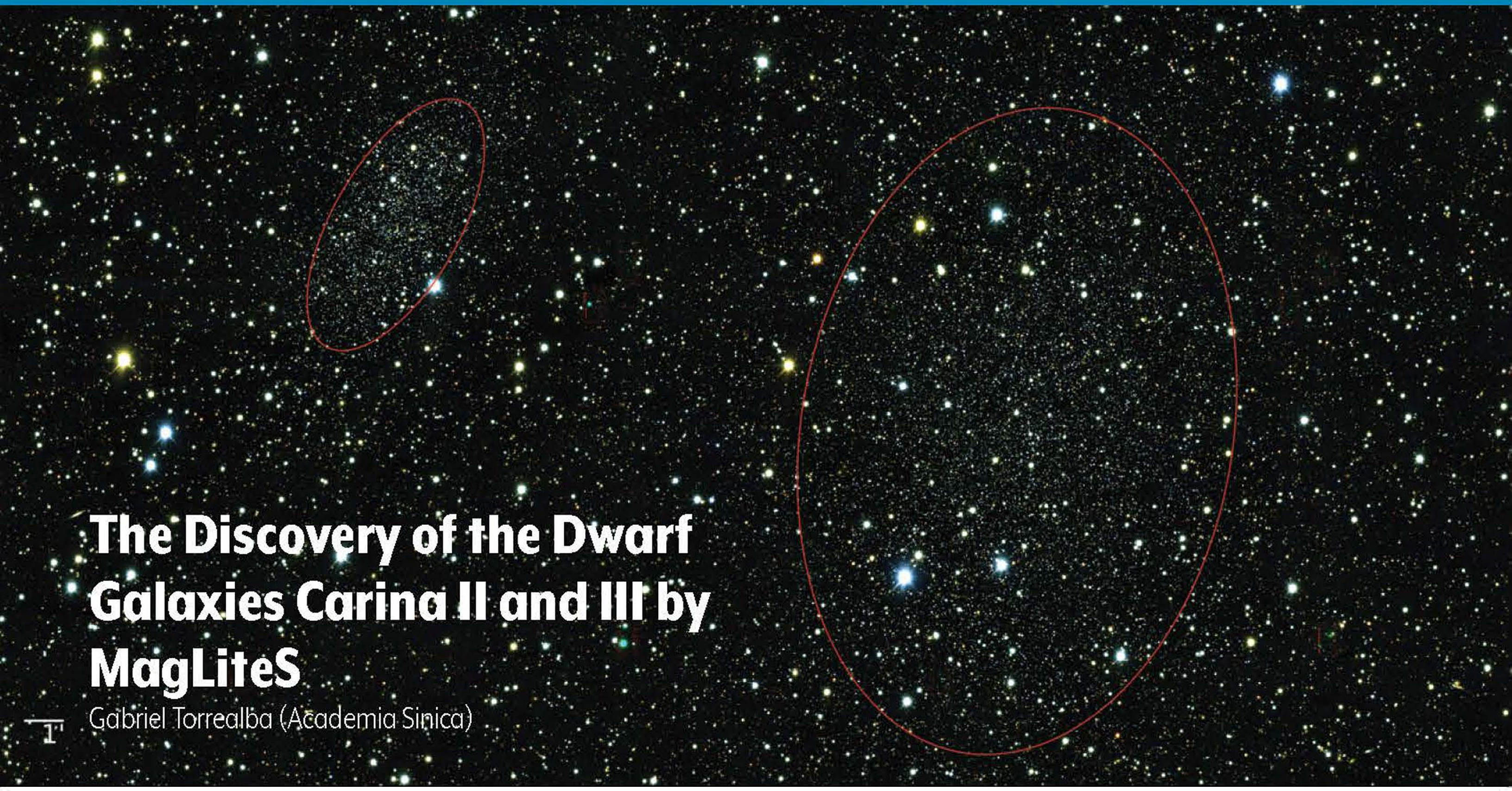

The Discovery of the Dwarf Galaxies Carina II and III by MagLiteS

Gabriel Torrealba (Academia Sinica)

The Milky Way (MW) provides a window to explore the smallest galaxies in the Universe, which are so dim that they are only detectable within a few kpc from us. Under the Lambda cold dark matter (LCDM) scenario of structure formation, these are some of the first galaxies to form. Based on their dynamics they are completely dominated by dark matter.

The formation of structure by LCDM is predicted to be hierarchical and is expected to happen on mass scales from galaxy clusters to ultra-faint galaxies. This means that a galaxy like the LMC should have brought its own system of satellite galaxies to the Milky Way, scattering them around the halo. Importantly, it is only in the Milky Way that we can test this prediction at the ultra faint level; hence a census of satellite galaxies around the Magellanic Clouds is an important observation.

