第58卷 第3期 天 文 学 报 Vol.58 No.3
2017年5月 ACTA ASTRONOMICA SINICA May, 2017

doi: 10.15940/j.cnki.0001-5245.2017.03.012 博士学位论文摘要选登

基于大尺度谱线成图技术对恒星形成反馈的研究

李会贤†

(中国科学院国家天文台 北京 100012)

恒星是宇宙的基本组成单元, 恒星如何形成是天文学研究的一个基本问题, 它在天体起源的研究中处于枢纽地位. 对于小质量恒星的形成, 虽然目前已有一个被普遍接受的基本的物理图景, 但其中的每一个过程都存在着物理和化学上的复杂性. 一个关键的问题是恒星形成对分子云的反馈影响, 对该问题的研究有助于我们更深入地理解恒星形成及分子云演化.

本文主要研究了恒星形成过程中的分子外向流和壳层结构这两种动力学现象对金牛座分子云的反馈影响. 首先, 我们使用美国五大学望远镜(FCRAO)对金牛座分子云约100平方度的^{12}CO(1-0)和^{13}CO(1-0)谱线的大尺度巡天数据及Spitzer望远镜在金牛座天区证认出的最完备的年轻恒星天体(YSOs)列表, 对该天区的分子外向流和壳层结构进行了全面、系统的无偏搜寻. 使用IDL语言自主开发的自动搜索程序在金牛座分子云里找到了55个分子外向流和37个壳层结构, 其中有31个分子外向流是新发现的, 所有的壳层结构均为首次发现. 我们得到了金牛座天区最完备的分子外向流和壳层结构样本, 给出了这些动力学结构的形态, 并对其进行了统计分析.

从驱动源上看, 大部分分子外向流都是由I型、Flat型和II型YSOs驱动, 在III型YSOs周围只找到了少数几个外向流. 这与前人得到的分子外向流活动一般发生在恒星形成早期的结论相一致, 驱动壳层结构的YSOs绝大部分为II型和III型, 只有少数I型和Flat型的YSOs位于壳层结构内部, 这说明在演化阶段上壳层结构晚于分子外向流. 从观测形态上看, 双极外向流和单极红瓣外向流占外向流总数的绝大部分, 这可能是因为金牛座分子云比较薄且有些外向流又靠近云的表面, 因此我们看到的蓝瓣外向流较少. 虽然外向流的红瓣数目远多于蓝瓣, 但外向流蓝瓣的总质量与红瓣的总质量相当, 外向流蓝瓣的总能量与红瓣的总能量也大致相当. 在搜索到的37个壳层结构中, 只有3个是正在膨胀的气泡, 其他都是有破损的壳层结构.

我们对分子外向流和壳层结构的物理参量进行了估算, 并定量分析了这些动力学结构对母云的反馈影响. 通过计算可知, 金牛座分子云的引力束缚能为$\sim 1.5\times10^{48}$ erg; 该天区分子外向流和壳层结构的总动能分别为$\sim 3.9\times10^{45}$ erg和$\sim 9.2\times10^{46}$ erg; 金牛座分子云的湍动能为$\sim 3.2\times10^{47}$ erg; 金牛座分子云的湍流耗散率大概介于6.6×10^{32} erg·s^{-1}至3.1×10^{33} erg·s^{-1}之间; 该天区分子外向流和壳层结构的总能量注入率分别为$\sim 1.3\times10^{33}$ erg·s^{-1}和$\sim 6.4\times10^{33}$ erg·s^{-1}. 通过比较可知, 无论是分子外向流还是壳层结构都没有足够的能量来与整个金牛座分子云的引力束缚能相抗衡, 同时他们也都没有足够多的能量来产生目前观测到的整个金牛座分子云的湍流, 但分子外向流和壳层结构都具有足够的能量注入率来维持整个金牛座分子云的湍流耗散.

该课题涉及对大尺度谱线巡天数据的理解及处理. 研究过程中均使用自主开发的数据处理及成图软件, 工作量巨大. 在此过程中学习并积累的经验对我国新建成的FAST (Five-hundred-meter Aperture Spherical radio Telescope)望远镜数据处理系统的设计及开发具有重要意义.

†2015-07-01获得博士学位, 导师: 国家天文台南仁东研究员、李菂研究员; lhx@nao.cas.cn

The Feedback of Star Formation Based on Large-scale Spectroscopic Mapping Technology

LI Hui-xian
(*National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012*)

Star Formation is a fundamental topic in astrophysics. Although there is a popular model of low-mass star formation, every step of the process is full of physical and chemical complexity. One of the key questions is the dynamical feedback during the process of star formation. The answer of this question will help us to understand the star formation and the evolution of molecular clouds.

We have identified outflows and bubbles in the Taurus molecular cloud based on the ~ 100 deg^2 Five College Radio Astronomy Observatory ^{12}CO(1-0) and ^{13}CO(1-0) maps and the Spitzer young stellar object (YSO) catalog. In the main 44 deg^2 area of Taurus, we found 55 outflows, of which 31 were previously unknown. We also found 37 bubbles in the entire 100 deg^2 area of Taurus, all of which had not been identified before. After visual inspection, we developed an interactive IDL pipeline to confirm the outflows and bubbles. This sample covers a contiguous region with a linear spatial dynamic range of ~ 1000.

Among the 55 outflows, we found that bipolar, monopolar redshifted, and monopolar blueshifted outflows account for 45%, 44%, and 11%, respectively. There are more red lobes than blue ones. The occurrence of more red lobes may result from the fact that Taurus is thin. Red lobes tend to be smaller and younger. The total mass and energy of red lobes are similar to blue lobes on average. There are 3 expanding bubbles and 34 broken bubbles among all the bubbles in Taurus. There are more outflow-driving YSOs in Class I, Flat, and Class II while few outflow-driving YSOs in Class III, which indicates that outflows more likely appear in the earlier stage (Class I) than in the later phase (Class III) of star formation. There are more bubble-driving YSOs of Class II and Class III while there are few bubble-driving YSOs of Class I and Flat, implying that the bubble structures are more likely to occur in the later stage of star formation.

The total kinetic energy of the identified outflows is estimated to be $\sim 3.9 \times 10^{45}$ erg, which is 1% of the cloud turbulent energy. The total kinetic energy of the detected bubbles is estimated to be $\sim 9.2 \times 10^{46}$ erg, which is 29% of the turbulent energy of Taurus. The energy injection rate from the outflows is $\sim 1.3 \times 10^{33}$ erg$\cdot$s^{-1}, 0.4–2 times the turbulent dissipation rate of the cloud. The energy injection rate from bubbles is $\sim 6.4 \times 10^{33}$ erg$\cdot$s^{-1}, 2–10 times the turbulent dissipation rate of the cloud. The gravitational binding energy of the cloud is $\sim 1.5 \times 10^{48}$ erg, 385 and 16 times the energy of outflows and bubbles, respectively. We conclude that neither outflows nor bubbles can provide sufficient energy to balance the overall gravitational binding energy and the turbulent energy of Taurus. However, in the current epoch, stellar feedback is sufficient to maintain the observed turbulence in Taurus.

We studied the methods of spectral data processing for large-scale surveys, which is helpful in developing the data-processing software of FAST (Five-hundred-meter Aperture Spherical radio Telescope).