

基于多种观测资料的双星轨道拟合研究

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双星轨道拟合研究的主要目标是给出双星系统完整的运动学参数, 包括质心运动学参数、二体轨道参数、恒星质量参数等. 这些参数不仅是高精度、高密度星表参考架的必要组成部分, 而且为恒星物理、星团和星系天文学等领域的研究提供了重要帮助.

近年来, 随着各种观测技术的发展和运用, 特别是空间天体测量、光干涉观测和高分辨分光观测的开展, 各种高精度的观测资料越来越多, 双星轨道拟合也成为当前天文学研究的重要研究课题.

针对联合多种观测资料的双星轨道拟合研究, 本论文开展了如下几方面工作:

一、基于新编的依巴谷中间天体测量资料, 开展了双谱线分光双星系统的轨道拟合工作, 得到了 13 个系统的完整轨道解及子星动力学质量. 其中的 7 个系统 (包括 HIP 9121, 17732, 32040, 57029, 76006, 102431 和 116360) 的完整轨道解由本论文首次给出. 通过多种内符合 (依巴谷光心轨道的可探测性、依巴谷光心轨道和谐轨道的一致性以及拟合参数相关性等) 及外符合 (与相对轨道、质光关系比较等) 检验, 验证了这些结果的可靠性. 在拟合过程中, 通过利用线性模型参数替代非线性模型参数的方法, 降低了非线性参数的维数, 从而提高了轨道拟合的可靠性; 此外, 发展了一种快速的网格优化算法, 进一步提高了双星系统的轨道拟合效率.

二、基于新编的依巴谷中间天体测量资料, 开展了单谱线分光双星系统的轨道拟合工作, 给出了通过内符合和外符合检验的 51 个系统的依巴谷光心轨道解. 在此基础上, 针对主星为主序星的 18 个双星系统, 利用质光关系估计其主星的质量, 进而给出了它们的完整轨道解和星等差等信息. 并为这些系统的进一步观测和研究提供了具体分析及有关观测历表.

三、Gaia 探测器将给双星系统轨道拟合研究带来海量的高精度观测资料, 为此本论文也开展了相关预研究, 着重讨论了两方面的问题: 首先讨论了地面长期的位置观测资料在 Gaia 双星轨道拟合中的作用. 通过数值模拟, 指出了地面的位置观测资料将对轨道周期在 8~25 yr 之间的 Gaia 双星轨道拟合提供重要帮助. 其次讨论了 Gaia 天体测量资料在分光双星系统完整轨道拟合中发挥的作用. 分析表明, 针对具有可靠谱轨道的现有双谱线分光双星系统, 约有 80% 的系统能够通过拟合 Gaia 的天体测量资料给出其完整轨道解. 而对于单谱线分光双星系统, Gaia 的观测资料仅能给出其中绝大多数系统的光心轨道解. 要得到完整轨道解, 依然需要来自于地面的进一步观测.

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Binary Orbit Determination by Using a Variety of Observational Data

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The binary orbit determination is a basic research area in astronomy, its main products are the kinematical parameters of binary, which contain the kinematical parameters of the mass center and the orbital parameters. These parameters are the necessary constituents of the astronomical reference frame with high precision and high density, and at the same time they provide a necessary kinematic basis to the studies of various observed phenomena of binaries. On the other hand, because the binary orbit determination is the only direct route to obtain the stellar masses, which is one of the most fundamental parameters in astronomy, it has received great attention from astronomers for a long time.

Present researches mainly focus on the orbit determination of binary by combining a variety of observational data.

First, by fitting the revised Hipparcos Intermediate Astrometric Data (HIAD), we determine the full orbits of the double-lined spectroscopic binary systems. By using a variety of tests, we obtain the reliable full orbital solutions and the component masses of 13 systems. For 7 of them, i.e., HIP 9121, 17732, 32040, 57029, 76006, 102431, and 116360, the full orbital solutions are determined here for the first time. In the fitting process, the efficiency is improved by developing a modified grid optimization method, which reduces the number of non-linear model parameters to one, and allows all parameters to be adjustable within a region centered at each grid point.

Second, photocentric orbital solutions of 51 single-lined spectroscopic binary systems are determined by fitting the revised HIAD. Then the full orbital solutions and the component masses are estimated by using the mass luminosity relation for the systems with the main sequence primary. Moreover, the observable ephemerides are further provided for the systems with the magnitude difference less than 5 mag.

Third, Gaia mission will bring us a large amount of astrometric data with high precision. This will promote the developing of the binary orbit determination. So, we carry out the pre-researches on the following two aspects. One is to discuss the role of the long term ground-based positional data in the orbit determination of the Gaia astrometric binaries. Simulations show that these positional data can significantly improve the efficiency of the orbit determination, especially for those binaries with periods from 8 to 25 years. Another is to discuss the role of the Gaia astrometric data in the orbit determination of the spectroscopic binaries. Analyses prove that full orbital solutions for over 80% of double-lined spectroscopic binaries with reliable spectroscopic orbits can be obtained by fitting the Gaia astrometric data. But for those single-lined, only photocentric orbital solutions can be obtained. In order to obtain their full orbital solutions, future ground-based observations are needed.