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Clump formation through colliding stellar winds in the Galactic Centre

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Abstract. We study the process of clump formation from hydrodynamic instabilities in stellar wind collisions, using analytical and numerical techniques. We show that the cloud G2 in the Galactic Centre could have been formed in this way, with the most promising sources being compact massive binaries, such as IRS 16SW.

Keywords. hydrodynamics – instabilities – stars: winds, outflows – Galaxy: centre

1. Introduction

The inner parsec of our Galaxy hosts hundreds of young, massive stars. Their stellar winds create the hot, diffuse ISM in the region, with only a small fraction of that material being finally accreted by the central super-massive black hole, Sgr A* (see Genzel *et al.* 2010, for a review). Numerical simulations have shown that cold, dense clumps are embedded in the ISM. These clumps constitute a large fraction of the matter captured at the Bondi radius, and may cause variability in Sgr A*'s activity on time-scales of several years (Cuadra *et al.* 2008). Their physical origin and evolution are not yet entirely understood, but they are thought to be produced as the result of hydrodynamic instabilities in stellar wind collisions (Calderón *et al.* 2016), specially when the thermal energy of the shocked gas is radiated very rapidly. Interestingly, G2 and other similar objects observed in Sgr A*'s vicinity (Gillessen *et al.* 2012, Pfuhl *et al.* 2015) could correspond to such clumps (Burkert *et al.* 2012, Schartmann *et al.* 2012). This work aims to study this process of clump formation in order to assess its relevance for the Galactic Centre.

2. Method and Results

Firstly, we followed an analytical approach to estimate the range of mass for clumps formed in symmetric colliding-wind systems (i.e., pairs of identical stars). To do so, we studied the stability of slabs formed in wind collisions to the *non-linear thin shell instability* (hereafter NTSI; Vishniac 1994). In our analysis (Calderón *et al.* 2016) we found that clumps can be generated with masses up to 100 $M_\oplus$. However, the stars need to be very close (< 2000 AU), their outflows have to be strong ($\dot{M} \sim 10^{-5}\ M_\odot\ \mathrm{yr}^{-1}$) and not very fast ($< 750\ \mathrm{km\ s}^{-1}$).

Secondly, we took the known sample of Wolf-Rayet stars in the inner parsec (Martins *et al.* 2007) and checked whether their winds can be radiative in order to excite the NTSI and create clumps. Our analysis (Calderón *et al.* 2016) shows that single stars would need

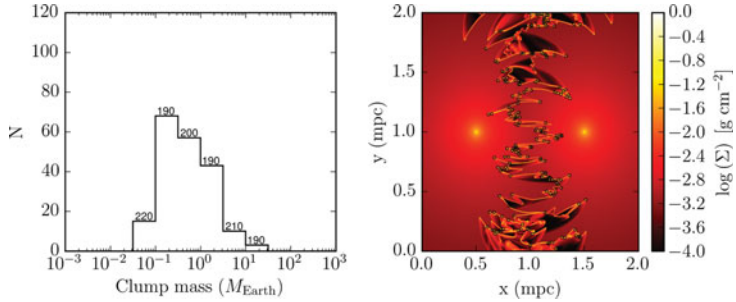

Figure 1. Colliding wind system simulation snapshot. Left panel: histogram of the clump masses. Clump mean velocities are shown on top of each bin (km s^{-1}). Right panel: surface density map. Detected clumps are shown as black circles.

to reach very short separations ($d < 200$ AU), which are never realised given their orbits (Cuadra *et al.* 2008). However, massive compact binaries, such as IRS 16SW, would be ideal clump sources.

Finally, we ran a hydrodynamical simulation of a colliding wind system. From this, we can estimate a clump mass function, formation rate, and also validate our analytical approach. We made use of the adaptive mesh refinement code RAMSES (Teyssier 2002) to simulate two identical stars fixed in space in 2D. We considered an isothermal equation of state as the wind parameters we chose give a very short cooling timescale. The stars are 200 AU apart, have mass loss rates of 10^{-5} $M_\odot$ yr^{-1}, and wind terminal speeds of 500 km s^{-1}. The slab resulting from the wind collision becomes unstable and form clumps (see Figure 1).

3. Conclusions

We have found that collisions of slow (< 750 km s^{-1}) Wolf-Rayet winds can generate clumps with masses up to 100 $M_\oplus$. To do so, stars need to achieve very short separations ($<$ 2000 AU). This makes clump formation unlikely to occur in the Galactic Center through stellar encounters, as their separations never get short enough. However, compact massive binary systems are promising clump sources. Specifically, the orbit of IRS 16SW makes this binary the best candidate to have created G2 (see Calderón *et al.* 2016). Finally, our simulations of colliding wind systems agree with our analytical predictions, forming clumps with masses up to 100 $M_\oplus$. Our results are consistent with the hypothesis of G2 being a gas clump formed in wind collisions.

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