Astrometry Operations and Software for VLTI/PRIMA

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Abstract

A search for extrasolar planets using the European Southern Observatory (ESO) Very Large Telescope Interferometer (VLTI) Phase-Referenced Imaging and Micro-Arcsecond (PRIMA) facility will become feasible starting in 2007. Most of the PRIMA hardware subsystems are currently (August 2004) under developed by industry. At the same time a scientific consortium has formed that will deliver two set of Differential Delay Lines (DDL) and PRIMA Astrometry Operations and Software (PAOS) to ESO. In this paper we describe the efforts by the consortium related to the operations and software for PRIMA astrometry. The flow of knowledge within the project is explained. The ultimate goal is being able to calibrate all PRIMA astrometric data acquired over the full lifetime of PRIMA (5 to 10 years) to a uniform accuracy of 10 micro-arcsecond. This will allow identification of long-term trends in the astrometric parameters due to planetary companions around nearby stars and to determine the distances and proper motions for the selected sources.

Keywords: Interferometry, astrometry, VLTI, PRIMA, extrasolar planets, software

1. Introduction

1.1. Astrometry and extrasolar planets

More than 120 giant extrasolar planets (http://exoplanets.org/) have been indirectly detected by measuring the radial velocity variations of the parent star. The limitations of this technique are that it does not give the inclination angles of the systems (it only puts a lower limit on the mass of the orbiting body). An additional limitation is that it can only be used for stars with a stable photospheric spectrum. The complementary technique of astrometry allows us to measure additional components of the orbital motions of the parent stars and allows us to fully characterizing the orbital parameters of the systems. The radial velocity technique is biased towards short-periods. Astrometry is biased towards long-periods.

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1.2. VLTI/PRIMA

The Phased Referenced Imaging and Micro-arcsecond Astrometry (PRIMA) facility at the Very Large Telescope Interferometer (VLTI) of ESO at Paranal (Chile) has been designed to provide 10 micro-arcsecond astrometry in the K-band. The procurement of the hardware is in progress, and astrometric operations with the Auxiliary Telescope (AT, Figure 1) are expected in 2007.

Figure 1: Close-up view of an 1.8 meter Auxiliary Telescope (courteously from ESO WWW-site).

1.3. Planet search consortium

A consortium (Quirrenbach et al. [1]) has formed which has the objective to:

1. Build two sets of differential delay lines for two telescopes (Figure 2);
2. Perform a study of the PRIMA astrometry error budget;
3. Develop a PRIMA astrometry calibrations and operations strategy;
4. Develop observation preparation software tools;
5. Develop data reduction and analysis software tools.

Details on the conceptual design of the differential delay lines are presented by Launhardt et al. [2]. Additional details on the other four deliverables are presented in Bakker et al. [3]. Design details on the design of data reduction and analysis software tools can be found in De Jong et al. [4].

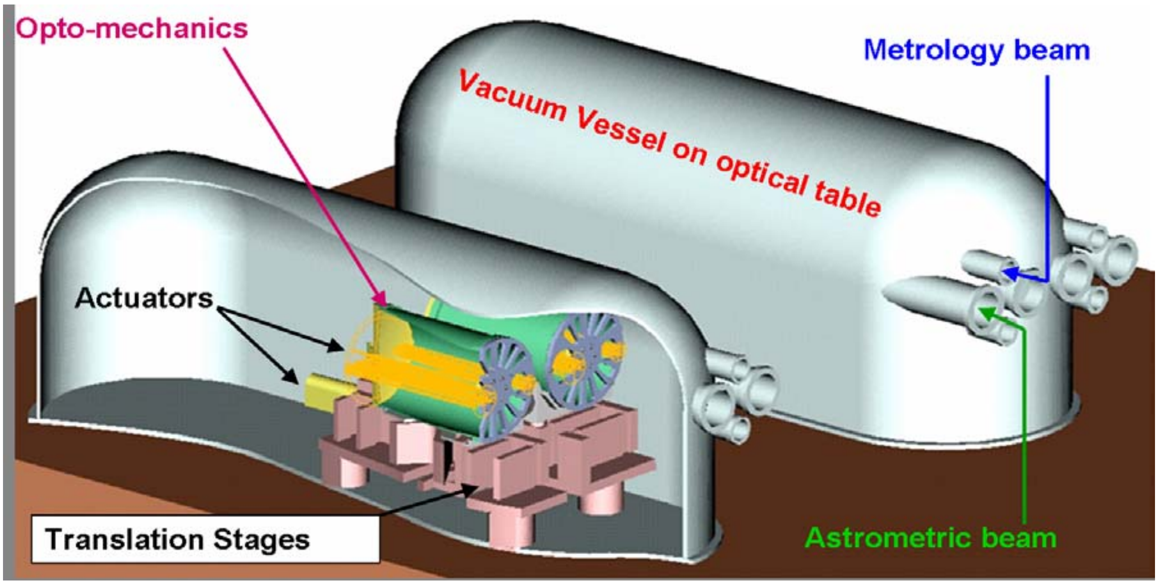

Figure 2: Conceptual design of the differential delay lines (Launhardt et al. [2]).

2. Flow of knowledge

Observing at an astrometric accuracy of 10 micro-arcsecond with the VLTI, uniformly calibrated over a period of 5 to 10 years, is a very ambitious goal. This requires that the developments and insights in the technical and scientific issues follow a flexible road-map. This road-map described the flow of knowledge in the project (Figure 3).

The flow of knowledge goes from understanding first the basic limitations and capabilities of the instrument through an extensive error analysis phase, followed by a calibration and operations strategy that minimizes the impact of the identified error sources.

