博士学位论文摘要选登

恒星绝热物质损失模型

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双星间的快速物质交换是一个非常复杂的过程，它涉及到双星演化的两个基本问题：物质交换的动力学不稳定性和公共包层的形成和演化. 这两个问题是双星演化中最不清楚的两个基本问题. 本论文通过建立相互作用双星之间的快速 (绝热) 物质损失模型，研究双星演化中物质交换的不稳定性判据和对公共包层的演化结局作出理论限制. 利用恒星绝热物质损失模型得到的结果，还有很多潜在应用. 比如，促进含双星的大样本恒星演化研究，改进演化星族合成方法等.

恒星绝热物质损失模型的建立，基于主星在快速物质损失过程中，恒星内部的热量来不及交换，满足绝热假设. 在模型中，我们假设恒星内部的熵轮廓和元素成分分布在物质损失过程中保持不变，而且恒星依然处于流体静力学平衡. 我们通过 FORTRAN95 程序实现了对模型的数值求解. 该模型亦得到在快速物质损失过程中恒星内部的光度分布和其它结构变量. 通过与含时的洛希瓣物质交换过程的对比，和与多方模型的小质量零龄主序恒星的对比，我们可以发现恒星的绝热物质损失模型可以更好地给出快速物质损失过程中主星的内部物理状态和性质.

双星系统中的主星进行物质交换过程中，若主星的物质损失率随着物质交换过程而不断增大，超过热力学时标对应的速率，那么就会发生动力学不稳定性，会导致主星与次星外形成公共包层. 若主星的表层对流区较厚时，一般在物质转移的早期就会发生不稳定的物质交换过程；若主星为辐射区外壳的主序星时，物质交换的后期只剩近似等熵的内部核时，可能会发生延迟的动力学不稳定物质交换过程. 我们利用绝热物质损失模型给出了动力学不稳定的物质交换的判据，当双星系统的初始质量比大于判据得到的临界质量比值时，将会发生动力学不稳定的物质交换. 本论文得到的双星动力学不稳定物质交换的判据更加合理，解决了巨星支恒星中多方模型的理论结果与观测的矛盾. 由快速 (绝热) 物质损失模型得到的动力学不稳定物质交换判据的结果可以作为大样本恒星演化的基本物理输入，从而促进大样本恒星演化的研究向前迈进一大步.

在研究公共包层的演化时，我们一般认为双星系统轨道能的释放提供公共包层抛射的能量，此过程需要知道公共包层演化初态和终态时的总能量. 由于在快速物质交换过程中恒星内部和外壳都对壳层的引力势能有贡献，我们不应只考虑物质交换刚开始时壳层的束缚能，而应在物质交换过程中对能量从内部到表面进行积分精确求解. 我们利用绝热物质损失模型，通过给出公共包层演化过程中的总能量，对比其能量差，再结合主星和次星在终态仍充满洛希瓣半径的限制，可以对公共包层演化过程中的恒星质量、质量比与轨道间距进行限制. 在以往近似方法中，为了解释观测，人们需要假设 3 倍甚至 10 倍的轨道能用于提供公共包层抛射的能量，这显然是不合理的；而我们利用快速 (绝热) 物质损失模型首次实现了对公共包层演化中主星总能量的精确求解，有助于解决以往理论与观测的矛盾.

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Adiabatic Mass Loss Model in Binary Stars

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Rapid mass transfer process in the interacting binary systems is very complicated. It relates to two basic problems in the binary star evolution, i.e., the dynamically unstable Roche-lobe overflow and the common envelope evolution. Both of the problems are very important and difficult to be modeled. In this PhD thesis, we focus on the rapid mass loss process of the donor in interacting binary systems. The application to the criterion of dynamically unstable mass transfer and the common envelope evolution are also included. Our results based on the adiabatic mass loss model could be used to improve the binary evolution theory, the binary population synthetic method, and other related aspects.

We build up the adiabatic mass loss model. In this model, two approximations are included. The first one is that the energy generation and heat flow through the stellar interior can be neglected, hence the restructuring is adiabatic. The second one is that the stellar interior remains in hydrostatic equilibrium. We model this response by constructing model sequences, beginning with a donor star filling its Roche lobe at an arbitrary point in its evolution, holding its specific entropy and composition profiles fixed. These approximations are validated by the comparison with the time-dependent binary mass transfer calculations and the polytropic model for low mass zero-age main-sequence stars.

In the dynamical time scale mass transfer, the adiabatic response of the donor star drives it to expand beyond its Roche lobe, leading to runaway mass transfer and the formation of a common envelope with its companion star. For donor stars with surface convection zones of any significant depth, this runaway condition is encountered early in mass transfer, if at all; but for main sequence stars with radiative envelopes, it may be encountered after a prolonged phase of thermal time scale mass transfer, so-called delayed dynamical instability. We identify the critical binary mass ratio for the onset of dynamical time scale mass transfer; if the ratio of donor to accretor masses exceeds this critical value, the dynamical time scale mass transfer ensues. The grid of criterion for all stars can be used to be the basic input as the binary population synthetic method, which will be improved absolutely.

In common envelope evolution, the dissipation of orbital energy of the binary provides the energy to eject the common envelope; the energy budget for this process essentially consists of the initial orbital energy of the binary and the initial binding energies of the binary components. We emphasize that, because stellar core and envelope contribute mutually to each other's gravitational potential energy, proper evaluation of the total energy of a star requires integration over the entire stellar interior, not the ejected envelope alone as commonly assumed. We show that the change in total energy of the donor star, as a function of its remaining mass along an adiabatic mass-loss sequence, can be calculated. This change in total energy of the donor star, combined with the requirement that both remnant donor and its companion star fit within their respective Roche lobes, then circumscribes energetically possible survivors of common envelope evolution. It is the first time that we can calculate the accurate total energy of the donor star in common envelope evolution, while the results with the old method are inconsistent with observations.