Multiple CO Outflows in Circinus: The Churning of a Molecular Cloud
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abstract

We present a millimeter wave study of a cluster of bipolar CO outflows embedded in the western end of the Circinus molecular cloud complex, G317-4, that is traced by very high optical extinction. For an assumed distance of 700 pc, the entire Circinus cloud is estimated to have a mass of about $5 \times 10^4$. The opaque western portion that was mapped in this study has a mass of about $10^3$, contains a number of embedded infrared sources and various compact 1.3 mm continuum sources, and has a remarkable filamentary structure with numerous cavities which appears to be the fossil remnants of past star formation activity. The most active star forming region in this part of Circinus is centered around a compact cluster of millimeter continuum sources associated with IRAS 14564–6254 and IRAS 14563–6301 which lies about 7 to the south. This region contains two known Herbig-Haro objects, HH 76 and HH 77, and a profusion of overlapping high velocity CO outflow lobes. Among these, we can clearly distinguish the two largest outflows in Circinus (flows A and B) which appear to originate from the two brightest IRAS sources. This region also contains at least two other prominent but overlapping bipolar CO outflows (flows C and C’), one of which may be associated with IRAS14564–6258. Two compact and relatively low velocity CO outflows lie at the northern periphery of the Circinus core and are associated with IRAS 14563–6250 (flow E), a source also detected as a 1.3 mm continuum source, and with IRAS 14562–6248 (flow G). A small but prominent reflection nebula associated with the nebulous star vBH65a and a co-axial Herbig-Haro jet, HH 139, is located at the southeastern edge of this cloud core and illuminates part of a cavity seen as a low extinction region. A faint and low mass CO molecular flow is associated with vBH65a and HH 139 (flow F). The infrared source IRAS 14580–6303 drives a small CO flow (flow I). A second, active center of star formation is centered on the source IRAS 14592–6311, the peculiar Herbig Ae/Be star vBH65b, about 20' to the southeast of the main cloud core; four HH objects, HH 140 to HH 143, and a compact CO outflow are located here (flow D). About 5 further south, IRAS 14596–6320 drives yet another outflow (flow H). Thus, the mapped portion of Circinus contains at least 10 CO emitting molecular outflows. Assuming that star formation has continued at a steady rate for the last several hundred thousand years, the Circinus cloud is expected to have produced dozens of young stars. Their outflows have severely altered the structure and kinematics of this cloud as evidenced by the multitude of prominent cavities and dust filaments that outline their boundaries. This level of star formation activity is consistent with the numerous post-outflow phase Hα emission line stars that have been found in this region. The Circinus cloud complex is an archetypical case where star formation activity may have profoundly affected the structure of a molecular cloud, producing its strikingly filamentary and cavitated appearance and providing further evidence that star formation may be a self regulated process.