博士学位论文摘要选登

本星系群旋涡星系盘的化学演化及恒星形成历史的研究

尹 君 †

(中国科学院上海天文台 上海 200030)

银河系、 M31 和 M33 是本星系群仅有的 3 个旋涡星系. M31 和银河系有类似的质量、光度和形态，而 M33 的重子物质质量仅约为银河系的 1/10. 从理论上对它们进行细致的比较研究，非常有利于进一步理解旋涡星系以及本星系群的形成和演化过程. 本文以银河系化学演化模型为参照，通过建立非瞬时循环假设下的唯象内落模型，详细研究了这 3 个旋涡星系的恒星形成和化学演化历史.

首先，我们把在银河系研究中十分成功的化学演化模型框架应用于 M31 盘的化学演化研究中，期望用一个简单统一的化学演化模型来同时描述银河系和 M31 盘各种观测量的径向轮廓和化学演化性质. 我们利用了尽可能多的观测数据来约束模型，尤其是对 M31 盘，首次采用了由紫外天文卫星 (GALEX) 得到的恒星形成率 (SFR) 轮廓作为观测约束. 论文详细总结了银河系和 M31 盘相关的观测数据，并对两个星系盘进行了比较. 当径向距离对标长进行归一化后，两个星系盘的现今径向轮廓表现出很多相似性. 我们发现基于气体面密度和 SFR 面密度的观测数据，银河系的恒星形成率可以用 “标准” 的 SFR 定律 (Kennicutt-Schmidt 定律，简称 K-S 定律) 或者修正的 K-S 定律 (恒星形成率与离开星系中心的距离成反比) 来描述，而 M31 却并不可以. 正如 M31 的气体百分含量偏低所暗示的，假如 M31 的恒星形成效率比银河系更高，那么我们的模型可以很好地再现银河系盘的主体特征和 M31 盘的大部分特征. 对于 M31 而言，模型与观测不一致的最主要原因可能是 M31 近期与伴星系经历过剧烈的相互作用，使得 SFR 和气体面密度之间的关系不满足任何一种 K-S 定律. 另一方面，在 M31 盘不同区域测得的恒星金属丰度分布函数 (MDF) 反映了盘在整个演化历史中恒星形成的累计效果，不会受到近期发生的事件的影响. 我们的模型很好地再现了 6∼21 kpc (除 16 kpc 处) 的 MDF. 整体而言， M31 和银河系盘都是由内而外形成的，两者有相似的内落时标. 我们的比较研究表明，如果 M31 更接近于典型的盘状星系，那么盘状星系的模型工作最好在宇宙学框架下来进行，本文所采用的唯象模型更适用于描述像银河系这样比较宁静的星系.

其次，我们把相似的模型应用于 M33 盘的化学 - 颜色演化研究上. 我们详细计算了 M33 盘的气体与 SFR 的面密度径向轮廓、气体百分含量、金属丰度、远紫外 (FUV) 和 K 波段的表面亮度及 FUV-K 颜色等参量的时间和空间演化历史，并与观测结果作比较. 我们建立了两种具有不同内落历史的模型，即坍缩模型和吸积模型，详细讨论了不同自由参数 (内落时标、内落延迟及外流效率等) 对模型结果的影响. 无论是坍缩模型，还是吸积模型，模型和观测数据的比较表明 M33 盘不可能通过气体快速坍缩过程而形成，相反，盘在整个演化过程中应该是通过缓慢吸积气体过程形成的. 观测数据表明， M33 是一个低金属丰度、富气体的小质量盘状星系，这也说明其演化并不充分，与缓慢吸积模型

†2009-06-30 获得博士学位，导师：上海天文台侯金良研究员； jyin@shao.ac.cn

相一致．此外，对 M33 盘各元素的金属丰度梯度的研究表明，外流对丰度梯度的演化起重要作用．在不考虑外流的情况下， M33 盘演化至今的丰度远高于观测值；而引入一定的外流后， 6 kpc 以内的丰度明显降低， 6 kpc 外因其丰度原来就比较低，所以变化并不明显，于是导致丰度梯度变平，更加接近观测到的丰度分布特征．当模型选取较长的内落时标并引入外流后，模型预言的 FUV-K 颜色梯度比观测结果略平．考虑到尘埃改正的不确定性，我们认为模型得到了合理的结果．

