

近地小行星探测和危险评估

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1994 年 7 月, 苏梅克 - 列维 9 号彗星的 21 个碎片以约 60 km/s 的速度撞击木星, 这是人类第 1 次直接观测到的大规模天体相撞. 这次事件表明地球面临着天体碰撞的现实威胁. 1995 年在纽约联合国大厦召开的预防近地天体撞击地球的国际科学会议上, 紫金山天文台提出了中国近地天体探测计划 (CNEOS). 1998 年, CNEOS 计划正式立项启动. 从选址建站、望远镜和 CCD 系统研制, 到投入试观测, 实现海量数据处理和碰撞危险评估, 经历了 7 yr 多时间. 本论文综述 CNEOS 观测系统的概貌, 搜索计划的提出和实施, 数据处理系统、小行星轨道研究和近地天体与地球碰撞危险评估系统的建立. 论文还概括介绍了作者在流星体对航天安全的影响及中程引力常数约束区域方面的研究工作.

2007 年美国国会采纳了 NASA 提出的新目标: 2020 年前对 90% 直径大于 140 m 的近地天体进行搜索、跟踪、编目和参数测量. 本论文从调研国际上小行星和近地天体研究的历史与现状出发, 阐明研究的科学意义, 深化 CNEOS 的科学目标.

CNEOS 工程包括盱眙选址建站、望远镜本体建造和 CCD 研制 3 个部分. 望远镜是 1.04/1.2/1.8 m 施密特型望远镜, 跟踪和指向精度超过设计指标, 适合近地天体搜索和观测. 探测器采用 4096×4096 漂移扫描 CCD. 本论文研究了漂移扫描的优缺点, 提出了相应的观测方法.

本论文研究了小行星驻留区域, 以及在各区域的视亮度分布, 提出了 CNEOS 观测方案制定的原则. 还研究了天文图像预处理, 星象搜索和交叉证认, 移动星象识别和移动目标分类的方法, 建立了海量观测数据处理的软件系统, 实现了数据的快速处理和国际共享. 试观测的 1 yr 里, 发现了 332 个新小行星, 包括一个 Apollo 型近地小行星 (2007 JW2), 还发现了一个木星族周期彗星 (P/2007 S1 (Zhao)). 观测数据量进入世界前八, 观测精度在观测大站中位于前列.

本论文的一项重要工作是小行星动力学研究, 建立了小行星初轨计算和轨道微分改进软件, 进行了轨道演化和星历表计算; 调研了近地天体与大行星的碰撞预报理论和方法发展的历程, 建立了地球碰撞预报的线性算法和软件, 进行了碰撞概率计算和危险评估的研究, 计算了当前碰撞概率最高的 3 个近地小行星在 200 yr 内与地球碰撞的概率, 评估了它们对地球构成的碰撞威胁.

流星雨对空间环境安全构成威胁, 经过大质量天体引力汇聚后的流星群会成倍增强这种威胁, 还会增加可观测的流星体流量. 本论文用数值算法探讨了 2011 年月掩北金牛流星雨, 有可能看到比原来预报增强 10 倍的北金牛流星雨.

在引力场测量实验中, 中程引力的测量相当有意义. 本论文利用地球卫星测量的地球引力常数、月球卫星测量的月球引力常数和月球激光测距测量数据来约束波长 λ 在 $1.2 \times 10^7 \sim 3.8 \times 10^8$ m 的中程引力常数模型, 得到该区间的约束为 $\alpha = 10^{-8} \sim 5 \times 10^{-8}$, 将约束精度提高了一个量级, 这个结果目前仍是国际上最新的.

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Survey and Risk Assessment of Near Earth Asteroids

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In 1994, 21 fragments of comet Shoemaker-Levy 9 impacted Jupiter with a velocity of about 60 km/s, which is the first grand collision between celestial bodies observed by human beings. The impact makes us informed definitely that the earth is faced with the small but serious threat of Near Earth Objects (NEOs). Chinese scientists of Purple Mountain Observatory proposed a plan of Chinese Near Earth Object Survey (CNEOS) in the conference on NEOs held in the building of the World Headquarters of United Nations, New York in 1995. This project started in 1998. During the past 7 years, CNEOS proceeded in selecting observational site, manufacturing telescope and CCD detector, carrying out observation, reducing mass data, and assessing impact risk from NEOs.

Will those so-called potential hazardous asteroids be the terminator of mankind? In 2007, NASA proposed the Spaceguard goal to detect, track, catalogue and characterize 90% of the potentially hazardous objects with diameters greater than 140 m. This dissertation reviews the current situation of research on asteroids and NEOs, which will greatly enhance our understanding of the planetary sciences.

The project of CNEOS, including selecting observational site, manufacturing telescope and CCD detector, had been put in practice since 1998. The telescope of CNEOS is a 1.04/1.20/1.80 m Schmidt telescope, equipped with a 4096 by 4096 CCD detector which has drift-scanning function. In this dissertation, the advantage and disadvantage of drift-scanning and corresponding observational method are discussed.

This dissertation discusses residential district of asteroids and distribution of visual magnitudes of asteroids. As a result, we draw three principles of observational plan. This dissertation also develops algorithms of pretreatment of astronomical image, extracting objects, and cross-identification, then discusses the methods of identifying and classifying of move objects, establishes software to realize the reduction of the mass data. Until November 2007, CNEOS had found 332 new asteroids including an Apollo type NEO and a Jupiter-family periodic comet. The observation quantity of CNEOS ranked the eighth among all 378 asteroid observation plans, and the accuracy of positional reduction was also quite well.

The dissertation carries out the research of dynamics of asteroids. A software on orbit determination, differential correction, dynamical evolution and asteroid ephemeris is reconstructed. This dissertation reviews the history of impact prediction theory, and covers the linear techniques for analyzing encounters, consisting of precise orbit determination and propagation followed by target plane analysis. The impact probabilities and risks between three NEOs and the earth in 200 years are calculated.

In this dissertation, a set of numerical algorithms are built to discuss the observational prediction of Northern Taurids under the effect of the lunar gravitational assembling in 2011. In addition, the earth satellite measurement, the lunar orbiter measurement and lunar laser ranging measurement are used to constrain the intermediate-range gravity from $\lambda = 1.2 \times 10^7 \text{ m} \sim 3.8 \times 10^8 \text{ m}$.