Large Scale Gas Dynamics In Massive Star Forming Regions at High Angular Resolution

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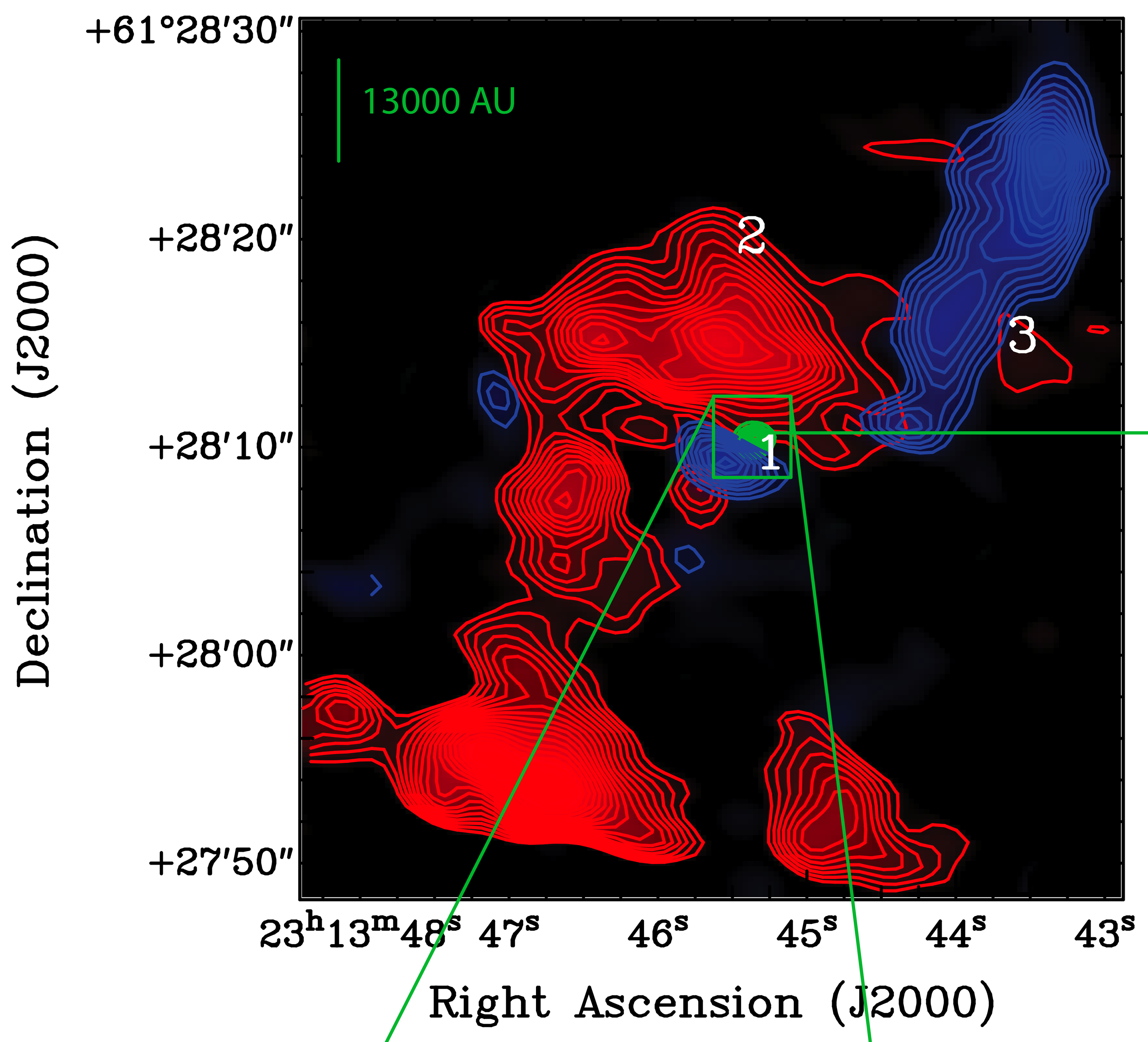
Massive stars play a large role in the evolution of galaxies, yet it is still unclear how they form. Only through observing the gas dynamics in enough massive star forming regions at high resolution, can we support or refute the outputs of simulations. Towards this goal, we observed a few high mass star forming regions at high angular resolution (~1") through combining two SMA configurations with JCMT short spacing data (Klaassen et al. 2009, 2010 submitted). Below, we show an example of the molecular gas dynamics found in NGC 7538 IRS1. For this source we find large scale infall and outflow as well as rotation of the warm gas around the HII region and suggest that star formation is still ongoing.

