An army of tiny robots that tracks galaxies

September 30 2015, by Lionel Pousaz

Why is the universe expanding at an increasing rate? Scientists will attempt to gain a better understanding of this phenomenon by mapping the distribution of galaxies in the universe. Astrophysicists and robotics engineers from EPFL are taking part in this scientific adventure.

Where is the universe headed? How is it possible that the galaxies are moving farther apart from each other at an increasing rate, defying the force of gravity that should at least slow this movement? To answer this question, researchers are going to map the distribution of galaxies in the universe very precisely. DESI, the Dark Energy Spectroscopic Instrument, is a project aimed at identifying the position of more than 30 million galaxies – out of the 100 to 200 billion that probably exist. It is based at the Lawrence Berkeley National Laboratory (LBNL, USA). The goal is to improve our understanding of dark energy: an ingredient that physicists added to their equations in order to account for the surprising fact that the expansion of the universe is accelerating.

Galaxies, because they are so massive, are among the most distant objects that we are able to observe. The light they emit shows that the universe is expanding. Over time and distance, their light spectrum shifts towards red – a phenomenon called redshift. The greater the redshift, the farther away the galaxy. The current record is held by EGS-zs8-1. Its redshift indicates a distance of 13.1 billion light years: what we see now is how it looked in our early universe.

Gathering light from the galaxies with optical fibers

To collect light from the galaxies, the researchers will place a large number of optical fibers on the focal plane of the telescope. If the fibers are positioned correctly, they will only capture the signal from the targeted galaxies. Currently, as part of the extended-BOSS/SDSS project being run at the Sloan telescope (New Mexico), researchers prepare plates by drilling 1,000 holes into them and then manually plugging optical fibers into them, one by one (see video). The technique is accurate but slow and tedious, since a new plate must be prepared for each observation.

The goal of DESI is to drastically accelerate the process of creating a 3D map of galaxies. To achieve this goal, it will build a platform composed of 5,000 optical fibers held in position by tiny robots, together covering the focal plane of the telescope. These tiny and highly precise robots have been designed at EPFL by teams headed by astrophysicist Jean-Paul Kneib and robotics engineers Mohamed Bouri and Hannes Bleuler, working together with colleagues from the University of Michigan and LBNL.

The resulting design will make it possible to reposition the 5,000 optical fibers in less than a minute and to measure redshift, one galaxy per optical fiber. In one night alone, it will be capable of establishing the position of around 150,000 objects. This means it will quickly reach the end goal of more than 30 million galaxies. The huge volume of data will allow precise measurements of the distance-redshift relation in the universe, with a margin of error of several tenths of a percent, versus around 1-2% currently.

From road traffic to astronomical instruments

Laleh Makarem, a post-doc working at EPFL with Denis Gillet, is tackling the programming of the robots, a real challenge, to say the least. The 5,000 robotic positioners will completely cover a surface area of

around a half meter squared. This means that when they are repositioned, they can collide and damage the fragile precision mechanisms.

Before taking on this project, the young researcher worked on modeling urban road traffic. That field of research is actually closer to that of astronomical instrumentation than one might think. "The algorithms that I developed represented each vehicle independently," said Makarem. "The vehicles move like separate entities that avoid collisions by adjusting for the movement of the other entities. That's exactly the same principle that makes the 5,000 robots move."

The role of the robotics engineers at EPFL is to contribute to the design, procurement and testing of the robot positioners themselves. Equipped with a miniature motor and a reduction stage for the motor's movement – a little like the gears on a bicycle – these positioners are very accurate. After a relatively approximate first movement, the positioners correctly move the optical fibers to within 5 thousands of a millimeter, exactly where they need to be to capture light from the targeted galaxies.

The robots will be assembled at the University of Michigan. The completed system will go into use in 2019 at the Mayall telescope in Arizona.

Provided by Ecole Polytechnique Federale de Lausanne