PROCEEDINGS OF SCIENCE

Minkowski's footprint: an ejected common envelope?

Javier Alcolea[*†]
Observatorio Astronómico Nacional (Spain)
E-mail: j.alcolea@oan.es

Roberto Neri
Institut de Radioastronomie Millimétrique (France)
E-mail: neri@iram.fr

Valentín Bujarrabal
Observatorio Astronómico Nacional (Spain)
E-mail: v.bujarrabal@oan.es

PoS(MRU)080

M 1–92 is a very well studied bipolar pPN that can be considered an archetype of these type of sources: it shows a clear axial symmetry, and the kinematics and momentum excess characteristic of this class of envelopes. We performed sub-arcsecond resolution observations of the J=2–1 rotational line of ^{13}CO in M 1–92, using the extended Plateau de Bure interferometer, for better studying the morphology and velocity field of the molecular gas in the central parts of the nebula. We found that the equatorial structure dividing the two lobes is a thin flat disk, which expands radially with a velocity proportional to the distance to the centre. The kinetic age of this equatorial flow is very similar to that found in the two lobes, suggesting that the whole structure was formed as a result of a single event 1200 yr ago. The small widths and velocity dispersion in the gas forming the lobe walls confirm that the acceleration responsible for the nebular shape could not last for more than 100-120 yr. In view of the similarity to the case of η Car, we speculate on the possibility that the whole nebula was formed as a result of a magneto-rotational explosion in a common-envelope system. We believe that the role of this formation mechanism, in the in the context of global PNe and pPNe shaping, should be further investigated.

From Planets to Dark Energy: the Modern Radio Universe
October 1-5 2007
The University of Manchester, UK

[*] Speaker.

[†] This contribution is based on observations carried out with the IRAM Plateau de Bure Interferometer. IRAM is supported by INSU/CNRS (France), MPG (Germany) and IGN (Spain).

1. Intruduction

M 1–92, also known as Minkowski's footprint, is a bipolar pre-planetary nebula (pPN). The central object is a binary system consisting of a 6,500 K primary star and a 18,000 K secondary [2]. A distance of 2.5 kpc is assumed adopting a normal post-AGB luminosity of $10^4\,L_\odot$ [5]. This axis-symmetric nebula has a size of $11''$ in the axial direction and $6''$ in the equatorial one, consisting of a two-lobe reflection nebula, divided by a dense equatorial component. The axis of symmetry is oriented at a position angle of 311°, and it is inclined with respect to the plane of the sky by 35°, with the northwest lobe pointing to us. Optical spectroscopy shows the presence of flows of ionised gas close to the star, with expansion velocities up to $750\,\mathrm{km\,s^{-1}}$ [2]. Line emission in Hα and in OI, OIII, NII, & SII is detected from the middle of the two lobes, tracing the location of shocks propagating along these jets [4]. The mass of the ionised gas is very low, $10^{-3}\,M_\odot$, compared with the total mass of the nebula, $0.9\,M_\odot$ [4], which is still largely in the form of molecular gas [3].

2. Observations & results

Using the new extended configurations of the IRAM Plataeu de Bure Interferometer (PdBI), we conducted additional observations of the J=2–1 rotational line of ^{13}CO at 220 GHz in M 1–92. We obtained new data in the A6q & B6q antenna layouts in the winter of 2006. After calibration, map production and cleaning we found that 30%-70% of the flux was lost because of the lack of short baselines in the new data. Since the new data set was obtained with the same spectral setup as before, we merged these data with those from our previous observations [3] (see [1] for additional details), resulting in maps with no significant missing flux, but with sub-arcsecond spatial resolution: beam size of $0\farcs50\times0\farcs35$. We also produced higher detailed maps using just the most extended configuration. Although these maps have lower S/N and most of the flux is lost, they are very useful to investigate the structure and dynamics of the equatorial disk dividing the two lobes.

The results (see figure) clearly display the structure and kinematics of the molecular gas in M 1–92. The two emptied lobes and the dividing equatorial structure are obvious, as well as the prominent linear velocity gradient in the axial directions: the Hubble-like velocity field often found in pPNe. It is noteworthy the small width of the walls of the lobes, less than 10^{16} cm, and their low excitation ($T_{\rm Br}$ about 10 K). However, most surprising is that the velocity field seen in the equatorial region, i.e. the disk, is not compatible with a relic of an AGB envelope. We do not see the signatures of an expansion with a constant radial velocity. On the contrary it seems that the velocity also increases linearly with the distance in this equatorial plane too. We derive a kinetic life-time of 1370 yr for the disk, to be compared with the 1060 yr found for the bipolar axial flow. In fact, adopting an inclination angle of the symmetry axis of $38\fdg5$ (still compatible with all the data), both ages become the same, 1200 yr. Using the higher resolution data, we confirm these results for the disk, that is flat and $1\farcs4$ in diameter.

