The Maybe Stream: A Possible Cold Stellar Stream in the Ultra-Diffuse Galaxy NGC1052-DF2

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1. A COLD STELLAR STREAM IN AN ULTRA-DIFFUSE GALAXY?

The nearby ultra-diffuse galaxy (UDG; van Dokkum et al. 2015) NGC1052-DF2 has recently been the subject of two papers (van Dokkum et al. 2018a,b) which focus on a lack of dark matter in this object (a subject of intense debate1), and on the properties of its globular cluster population. In this

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1 Much of the discussion occurred on social media, but see Martin et al. (2018) for a critique, and https://www.piervandokkum.com/ngc1052-df2 for a response.
Research Note we draw attention to another aspect of this galaxy: it contains a very thin ‘S-shaped’ structure made up of resolved stars (Figure 1). In this note we point out the possibility that this structure is a cold stellar stream, which we refer to as ‘The Maybe Stream’.

Figure 1. An image of NGC1052-DF2 constructed by combining the F814W and F606W data to represent ‘true’ colours. The right-hand inset shows a portion of F814W image, centred on the candidate ‘S-shaped’ (actually, ‘ʌ’-shaped) cold stellar stream (‘The Maybe Stream’). The candidate stream is clearly visible in both filters and portions of it are resolved into stars. The feature is also visible in a Gemini $i$ band image, particularly after subtracting a model for the smooth light (bottom left). Objects labeled ‘A’ and ‘B’ are candidates for the stream nucleus. The object marked ‘GC’ is a globular cluster (see van Dokkum et al. 2018b).
The most distant cold stellar stream known is the Pisces/Triangulum stream (Bonaca et al. 2012; Martin et al. 2013) at a distance of only $\sim 35$ kpc. NGC1052-DF2 lies at a distance of $\sim 20$ Mpc (see van Dokkum et al. 2018a) and is thus about $500 \times$ further away. A typical Milky Way cold stream is $\sim 10$ pc wide, which at a distance of $\sim 20$ Mpc corresponds to a width of about 0.1 arcsec. This width is consistent with that of the observed structure.

Our interpretation of this structure as a cold stream is tentative. Figure 1 is based on two orbit (one orbit per filter) $F606W$ and $F814W$ Hubble Space Telescope ($HST$) imaging. The galaxy is marginally-resolved, and the putative stream is composed of many strong positive surface brightness fluctuations superposed on two opposing thin ‘arcs’ of background light. There is no obvious difference between the color of the candidate stream and that of the rest of the galaxy.

Three candidates for the nucleus of the stream are marked as ‘GC’, ‘A’, and ‘B’ on Figure 1. Candidate ‘A’ is likely a background galaxy. Candidate ‘B’ is very intriguing. It lies directly on the lower arc of the candidate stream, and is one of the reddest objects on the entire ACS image, with $(F606W - F814W) \sim 3.5$ mag. It has $F814W \sim 23.5$ mag, and is not resolved. While very red, it is almost certainly not a TP-AGB star, as it is about three magnitudes brighter than the tip of the RGB. Object ‘GC’ is the globular cluster GC-85 (see van Dokkum et al. 2018b). This globular cluster is elongated in the same direction as the stream, but it does not appear to be connected: the stream appears to curve to the South (toward object ‘B’). Finally, we note that the stream may be an “orphan” (see Belokurov et al. 2007), where the progenitor object is either completely disrupted or presently far removed from the densest region.

2. TOPOLOGY OF THE CANDIDATE STREAM

Cold streams are presumed to originate from disrupting dwarf galaxies or globular clusters, and if the candidate stream is real its abrupt curves would be very remarkable. The shapes of streams are sensitive to the strength and shape of the gravitational potential (Helmi 2004; Johnston et al. 2005; Lux et al. 2012), as well as to its substructure (Carlberg 2009; Yoon et al. 2011; Carlberg 2017). Once a stream is set up in a galaxy such as NGC1052-DF2, additional sharp turns might be the product of few-body dynamics, because the unusual properties of the galaxy make it more probable
that a stream would overlap with the spheres of influence (SOI) of the individual globular clusters in the system. In the Milky Way, a typical globular cluster has a mass of $2 \times 10^5 \, M_\odot$ and orbits at 5 kpc (Harris 1996), with an enclosed Galactic mass of $5 \times 10^{10} \, M_\odot$, resulting in an SOI radius of 33 pc. In NGC1052-DF2, the corresponding values are $8 \times 10^5 \, M_\odot$, with 2.5 kpc and $1 \times 10^8 \, M_\odot$ (van Dokkum et al. 2018a), resulting in clusters with an enormous SOI radius of 360 pc, about ten times larger than for clusters in the Milky Way. While strong accelerations are not expected at large distances within the SOI, these numbers make the point that strongly bent streams might be more commonly seen in some ultra-diffuse galaxies than in more conventional galaxies.

The currently-available data are not deep enough to confirm the existence of the stream beyond reasonable doubt. The eye is very good at detecting patterns, and random clumps of giant stars can line up to form phantom features. Deeper data obtained with HST or JWST will be able to either confirm or refute the reality of The Maybe Stream.

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