Outflow

We see outflows coming from two sources: NGC 7538 (Fig 1) and G28.2. In Figure 1, the green contours show the continuum emission from the HII region while the blue and red contours show the blue and red shifted CO emission integrated from 6-20 km/s from the source rest velocity (-59 km/s). The three numbers show the positions of the IRS 1, 2 and 3 regions, all of which fit within a single JCMT pixel. For our sources, when we see a large scale outflow, it is produced by the single largest HII region within each map.

Fig 1: Large scale outflow from NGC 7538 IRS1. The structures visible on large scales can be traced back to the single HII region (shown in green). The numbers show the HII regions present within a single JCMT pixel.



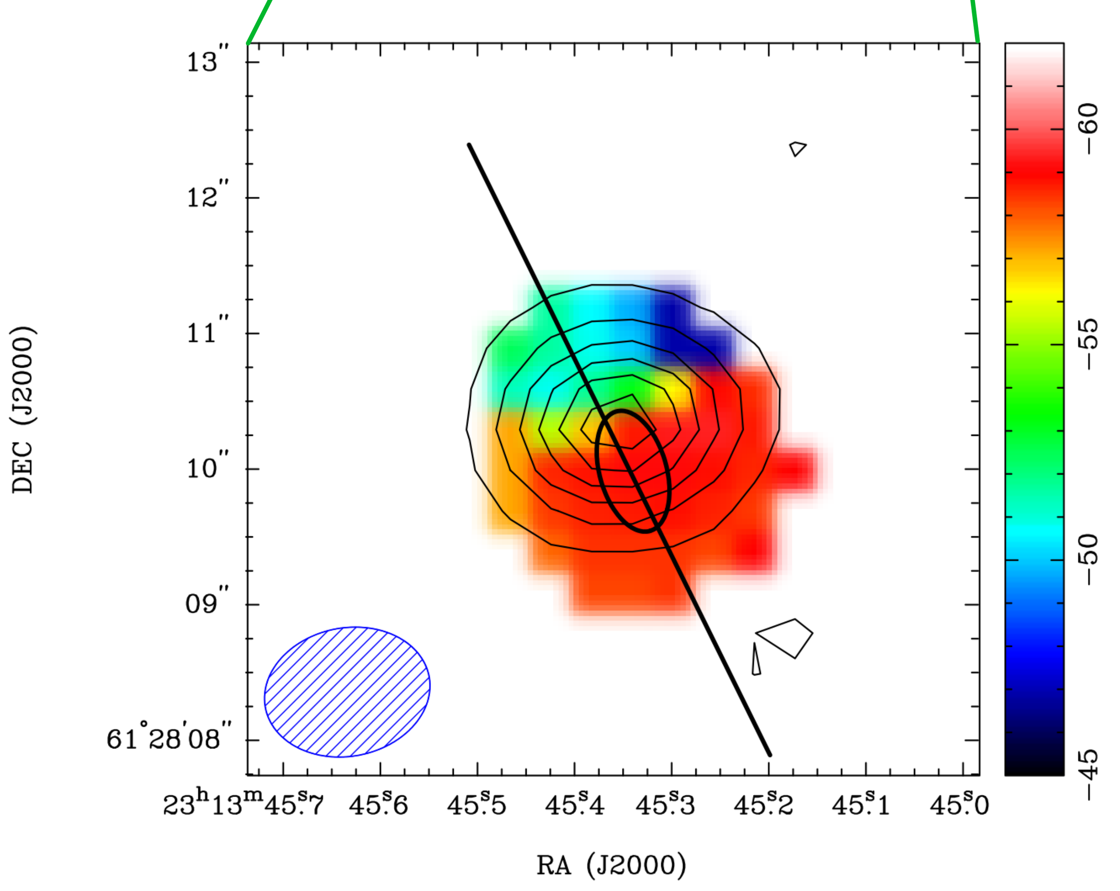
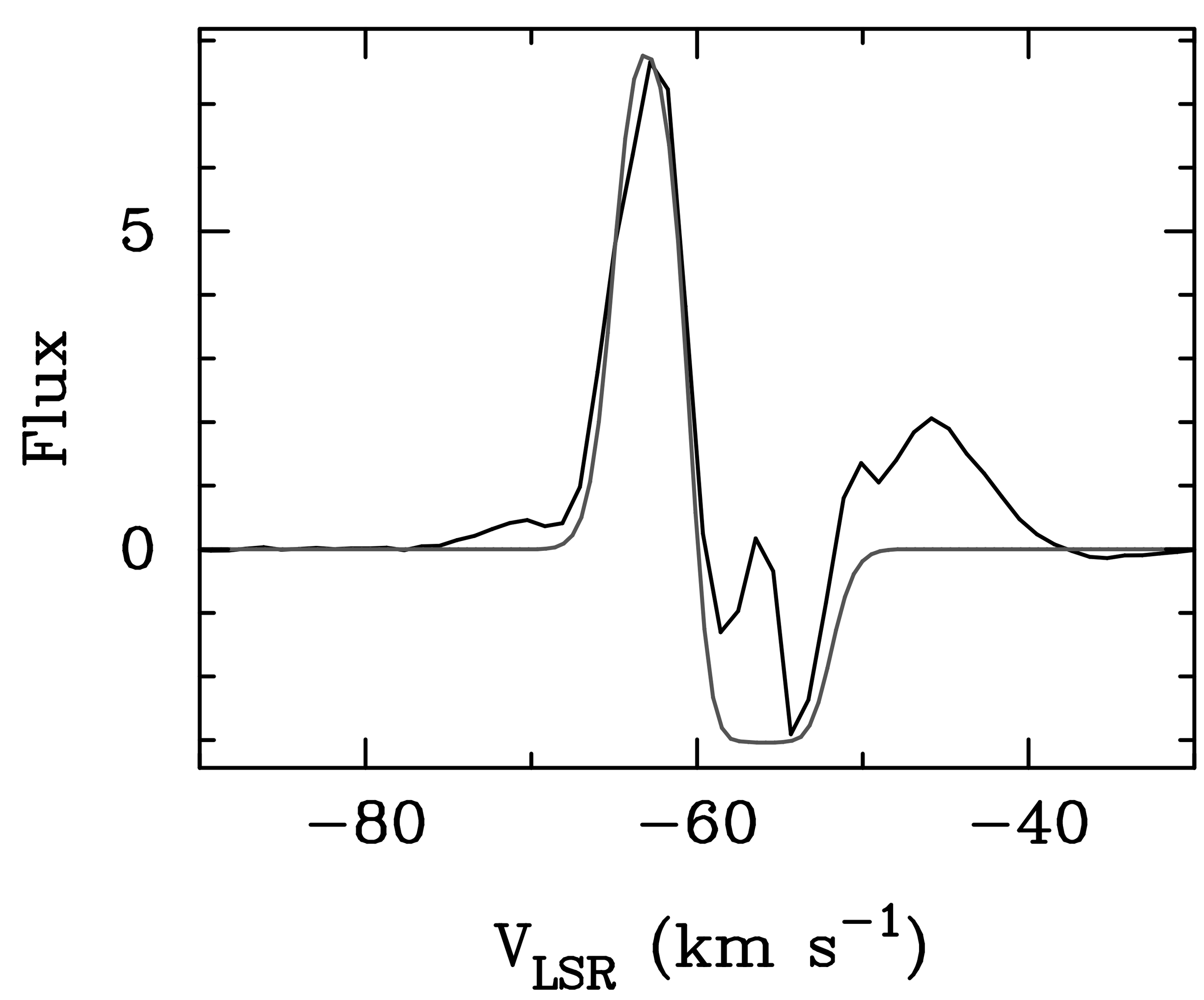


