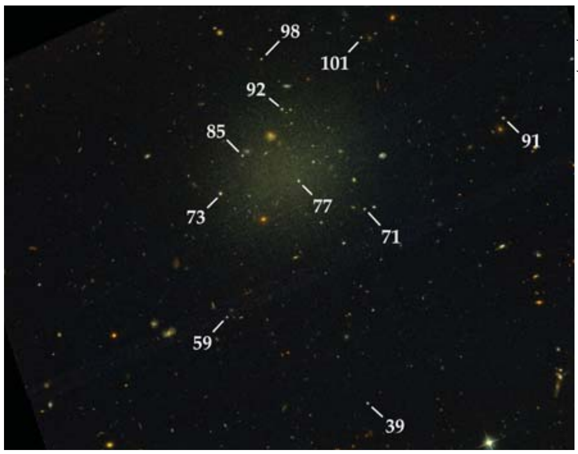
PHYSICS UPDATE

These items, with supplementary material, first appeared at www.physicstoday.org.

A GALAXY WITH SURPRISINGLY LITTLE DARK MATTER

Stars in the Milky Way account for only a few percent of our galaxy's mass. According to the consensus picture of galaxy formation, most of the mass in the Milky Way—and every other galaxy—is housed in a sphere of dark matter, the nonluminous, feebly interacting substance whose identity is still a mystery. Now Pieter van Dokkum of Yale University and his international team have identified a galaxy, NGC 1052-DF2, that challenges the standard formation picture: Its mass in dark matter is at most about the same as its mass in stars, and possibly it is much less.

The figure shows a *Hubble Space Telescope* image of the faint galaxy; the 10 labels indicate star clusters on the outskirts. From Doppler-shift measurements of each cluster's absorption spectrum, the researchers could obtain the speed at which the cluster orbits the galaxy.



NASA, ESA, AND PIETER VAN DOKKUM

Just as, in our solar system, the mass of the Sun can be deduced via Kepler's third law from the speed and radius of a planet, so the mass of NGC 1052-DF2 can be estimated from the speeds and locations of the star clusters. NGC 1052-DF2 can't be approximated as a point, but even in the more complicated galactic system, smaller orbital velocity means smaller mass. And the cluster velocities were so small that NGC 1052-DF2's stars might account for all of the galaxy's mass, though a more sober conclusion is that, at the 95% confidence level, the dark-matter mass is at most approximately equal to the mass in stars. That's still more than two orders of magnitude less dark matter than expected.

Astrophysicists do not know for sure how NGC 1052-DF2 formed. One possibility is that it was created during galaxy merger, a process that can fling out gas without ejecting dark matter.

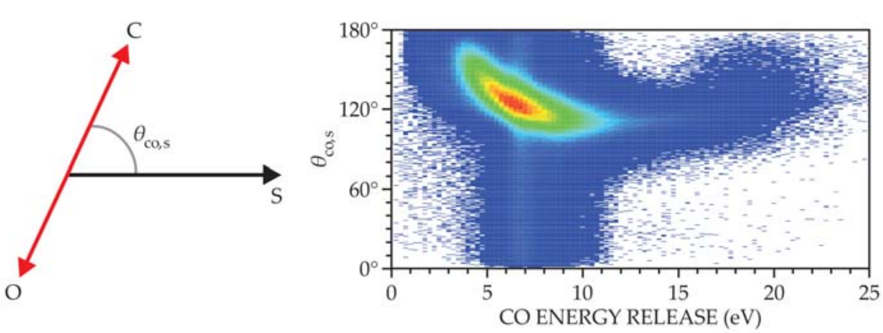
Ironically, the existence of a galaxy with little or no dark matter would falsify some alternatives to dark matter. Modifications to Newtonian dynamics and other fixes have been invoked to explain the dynamics observed in other galaxies. Those approaches, however, necessarily mimic the effects of a dominant dark-matter component and thus are not compatible with the relatively lethargic movement of NGC 1052-DF2's satellite clusters. (P. van Dokkum et al., *Nature* **555**, 629, 2018.) —SKB

THREE-BODY FRAGMENTATION IN A NEW FRAME

A common problem in several subfields of physics is reconstructing the process by which a body—a molecule, nucleus, or high-energy particle—breaks apart into three or more fragments. Even when all fragments are detected and their velocities measured, it's not always easy. Across fields, researchers distill and interpret the fragmentation's essential features with a suite of powerful tools, including the Dalitz plot, a visualization of the kinetic energy carried by each fragment. But ambiguities can still remain.

Consider, for example, the breakup of triply ionized carbonyl sulfide, OCS^{3+}, into O^+, C^+, and S^+. Three fragmentation channels are possible: two that are sequential, in which either the O–C or the C–S bond breaks first, and one that is concerted, in which both bonds break at the same time. For each of the sequential channels, conservation of momentum during the first bond-fission step imposes a constraint on the atoms' final velocities—and thus on the signal's position on a Dalitz plot. But concerted fragmentation can yield velocities that mimic those of either sequential process, making it difficult to completely disentangle the three channels.

Now Itzik Ben-Itzhak, Brett Esry, and their colleagues at Kansas State University have devised a way to separate sequential from concerted breakup, even when their signals overlap. The key is to translate the system into the center-of-mass frame of one of the putative intermediates—CO^{2+} in this case—and to calculate $\theta_{CO,S}$, the angle between the C^+ and S^+ velocities, as shown in the left panel. If the C–S bond really does break first and the CO^{2+} fragment rotates for a while before dissociating, then all values of $\theta_{CO,S}$ are equally likely. So when $\theta_{CO,S}$ is plotted against some independent quantity, such as the apparent kinetic energy released in the CO^{2+} dissociation, the sequential channel with the CO^{2+} intermediate appears as a vertical stripe, as shown in the right panel.



Apart from experimental artifacts at the top and bottom, the stripe is uniform, so one can easily deduce its width and intensity profile across all values of $\theta_{CO,S}$ to calculate how many events it comprises. The remainder of the data are still a mishmash of the concerted channel and the sequential channel in which the O–C bond breaks first. To separate them, the researchers repeat the process: Translate into the CS^{2+} frame and calculate $\theta_{CS,O}$. (J. Rajput et al., *Phys. Rev. Lett.* **120**, 103001, 2018.) —JLM PT