C-19: Tidal debris of a dark matter-dominated globular cluster?

Observatoire astronomique de Strasbourg | ObAS

Raphaël Errani and friends from the Pristine collaboration

rerrani.github.io

arXiv:2203.02513

Observational overview. The recently discovered C-19 stellar stream is a collection of kinematically associated metal- poor stars in the halo of the Milky Way lacking an obvious progenitor. The stream spans an arc of $\sim 15°$ on the sky. The narrow metallicity dispersion of stars with available spectra, together with light element abundance variations, suggest a globular cluster (GC) origin. The observed metallicity ([Fe/H] ≈ -3.4), however, is much lower than that of any known GC, and the unusual width and velocity dispersion of the stream are consistent with a possible dwarf galaxy origin.

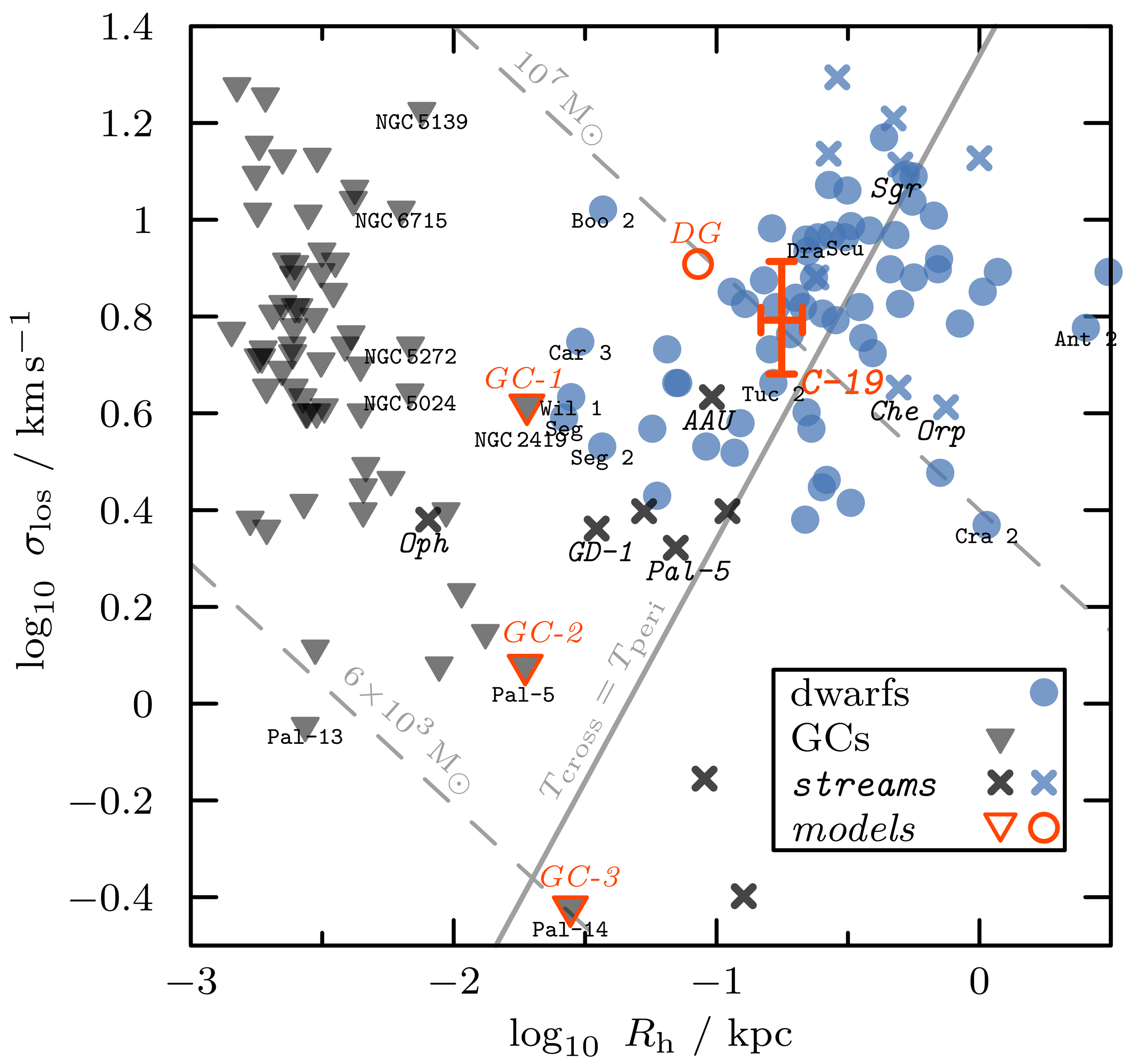

Fig. 1: The C-19 stellar stream has a width and a velocity dispersion exceeding those of known globular cluster streams, and structurally place C-19 closer to the regime of dwarf galaxies than that of globular cluster streams. Half-light radii R_h and line-of-sight velocity dispersions σ_{los} of dwarf galaxies (blue, filled circles) and globular clusters (grey, filled triangles) with luminosities $L < 10^7\,L_\odot$, compared against the characteristic width and velocity dispersion of the C-19 stream (red errorbars).