3. On the nature of M1-92

If we assume that a single Hubble-like velocity field applies to all parts of the nebula, the easiest explanation for this kinematics would be that M 1-92 resulted from a single acceleration

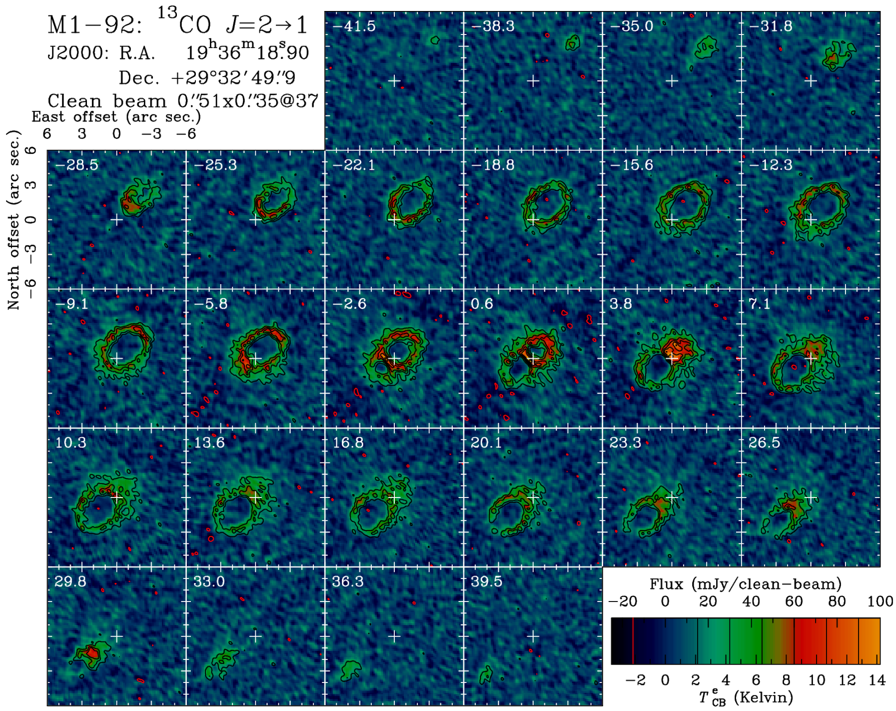

Figure 1: Fig 3. The 3.25 km s^{-1} spectral resolution channel maps of ^{13}CO J=2–1 in M 1–92 obtained from the old+new data combined.

event. Given the small width and velocity dispersion of the lobe walls, that interaction lasted less than about 10% of the kinetic age of the gas, i.e. less than 120 yr, resulting in the astonishing mass loss rate of at least 7.5 $10^{-3}\,M_\odot\,\mathrm{yr}^{-1}$. We see no traces of the former AGB envelope, just the result of this huge post-AGB explosion. The above depicted scenario resembles a 1-2 orders of magnitude scale-down version of the η Car nebula. For this unique object, a model has been developed in which a magneto-rotational explosion can launch flows in the axial and equatorial directions [6]. For this mechanism to operate, it is necessary to have a binary system in a common envelope phase [7], a scenario that we believe should be further investigated for the case of M 1–92. If true, the nebula will be just the result of the explosive ejection of the former common envelope of the binary system.

References

[1] J. Alcolea, R. Neri, V. Bujarrabal, (2007), A&A **468**, L41

[2] A. Arrieta, S. Torres-Peimbert, L. Georgiev, (2005), ApJ **623**, 252

[3] V. Bujarrabal, J. Alcolea, R. Neri, (1998), ApJ **504**, 915

[4] V. Bujarrabal, J. Alcolea, R. Sahai, J. Zamorano, A.A. Zijlstra, (1998), A&A **331**, 361

[5] M. Cohen, L.V. Kuhi, (1977), ApJ **213**, 79

[6] S. Matt, A. Frank, E.G. Blackman, (2006), ApJ **647**, L45

[7] J. Nordhaus, E.G. Blackman, (2006), MNRAS **370**, 2004