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Analogue Simulation and Orbit Solution Algorithm of Astrometric Exoplanet Detection† ⋆

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Abstract Astrometry is an effective measure to detect exoplanets. It has many advantages that other detection methods do not bear, such as providing three dimensional planetary orbit, and determining planetary mass, etc. Astrometry will enrich the sample of exoplanets. As the high-precision astrometric satellite Gaia (Global Astrometry Interferometer for Astrophysics) was launched in 2013, it is predictable that there will be abundant long-period Jupiter-size planets to be discovered by Gaia. In this paper, we specify the α Centauri A, HD 62509, and GJ 876 systems, and generate the synthetic astrometric data with the single-time astrometric precision of Gaia. Then we use the Lomb-Scargle periodogram to analyze the periodical signal of planetary orbit, and use the Markov Chain Monte Carlo (MCMC) algorithm to make the orbit inversion of the planetary system, the obtained result is well coincident with the initial parameters of the planet.

Key words astrometry, planets and satellites: evolution, astrometric satellites: Hipparcos, Gaia, methods: Lomb-Scargle periodogram, Markov Chain Monte Carlo (MCMC)

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1. INTRODUCTION

Since 1995, by the ground-based radial velocity observation, Major et al. discovered the first exoplanet revolving around a main-sequence star—Peg 51b[1], sofar more than 3000 exoplanets have been discovered by different methods (see Fig.1). At present, the methods for exoplanet detection are mainly as follows: the radial velocity method, transit method, TTV (Transit Timing Variation) method, direct imaging method, microlensing method, pulsar timing method, and astrometry. From Fig.1 we can find that sofar most exoplanets are discovered by the radial velocity method and transit method. In the early period, the exoplanets were mainly discovered by the ground-based radial velocity observations. In 2009, NASA launched the Kepler satellite, and more than 4600 exoplanet candidates were discovered by the transit method, in which most of them are believed to be planets. In 2010, based on the astrometric method, in terms of the PHASE (Palomar High-precision Astrometric Search for Exoplanet Systems) sky survey project of the Palomar Observatory, Muterspaugh et al. discovered a possible planet HD 176051 b with a mass of $1.5\,\mathrm{M}_{Jupiter}$[2]. In 2013, the European Space Agency (ESA) launched successfully the new-generation high-precision astrometric satellite Gaia, it will greatly promote the discovery of exoplants, and reveal further the variety and complexity of planetary systems.

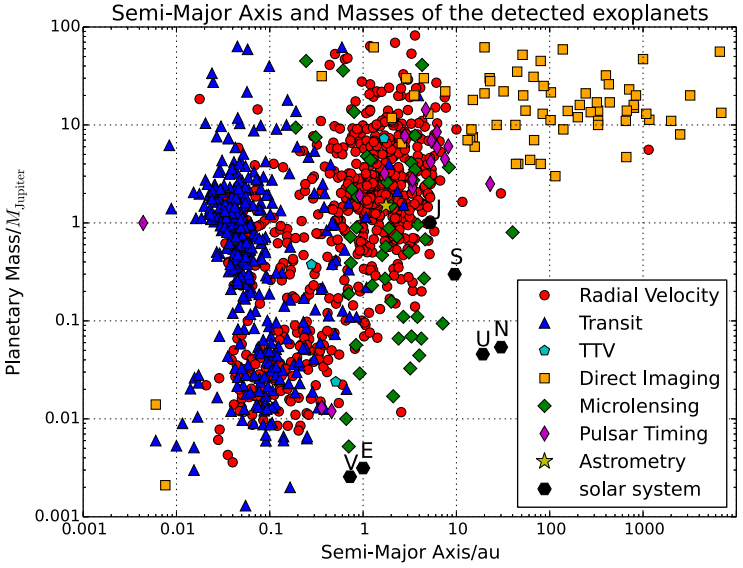

Fig. 1 The semi-major axes and masses of the detected exoplanets. The x-coordinate indicates the semi–major axis, and the y-coordinate indicates the planetary mass. The planets in the solar system are shown as black hexagons. The data come from Exoplanet.eu.

Compared with the radial velocity method and transit method, the astrometric method has the following characteristics: (1) it can give the orbital inclination i, and relieve the