Chemical Evolution and Star Formation History of the Disks of Spirals in Local Group

YIN Jun
(*Shanghai Astronomical Observatory, Chinese Academy of Sciences, Shanghai 200030*)

Milky Way (MW), M31 and M33 are the only three spiral galaxies in our Local group. MW and M31 have similar mass, luminosity and morphology, while M33 is only about one tenth of MW in terms of its baryonic mass. Detailed theoretical researches on these three spirals will help us to understand the formation and evolution history of both spiral galaxies and Local group. Referring to the phenomenological chemical evolution model adopted in MW disk, a similar model is established to investigate the star formation and chemical enrichment history of these three local spirals.

Firstly, the properties of M31 disk are studied by building a similar chemical evolution model which is able to successfully describe the MW disk. It is expected that a simple unified phenomenological chemical evolution model could successfully describe the radial and global properties of both disks. Comparing with the former work, we adopt an extensive data set as model constraints, including the star formation profile of M31 disk derived from the recent UV data of GALEX. The comparison among the observed properties of these two disks displays very interesting similarities in their radial profiles when the distance from the galactic center is expressed in terms of the corresponding scale length. This implies some common processes in their formation and evolution history. Based on the observed data of the gas mass surface density and SFR surface density, the SFR radial profile of MW can be well described by Kennicutt-Schmidt star formation law (K-S law) or modified K-S law (SFR is inversely proportional to the distance from the galactic center), but this is not applicable to the M31 disk. Detailed calculations show that our unified model describes fairly well all the main properties of the MW disk and most properties of M31 disk, provided that the star formation efficiency of M31 disk is adjusted to be twice as large as that of MW disk (as anticipated from the lower gas fraction of M31). However, the model fails to match the present SFR in M31 disk by predicting too much SFR in the outer disk. We attribute this disagreement to the fact that M31 has been perturbed recently by a violent encounter. The observed SFR profile of M31 caused by this encounter does not seem to follow any form of the K-S law. On the other hand, the stellar metallicity distribution functions (MDFs) measured along the disk of M31 indicate the integrated star formation during the whole disk history and should not be affected by recent events. Our model reproduces rather well those distributions from 6 kpc to 21 kpc (except the region at 16 kpc). Basically, the disks of MW

and M31 are formed "inside-out" with similar infall timescale. If M31 is closer to a typical disk galaxy, it would be the best that the researches on the models of this disk galaxy are carried out within the cosmological framework. Simple models, like the one adopted in this thesis, could be used to describe the quiescent galaxy, like the MW.

Secondly, the similar model is applied to investigate the formation history of M33 disk. We calculate the radial profiles of gas surface density and SFR surface density, gas fraction, abundances, the surface brightness of FUV and K bands, FUV-K color gradient and so on. All those properties are compared with observations if available. Two different infall histories, namely collapse model and accretion model, are adopted respectively. The effects of free parameters (infall timescale, infall delay time and efficiency of outflow) on the model results are discussed in detail. It is found that the disk of M33 can not be formed by fast collapse process. Observations show that M33 is much smaller and less massive than MW, but has larger gas fraction and lower metallicity. This implies that it should be formed by slow accretion process and is consistent with the slow accretion model. We study the abundance gradients of different elements in M33 disk and find that outflow should play an important role in the evolution of abundance gradients. The present abundances will be much higher than the observation if without outflow. When the disk undergoes an outflow with a similar strength to the local SFR, the abundance within the radius of 6 kpc will be reduced dramatically, but no noticeable change occurs in outer regions, resulting in a flatter abundance gradient. This is consistent with the observed features. Our model predicts a slightly flatter FUV-K color gradient when the long infall timescale and proper outflow are adopted. Considering the uncertainty of the extinction correction, the results are acceptable.