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博士学位论文摘要选登

Ia 型超新星前身星模型及其相关天体研究

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Ia 型超新星具有可校准的光度，可当作标准烛光，用来测定宇宙学距离，从而探索宇宙的形状. 然而， Ia 型超新星的前身星仍不清楚，这将直接影响当前宇宙学结果的可靠性. 本文在 Ia 型超新星前身星模型及其相关天体方面做了系统性的工作，下面是我们取得的一些主要的研究结果：

(1) 近年来人们观测发现，约有一半的 Ia 型超新星的延迟时标小于 100 Myr (Ia 型超新星的延迟时标是指从恒星形成后到发生超新星爆炸的时间间隔). 这些超新星是怎么来的？为解决这一难题，我们提出了 Ia 型超新星的氦双星前身星模型. 在该模型中，一颗碳氧白矮星从一颗氦星或者氦亚巨星吸积物质，最后发生 Ia 型超新星爆炸. 该模型可以解释短延迟时标 (<100 Myr) Ia 型超新星的形成.

(2) 系统研究了长延迟时标的 Ia 型超新星前身星模型，发现 WD+MS 以及 WD+RG 模型对长延迟时标 (>1 Gyr) 的 Ia 型超新星具有贡献，而 WD+MS 模型则是最主要的一种贡献. 这些长延迟时标 Ia 型超新星对当前的星系化学演化模型也有影响，它们会较晚地产生铁.

(3) 发现由双白矮星并合模型得到的银河系中 Ia 型超新星的诞生率约为 $2.9\times10^{-3}\ \mathrm{yr}^{-1}$, 该结果与观测值接近，而由白矮星吸积模型 (包括 WD+He 星、 WD+MS 以及 WD+RG 模型的贡献) 得到的诞生率仅占观测的 $1/2\sim2/3$. 在这些吸积模型中， WD+He 星模型可以贡献 14% 的 Ia 型超新星，这与由观测得到的弱双峰延迟时标分布相吻合，而这种弱双峰延迟时标分布对宇宙学研究具有重要意义.

(4) 白矮星吸积模型在发生超新星爆炸后会剩下一颗残留伴星，但是到目前为止还没有一颗得到证认的残留伴星. 我们给出了银河系内当前时刻各种吸积模型的残留伴星的多种观测特性 (例如：空间速度、质量、表面温度、表面重力加速度、光度、自转速度、化学丰度等), 这便于在今后的实际观测中搜寻这些残留伴星，从而检验前身星模型.

(5) 超高速星是一类神秘的天体，它的形成机制仍然不清楚. WD+He 星模型在发生超新星爆炸后会剩下一颗高速氦星 ($>400\,\mathrm{km/s}$), 这些残留氦星对超高速星这类天体的形成具有贡献，可以解释 US 708 这类超高速星.

(6) 近年来，观测支持单个低质量白矮星 ($<0.45\ M_{\odot}$) 这类天体的存在，但是其形成机制仍然是个谜，它们不能由当前的单星或双星演化产生. 我们发现长延迟时标 Ia 型超新星的残留伴星将演化成低质量白矮星，可以解释单个低质量白矮星这类天体的形成.

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The Progenitors of Type Ia Supernovae and the Related Objects

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Type Ia supernovae (SNe Ia) are good cosmological distance indicators due to their high luminosities and remarkable uniformity, and thus are used for determining cosmological parameters. However, several key issues related to the nature of their progenitor systems are still not well understood. In this thesis, the progenitors of SNe Ia and the related objects are systematically investigated. Some main results are obtained as follows:

(1) Recent observations implicate that about half of SNe Ia explode soon after starburst, with delay times less than 100 Myr, but previous models do not predict the young populations of SNe Ia. The WD + He model is proposed to solve this mystery. In this model, a carbon-oxygen WD (CO WD) accretes material from a He main sequence (MS) star or a He subgiant to increase its mass to the Chandrasekhar mass limit. It is found that this scenario can explain SNe Ia with short delay times (< 100 Myr).

(2) The progenitor model of SNe Ia with long delay times is systematically studied. It is found that SNe Ia from the WD + MS and WD + RG channels can contribute to the old populations (> 1 Gyr) of SNe Ia, in which the WD + MS channel may be the main contributor.

(3) It is found that the Galactic SN Ia birthrate from the double-degenerate (DD) model is close to those inferred from observations, while the birthrate from the single-degenerate (SD) model (including the contribution from the WD + MS, WD + RG and WD + He star channels) accounts for only about $1/2 \sim 2/3$ of the observations. In these SD models, the WD + He star channel produces 14% of all SNe Ia, which constitutes the weak bimodality suggested by recent observations.

(4) The companions in these SD models would survive after SN explosion. However, there has been no conclusive proof yet that any individual object is the surviving companion of a SN Ia. We show the distributions of many properties of the surviving companion stars of these SD models at the moment of SN explosion in the Galaxy. The properties can be verified by future observations.

(5) Hypervelocity stars (HVSs) belong to one type of mysterious objects and their formation is still unclear. The surviving companions from the WD + He star channel have high spatial velocities (> 400 km/s) after SN explosion, which could be an alternative origin for HVSs, especially for HVSs such as US 708.

(6) The existence of a population of single low-mass WDs (LMWDs) ($< 0.45\ M_{\odot}$) is supported by some observations at present. However, its formation is still a puzzle. It is found that the surviving companions of the old SNe Ia have low masses, which could explain the formation of the population of single LMWDs.