Laboratory analog for collision of outflow with dense clouds in protostar or starburst galaxy M82

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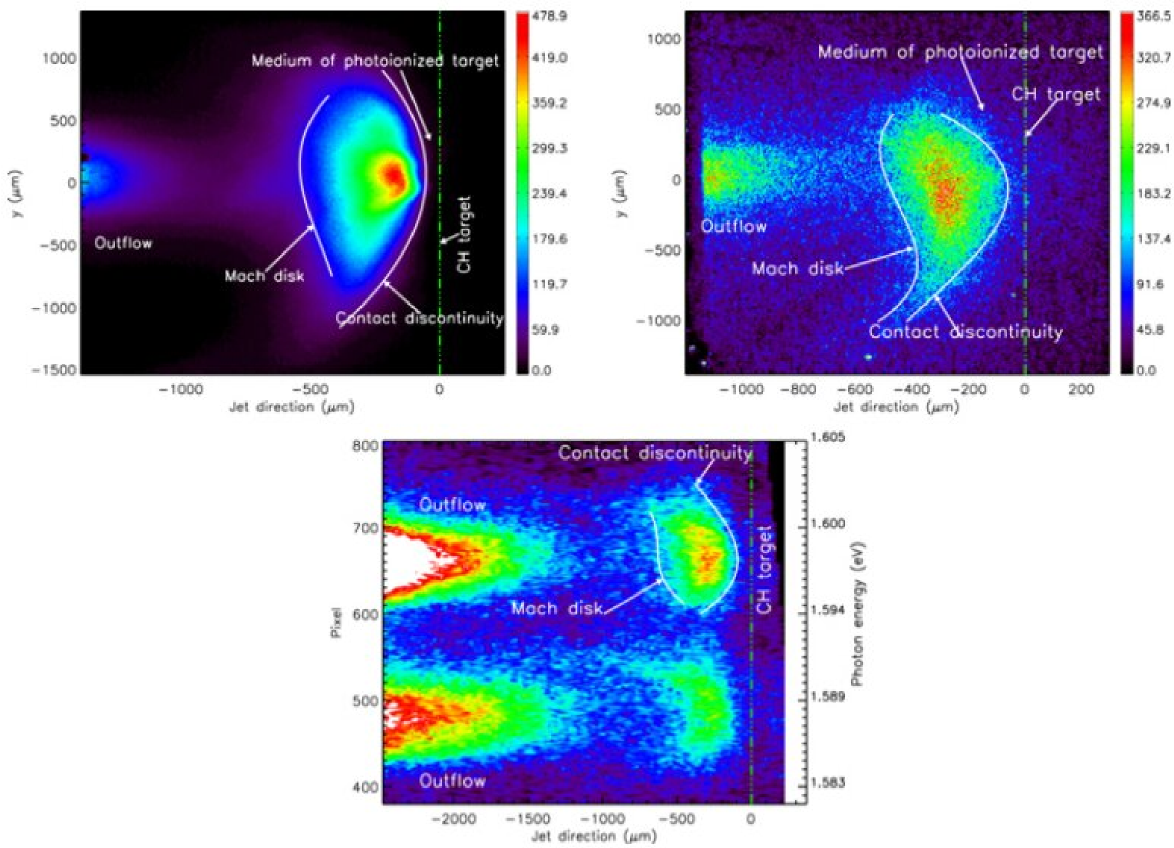

The X-ray morphology of the outflow and its interaction with a low-temperature medium from the photoionized CH target recorded using wide-field pinhole cameras with an energy band above 1 keV, and by an X-ray spectrometer with spatial resolution in the outflow direction. Left: due western (W) pinhole camera. Right: southeastern (SE) pinhole camera tilted to top. Bottom: due eastern (E) spectrometer tilted to top. The y-axis is also the energy dispersion direction; see the right label with photon energy in keV. Note: the data are taken from different experimental shots over 2 yr with interaction distances of 3.3–3.6 mm. Credit: *The Astrophysical Journal* (2022). DOI: 10.3847/1538-4357/ac3de8

Outflow or jets are an important feature for the star-formation region, and are the main solution for researchers to explain many key issues in star-formation. Properties, such as morphologies, size, and velocities, of outflows provide fossil records of the mass ejection and, by inference, the mass accretion histories of forming young stars.

X-rays can trace the nearest origin of outflow, and to explore the mechanism of jet production and its collimation. The mechanism is still not clear, although various feedback models of interaction with interstellar medium have been suggested to explain the X-ray emissions.

Recently, a study led by Profs. Zhao Gang and Liang Guiyun from the National Astronomical Observatories of the Chinese Academy of Science (NAOC) has reported a laboratory analog for the collision of outflow with dense clouds in Herbig-Haro 248 and starburst galaxy M82.

The results were published in *The Astrophysical Journal* on February 2.

By using the powerful laser facility of Shengguang-II sited at Shanghai, a supersonic outflow with a velocity of 330 km/s was generated, which is comparable to that in protostellar outflow. This provides an excellent opportunity to investigate the outflow feedback in a star-formation region.

For both large-scale astrophysical plasma and small-scale laboratory plasma, the fundamental physical principles are the same. By using scaling law in time, spatial and density, the two plasmas are similar in many aspects. "We can reproduce and investigate the astrophysical phenomenon, as in HH 248 or M82, in laboratory, and further reveal the fundamental physics in astrophysics," said Prof. Liang Guiyun, first author of the study.

"Through such experiments, we've found a different conclusion that the X-rays in HH 248 are mainly from the outflow material heated by reverse shock, namely the Mach disk. It differs from the past understanding that X-rays are from interstellar medium heated by shock," said Prof. Liang

By a sophistical emission model, they deduced that charge exchange took place in such a laboratory miniature, as in the cases of HH 248 and Cap in M82.

However, there are still some differences after scaling law for the two different systems. A further laboratory exploration is necessary to figure the pictures of outflow interaction in protostars.

More information: G. Y. Liang et al, Charge-exchange X-Ray Signature in Laboratory Outflow Interaction with Neutrals, *The Astrophysical Journal* (2022). DOI: 10.3847/1538-4357/ac3de8

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