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Quick-MESS: A fast statistical tool for Exoplanet Imaging Surveys

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Abstract. Several tools have been developed for the analysis of the results of direct imaging exoplanet surveys, mostly using a combination of Monte-Carlo simulations or a Bayesian approach. Here we present a novel approach to the statistical analysis of Direct Imaging surveys, called Quick-MESS, which allows for a much faster and flexible analysis.

Keywords. stars: low-mass, brown dwarfs,(stars:) planetary systems, methods: statistical

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1. Quick MESS

Upcoming direct imaging (DI) surveys will enable the statistics of planets at large ($a > 5$ AU) separations to be determined, complementing those from transit and RV surveys . Tools to investigate these surveys have been developed and typically use Monte-Carlo simulations or a Bayesian approach (see e.g. Chauvin *et al.* 2010, Lafreniere *et al.* 2008, Nielsen *et al.* 2010, Bonavita *et al.* 2012). Here we present Quick-MESS, a novel tool that uses a grid-based approach to analyzing DI surveys.

The main steps of the code, explained in detail in Bonavita *et al.* (2013) can be summarized as follows:

(a) Evaluate the probability of detection as a function of the eccentricity and the normalized separation. By using the normalized separation rather than the projected separation (ρ) or the physical separation (a), the resulting projection probability map is scale-free and only needs to be calculated once

(b) Convert the contrast curve of the instrument into a minimum detectable planet mass as a function of projected separation using planetary evolutionary models (e.g. Baraffe *et al.* (2003), Burrows *et al.* 2003).

(c) For each star in sample, calculate the expected probability of finding a planet as a function of semi-major axis (a) and planetary mass (M_p), by converting the normalized separation of the projection probability map in to a projected separation for a given a using the distance to the star and the contrast curve.

(d) Choose a probability function for planetary mass and semi-major axis and fold those into the planet-probability as found in step (c). This step can be repeated with a different choice of planet parameter distributions, and using the same planet-probability, this being the key for the speed and flexibility of QMESS.

This approach leads to a substantial reduction in the required computational time with respect to other tools based on Monte-Carlo sampling of the planet distribution. QMESS

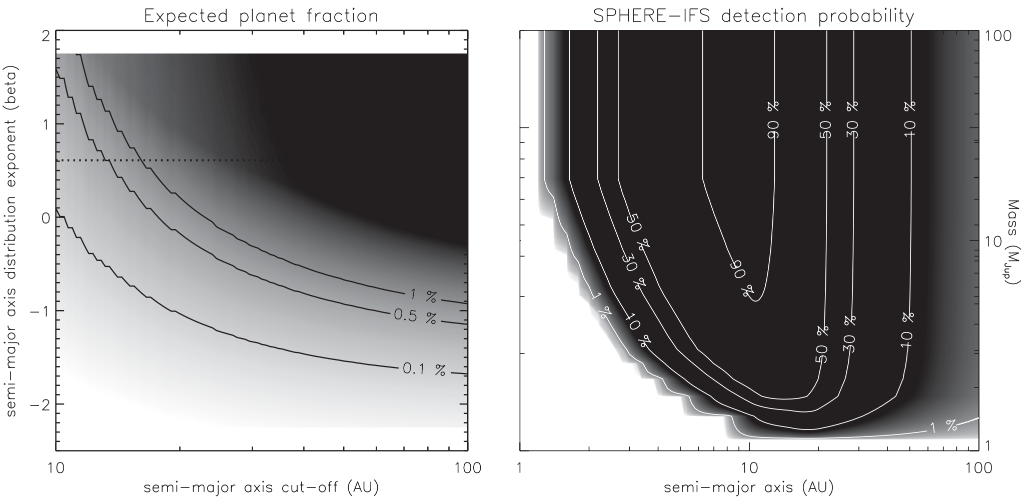

Figure 1. Left: Expected planet fraction for the GDPS survey (Lafreniere *et al.* 2008) assuming different semi-major axis distributions (power law with index beta) extrapolated to up to several maximum values (cut-off). The dotted line highlights the beta value found from the RV results ($\beta = -0.61$, see Cumming *et al.* 2008). **Right:** Predicted detection probability for a 10 Myr old A0V star at 20 pc, if observed with SPHERE-IFS (Beuzit *et al.* 2008).

is also an extremely flexible tool, enabling the study of a large range of parameter space for the mass and semi-major axes distributions (see left panel of Fig. 1) without the need of re-simulating the planet distribution. In addition to the analysis of a survey, QMESS can also be used to assess the performances of, and to select the most suitable targets for new surveys, instruments and/or different observing strategies (see right panel of Fig. 1)

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