Fig 3: SO_2 first moment map showing the direction of rotation of the warm gas surrounding the HII region in NGC 7538 IRS1

Infall

We detect inverse p-cygni profiles in CO towards two of sources; NGC 7538 (Fig 2) and G10.6. PV diagram arcs (not shown) confirm the infall direction is preferentially along the plane of rotation. Two layer infall modeling (as described in Di Francesco et al. 2001) suggests infall velocities of 2.3 and 2.5 km/s (respectively) and mass infall rates of 10^{-4} $M_\odot$/yr. For this sources, the model is shown as a grey line in Figure 1. Infall has also been detected in the ionized gas towards G10.6 (Keto & Wood 2006) suggesting these motions transcend the ionization boundary.

Fig 2: The CO spectrum, shown in black, comes from integrating the spectrum over the face of the unresolved HII region in NGC 7538 IRS1. The grey line shows a 2 layer infall model which suggest an infall velocity of 2.3 km/s and mass infall rate of 10^{-4} $M_\odot$/yr



Rotation

We have shown that the warm gas surrounding these HII regions is undergoing bulk rotation (Fig 3), and that the ionized gas within the HII regions in W51e2 and G28.2 appears to be undergoing the same bulk motions. The pressure broadening present in the RRLs from the other sources is so great that any possible rotation signature is buried in the line width.

Conclusions

We find that the large scale structures can be linked back to a single HII region, and that for the smaller scale structures at least (infall and rotation), the dynamics appear to penetrate the ionization boundary. The continued ionized and molecular infall and rotation combined with the outflows being traceable back to the edges of the HII regions suggests that accretion onto the central stars is ongoing, despite the presence of the HII regions