Precessing Outflow in L1551 IRS5 Protostellar System

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Introduction
The multiple protostellar system L1551 IRS5 exhibits a large-scale bipolar molecular outflow that span ~1.5 pc on both NE (redshifted) and SW (blueshifted) sides of the system. We have studied this outflow with in ~4000 AU of its driving source(s) with the SubMillimeter Array. Our CO(2-1) image at 4″ (~560) resolution reveals a previously unknown S-shaped structure spanning ~10° from center with an opposite velocity pattern to the large-scale outflow. This newly found component mostly likely comprises a precessing outflow driven by a recently reported candidate third protostellar component.

Observations
Telescope: SMA
Line: CO (J=2-1; 230.538 GHz)
Primary Beam (FWHM): ~57″
Synthesized Beam: 4.7″ x 2.3″, P.A. = -66.7°
Velocity Resolution: ~0.27 km s\(^{-1}\)

Results
Figure 1 shows the CO(2-1) integrated intensity map. The most prominent feature in this map is an X-shaped structure. The X-shaped component comprise the base of the large-scale outflow. The next most prominent feature in the integrated-intensity map of Figure 1 is the S-shaped structure which is located between the blueshifted and redshifted arms of the X-shaped structure and extends to ~10° from center. The velocity pattern of the S-shaped structure is opposite to that of both the X-shaped structure and large-scale bipolar molecular outflow.

Discussion
Given that the S-shaped component exhibits a velocity pattern opposite to the X-shaped component and large-scale bipolar molecular outflow, it is unlikely to comprise material entrained by the collimated winds of the two main protostellar components. The morphology of the S-shaped component resembles a precessing outflow. We adopt the following simple model to assess both its morphology and kinematics (adapted from Eislöffel et al. 1996):

\[
\begin{align*}
\begin{pmatrix} x \\ y \end{pmatrix} &= \begin{pmatrix} \cos \psi & -\sin \psi \\ \sin \psi & \cos \psi \end{pmatrix} \begin{pmatrix} \alpha \cdot \sin(2\pi t/\lambda + \phi_0) \\ \lambda \end{pmatrix} \\
\end{align*}
\]

The line-of-sight velocity can be derived from the equation:

\[
V_{\text{LOS}} = V_{\text{LSR}} + V_{\text{CO}} [\cos \theta \sin \iota + \sin \theta \cos \iota \cos(2\pi t/\lambda + \phi_0)]
\]

Here \(\psi\) is the position angle of symmetry axis on the plane of sky, \(\alpha\) the precession amplitude, \(\lambda\) the precession length scale, \(\iota\) the distance from the source, \(\phi_0\) the initial phase at the source, \(\iota\) the inclination angle of the outflow symmetry axis to the plane of the sky, \(\theta\) the precessing angle and \(V_{\text{CO}}\) the assumed CO(2-1) velocity.

The S-shaped component is likely driven by a recently found 3\(^{rd}\) protostellar component in L1551 IRS5 (Lim & Takakuwa 2006). Precession of the S-shaped component may be caused by the precession of the circumstellar disk, owing to the tidal interaction between the 3\(^{rd}\) protostar and its massive neighbor, as shown by Bate et al.(2000). We also derive the precession period of the jet of 130–400 years. It is compatible with the prediction of Bate et al.(2000).

References