Modelling. We fit an orbit that matches approximately the sky location $\{\alpha, \delta\}$, proper motions $\{\mu_\alpha, \mu_\delta\}$, and radial velocities v_{los} (if available) of C-19 member candidates. Our simple static Milky Way-like potential consists of a bulge, a think and a thick disc, and a surrounding dark matter halo. For the C-19 orbit, we find pericentre and apocentre distances of $r_{peri} \sim 10$ kpc and $r_{apo} \sim 20$ kpc, respectively. On this orbit, we evolve N-body models resembling the globular clusters NGC 2419 (model GC-1), Pal-5 (GC-2) and Pal-13 (GC-3), modelled as self-gravitating Plummer spheres. We also explore a model where C-19 originated from a dwarf galaxy-like progenitor (DG), consisting of a King stellar cluster embedded in a spherical NFW dark matter halo. The orbital energies of the stars are chosen so that the embedded stellar cluster may fully disrupt on the C-19 orbit.

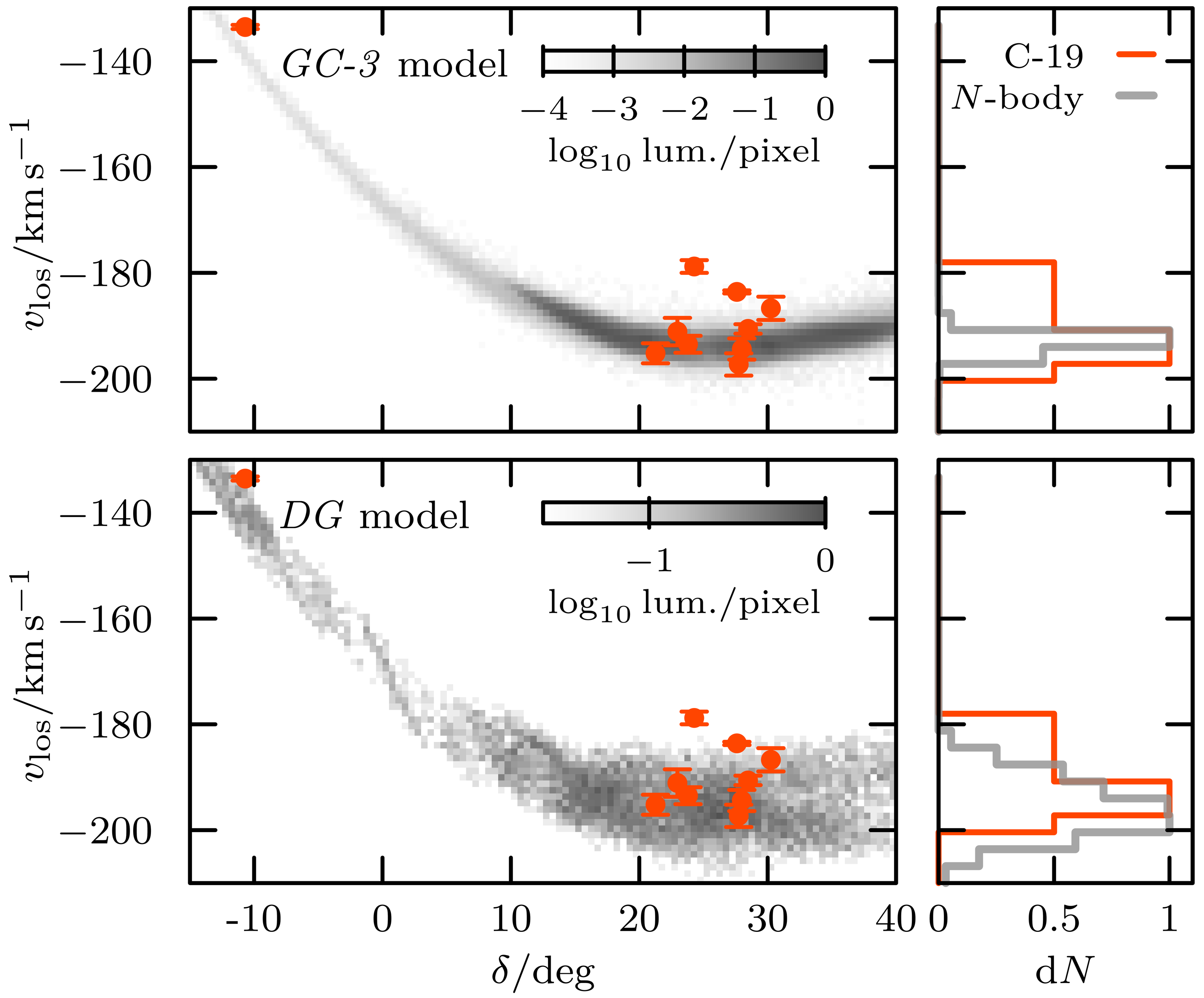

Fig. 2: The dispersion in line-of-sight velocity σ_{los} can't be reproduced by a self-gravitating globular cluster model that fully disrupts on the C-19 orbit (top panel), while a dark matter-dominated dwarf galaxy-like model results in a tidal stream with matching dispersion (bottom panel).

