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Press Release

Runaway pulsar shoots out jet 37 light years long

International project including Tübingen astrophysicists discovers longest X-ray jet ever found in our galaxy

Tübingen, 19 February 2014

An international team of astrophysicists including scientists from the University of Tübingen's Institute for Astronomy and Astrophysics has discovered a system in our galaxy which is expelling a remarkable jet of highly energetic particles. The new findings are reported in the latest edition of the international journal for Astronomy and Astrophysics, accompanied by a press release from NASA's Chandra X-ray observatory.

Originally discovered by the European Space Agency's INTEGRAL satellite, the system is called IGR J11014-6103. The energy source inside it is a pulsar, a rapidly spinning neutron star that was born in a supernova explosion 10,000-20,000 years ago. Since then, the pulsar has been moving very rapidly away from the debris of the explosion, a cloud of hot plasma (named MSH 11-61A) which remains centered at the location of the exploded star and whose expansion is slower.

The new extensive follow-up observations of IGR J11014-6103 were carried out with NASA's Chandra X-ray observatory and with the Australian CSIRO radio telescope array ATCA. The new X-ray and radio observations confirm the high speed of the pulsar of more than 1000 km/sec and its association with the supernova remnant MSH 11-61A. "That alone would be interesting, because we can study a supersonically moving pulsar with extreme speed that leaves a trail of ejected particles behind," says Gerd Pühlhofer of the High Energy Astrophysics group at the University of Tübingen, one of the co-authors of the new publication. "This cloud of particles we call a *pulsar wind nebula*, which for such high-speed systems forms a beautiful comet-like shape of particles shining in X-rays and radio waves."

The truly amazing feature of the system, however, is a long, highly collimated particle *jet* emerging nearly perpendicularly to the direction of the pulsar motion. The jet reveals itself through X-ray emission of highly energetic particles that are moving at about 80% of the speed of light away from the pulsar. Moreover, with a length of about 37 light years (about 10 times the distance between the Sun and its nearest neighboring star), the jet is the longest X-ray jet ever detected in the Milky Way.

The jet is so extraordinary that the researchers had to ask themselves whether what they had detected was really a jet launched by the pulsar system IGR J11014-6103. “We had to eliminate the possibility that the pulsar and the apparent jet are not just by coincidence perfectly aligned in projection at the sky, but are located at totally different distances along the line of sight,” explains Lucia Pavan of the University of Geneva and lead author of the paper. “Or that the pulsar had just hit a previously existing feature which was illuminated by the pulsar wind.” Luckily, the jet displays a very prominent modulation pattern that excludes those alternative scenarios. The modulation indicates that the neutron star’s spin axis is wobbling as the star moves along, in a way called free precession, similar to the motion of a gyroscope. Since the jet – if connected to an isolated pulsar like IGR J11014-6103 – must emerge in the direction of its spin axis, this can easily explain the jet’s appearance.

The team now has to understand what makes this pulsar so special that it produces a jet with such high efficiency. “Theory and observations tell us that normally, the neutron star’s spin axis should point in the direction of the pulsar motion,” says co-author Pol Bordas of the University of Tübingen. “Obviously, this is not the case here. This together with the extreme speed of the pulsar may hold the clue to understanding why the jet is so bright.”

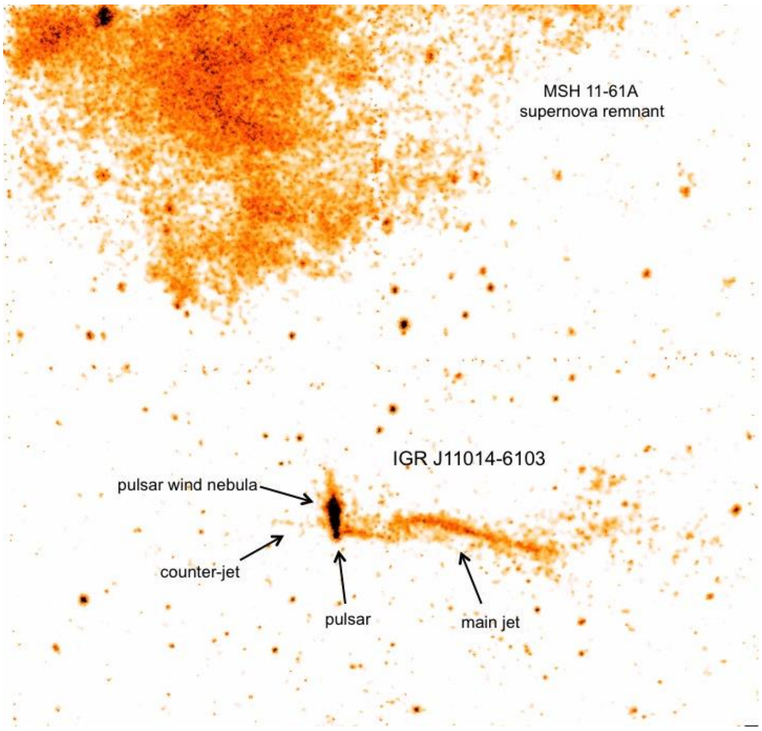
But this is not the end of the story. “Even if we still have to understand how the jet is launched, the sheer fact of where it points to tells us unequivocally that the neutron star’s spin axis is perpendicular to the pulsar motion, which is exceptional,” says Gerd Pühlhofer. The answer to why this is so must lie in the way the neutron star was created: The Lighthouse Nebula, as the authors call the system due to its appearance in X-rays, also gives clues to the nature of the supernova event that formed both the pulsar in IGR J11014-6103 and the supernova remnant MSH 11-61*A*. “Current ideas that could explain what we see are quite exotic. An extremely fast rotating iron core just before the explosion of the pre-supernova star has been suggested as possibly giving birth to such a high-speed pulsar with a misaligned spin axis, but it seems that this model is not widely accepted.” Another possible scenario is a special supernova that just didn’t make it to an extreme explosion producing a gamma-ray burst.

Reference: L. Pavan[1], P. Bordas[1,2,*], G Pühlhofer[2], et al., A&A 2014, vol. 562, A122,
[1]: ISDC, University of Geneva
[2]: IAAT, University of Tübingen
*: Now at Max-Planck-Institut für Kernphysik Heidelberg

Link to original publication: http://dx.doi.org/10.1051/0004-6361/201322588

Press Release of NASA, Chandra X-ray Observatory:
http://chandra.harvard.edu/press/14_releases/press_021814.html

Institute for Astronomy and Astrophysics Tübingen: http://www.uni-tuebingen.de/en/4656



IGR J11014-6103 seen in X-rays by the Chandra satellite telescope. Image: **ISDC/L. Pavan, Astronomy&Astrophysics 2014, 562, A122**

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