled 3D-distances to the ten brightest SPT-PCs. Strikingly, SPT2349-56, at z = 4.3 or just 1.4 Gyr after the big bang, contains enough cold gas and dust to form ~10^{12} M_o of young stars at the current SFR[3,4,5,6,7]. Fifteen ULIRGs are found within only 70 kpc in projection[7,8] (Fig. *a*) of which the central triplet hosts a radio AGN[2] and a ~60 kpc Ly-α blob offset to the east[1]. Deep, multi-cycle [CII]158μm line observations show numerous fainter, gas-rich galaxies with highly velocity-overlapping, disturbed morpholgies - a strong indicator for the imminent PC core collapse[7] (Fig. *b* & *d*).

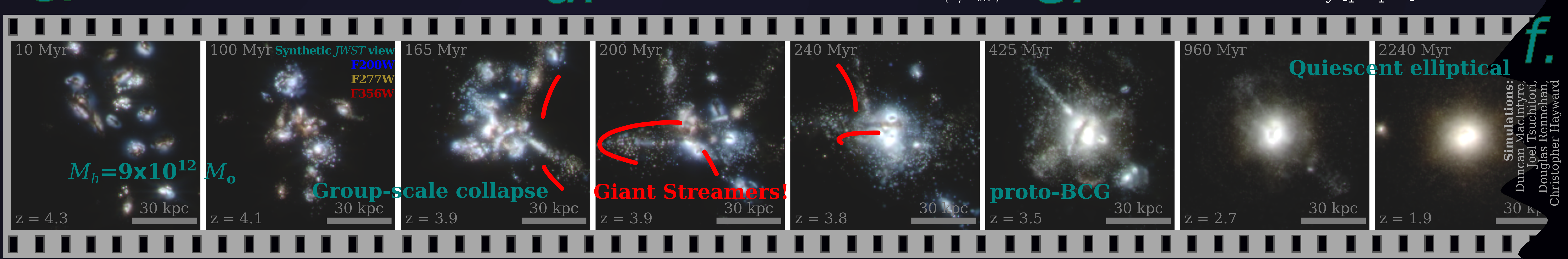
Giant streamers of shocked ionized carbon enrich the proto-intracluster medium

At least half of the SMGs in SPT2349-56 share the same cluster caustic in phase space (see Fig. *d*), hinting at a similar dynamical history. Surprisingly, we find that the beacon for this monolithic collapse are bright tidal streamers, serendipitously discovered with *ALMA*. Clumpy ionized carbon arcs, bright in [CII] (red in Fig. *a*, *b*), extend coherently over l_{3D}~60 kpc, and follow the galaxy-caustic as they orbit the core. Cold stripped material, $L_{[CII]}$ = 3.0±0.2 x10^9 L_o, traces the ejected gas mass of 8.9±0.7 x10^9 M_o - an early intracluster medium. Importantly, we measure a ten times lower mass-to-light ratio ($\alpha_{[CII]}$ = 2.95 M_o/L_o). This is explained by a strong boost in [CII]-luminosity over FIR, emitted by shocked molecular clouds in a group-sized stripped ridge (Fig. *c*). Supported by numerical simulations (Fig. *f*), these gaint streamers are a signpost for the rapid assembly of a proto-BCG within just ~300 Myr[6].









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