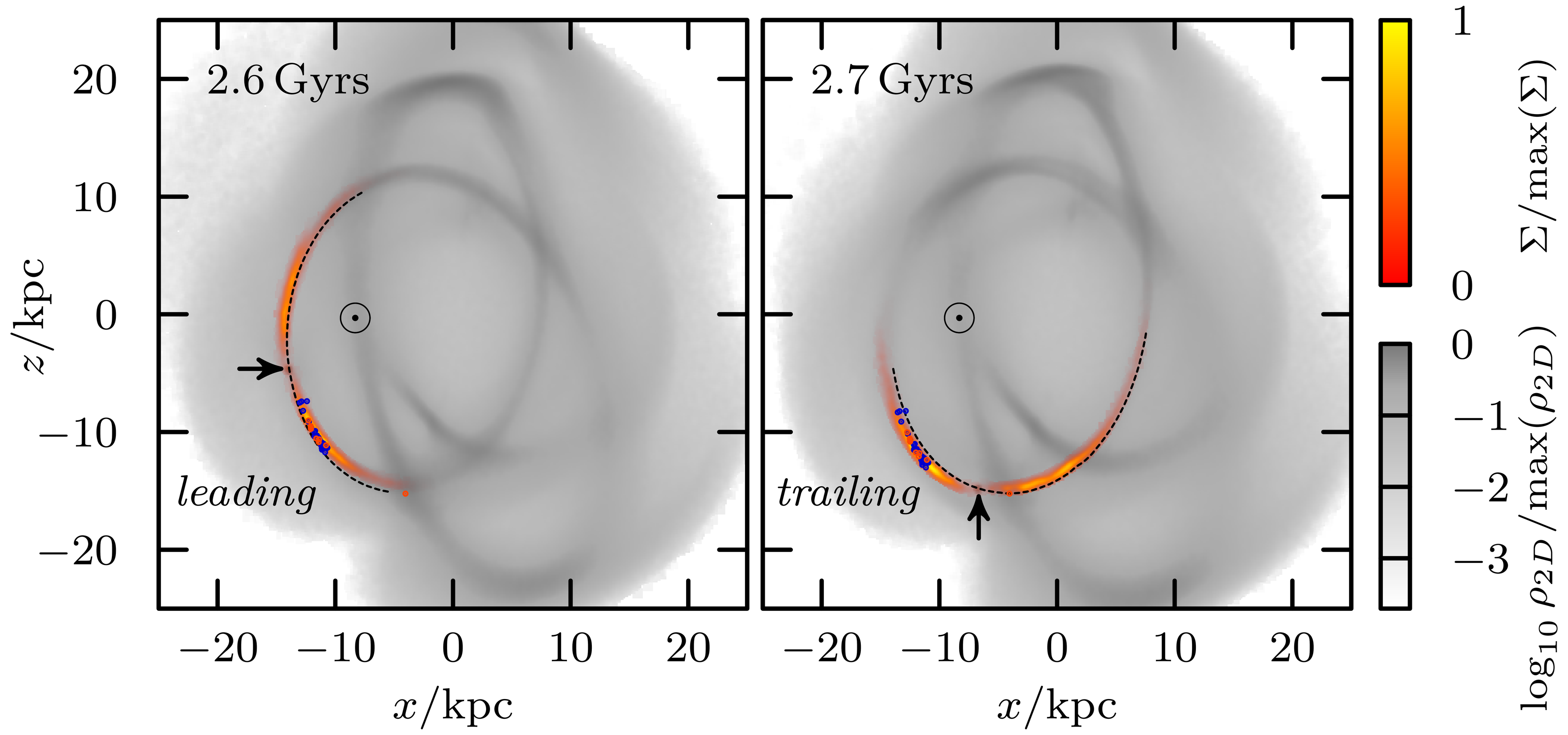

Fig. 3: The stellar cluster originally embedded within a dark matter subhalo has been completely dispersed. This scenario is a possible model for the formation of the C-19 stream, with either the leading or the trailing stream corresponding to C-19. Observed stream members are shown using red and blue points (with distances adjusted), in good agreement with the streams of the disrupted dwarf galaxy-like model. Note that while no bound stellar remnant remains, the dark matter subhalo does not fully disrupt.

Results. (i) Self-gravitating globular cluster progenitors similar in structure to NGC 2419 and Pal-5 are too dense to be fully disrupted on C-19's orbit over a period of 10 Gyrs. These may be ruled out by the lack of a bound luminous remnant associated with C-19. **(ii)** A self-gravitating progenitor similar to the Pal-14 globular cluster matches the integrated luminosity of C-19 and disrupts fully, but yields a stream too kinematically cold to match C-19's observed velocity dispersion. **(iii)** A dark matter-dominated dwarf galaxy-like progenitor, where stars follow a King-like profile embedded in a low-mass cuspy cold dark matter model near the hydrogen cooing limit, is able to reproduce the width and velocity dispersion of C-19, leaving behind no bound stellar remnant.

erc European Research Council — cnrs — Université de Strasbourg — PRISTINE