The MagLiteS program was conceived to survey the satellites brought to the Milky Way by the Magellanic Clouds, hence its name, which is short for Magellanic Satellites Survey (see Drlica-Wagner et al., 2016). MagLiteS observes the outskirts of the Magellanic Clouds, charting regions previously unexplored by other photometric surveys. This area was selected based on arguments advanced by Jethwa, Erkal, and Belokurov (2016), who predict that up to 70 satellites could have been brought by the LMC to the MW and place them preferentially close to the Clouds. The survey uses the Dark Energy Camera (DECam) on the Blanco 4m telescope at Cerro Tololo Inter-American Observatory to map ~1200 square degrees surrounding the southern parts of the Magellanic clouds. At the completion of the survey, about five new satellites are expected to be discovered according to models, of which four should be of a Magellanic origin.

The hunt for satellites around the LMC has been successful so far. Several satellites were found in the DES (Koposov et al., 2015; Drlica-Wagner et al., 2015), and a further discovery was made with MagLiteS (Drlica-Wagner et al., 2016), but this is still far from the total expected yield. In our work (Torrealba et al., 2018), we added an intriguing pair to this list. By applying a systematic search procedure to the MagLiteS data, we were able to identify two stellar systems only 18' apart. The two satellites, named Carina II and Carina III, are well described by a metal-poor and old stellar population at a distance of 36 and 28 kpc from the sun, respectively. Their estimated absolute luminosities are $M_V = -4.5$ and $M_V = -2.4$, which, combined with their sizes (90 and 30 pc), places them in the ultra-faint regime. In Figure 1 we show the region of the sky where the Carinas are located.

Spectroscopic follow-up of the systems (see Li et al., in prep. for details) confirm them as coherent stellar systems, both likely dark matter-dominated dwarf galaxies. But, despite their close physical distance, a systematic velocity difference in excess of ~200 km/s makes a direct link between the two Carina systems unlikely. On the other hand, their velocities are consistent with them being part of the satellite system of the LMC (instead of the MW) and may remain bound to the large cloud even today. Hence, we are now one step closer to understanding how the system of satellites around the MW has been shaped by foreign satellites brought in by the LMC—a direct conclusion of the hierarchical formation scenario. In addition, the two systems seems to lie in a planar structure around the Magellanic Clouds (Jethwa, Erkal, and Belokurov, 2016). The plane is shown in Figure 2 as a dashed black line. Physically, the plane

continued

Figure 1. Color image of the region around Carina II and Carina III from follow-up DECam observations. The small elongated accumulation of stars to the left corresponds to Carina III, while the larger blob to the right is Carina II. The location and sizes of the satellites are illustrated by artificially adding stars to the satellites to boost their surface brightness by 40x. The satellites are invisible to the eye in the actual observations.

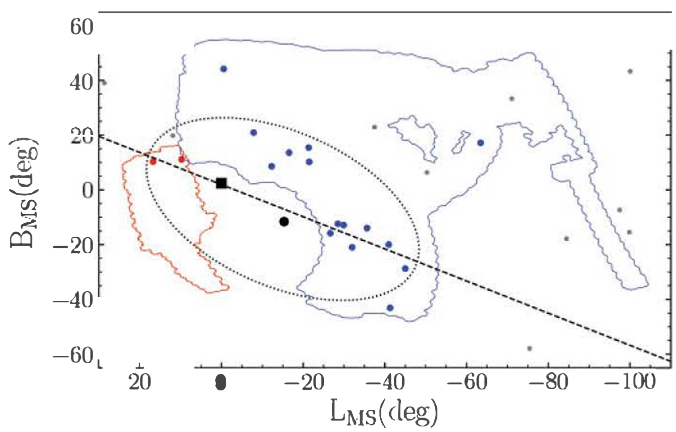

Figure 2. Distribution of galaxies around the Magellanic Clouds in the Magellanic stream coordinates. The black line shows the best fit plane. Red points show satellites discovered in MagLiteS, and blue points show satellites from DES. The LMC and SMC are shown with a black square and circle, respectively. (Figure from Torrealba et al. 2018.)

is impressively thin—with an RMS of less than 3 kpc—but very extended, including galaxies from ~30 kpc to in excess of ~100 kpc. Increasing evidence shows that rotating planar structures are perhaps common in the universe, but relatively rare in simulations (see, e.g., Müller et al., 2018). If coherent rotation of the planar configuration in the Magellanic Cloud is observed, it will confirm that they can be present in a wide range of masses, adding an interesting ingredient to the mysterious puzzle.

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