Once the error budget and strategy/plan have been finalized, software tools can be developed. At least two major tools are required to exploit the instrument:

- Tools that will allow astronomers to prepare their observations;
- Tools that will allow astronomers to reduce and analyse PRIMA astrometric data.

Software to run the instrument is of course mandatory and will be developed by ESO as part of the overall VLTI software infrastructure or is provided by other groups.

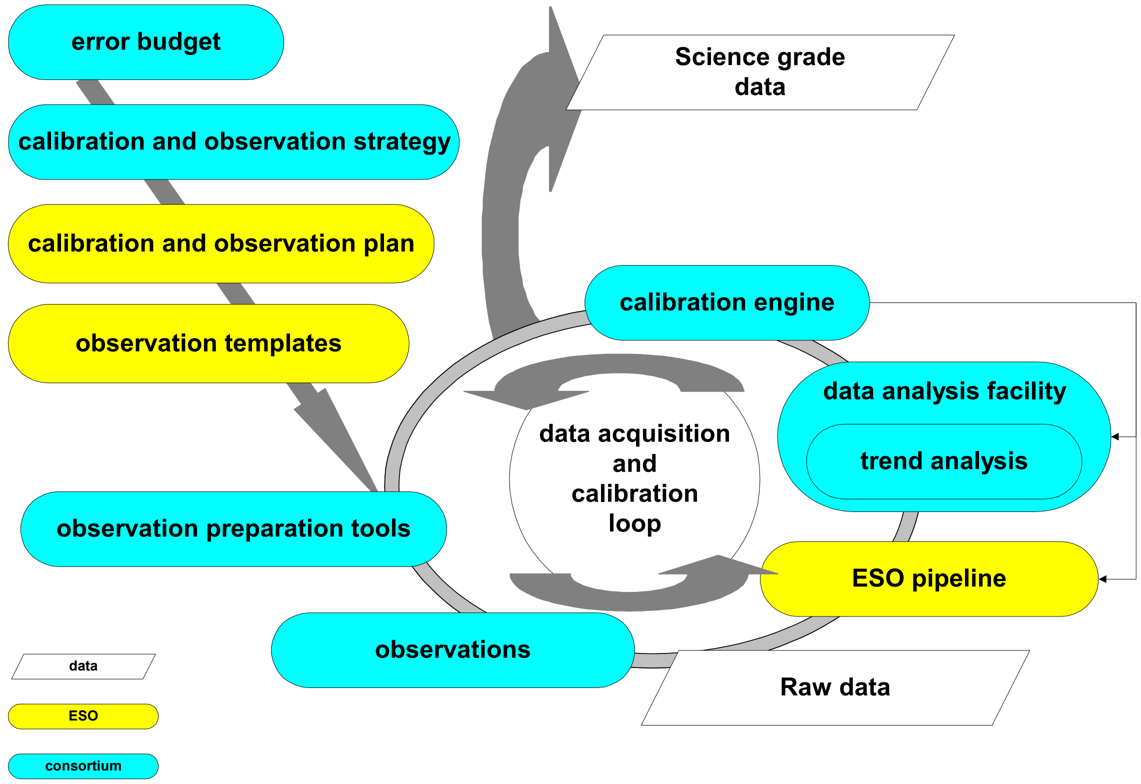

Figure 3: Flow of knowledge within the consortium's PRIMA astrometry operations and software activities.

3. Studies

Two studies will be conducted. Both studies are aimed at optimising the accuracy and efficiency of PRIMA astrometry. These studies are:

3.1. PRIMA astrometry error budget

Construction of an error tree follows the following procedure:

- Top-down: allocation of individual errors;
- Bottom-up: estimation of performance of subcomponents and external error sources.
- Iteration of previous steps until the top-down and bottom-up error budgets match.
    - re-balancing the error allocations;
    - improving the calibration procedures etc.,

Category of error sources under considerations are:

- Astrophysical errors;
- Atmospheric errors;
- Instrumental errors;
- Calibration errors.

3.2. PRIMA astrometry calibration and operation strategy

An analysis of the different approaches to calibrate an observation will be made. An assessment on how these approaches impact the performance of PRIMA. Approaches under consideration are:

- Grid of visual binaries;
- Grid of baseline calibrators;
- Instrumental techniques for calibration.

An analysis of the different approaches to observe will be made. An assessment on how these approaches impact the performance of PRIMA. Approaches under consideration are:

- Observing sources only at their highest elevation;
- Observing a science source with multiple reference stars, and also reference-to-reference star.

4. Software

In addition to the software required to operate the instrument (which is largely developed by ESO) two software packages are required to fully exploit the scientific capabilities of PRIMA. These are:

- PRIMA astrometry observation preparation tools;
- PRIMA astrometry data reduction and analysis tools.

4.1. PRIMA astrometry observation preparation tools

Tools that will help the astronomer to prepare a science program with PRIMA/VLTI. It will include among others:

- Scheduler;
- Ephemeris calculator;
- Acquisition time calculator;
- Exposure time calculator;
- Observation block creator.

4.2. PRIMA astrometry data reduction and analysis tools

A three stages data reduction process is planned:

Stage 1: On-line pipeline processing of the last exposure.

Stage 2: On-line pipeline processing of one night of data, and improved calibration (e.g. baseline).

Stage 3: Off-line processing of 5 up to 10 years of data. Self calibration of the full data set. Requires a dedicated Interactive Data Analysis Facility (DAF) and delivers science grade output (de Jong et al. [4]).

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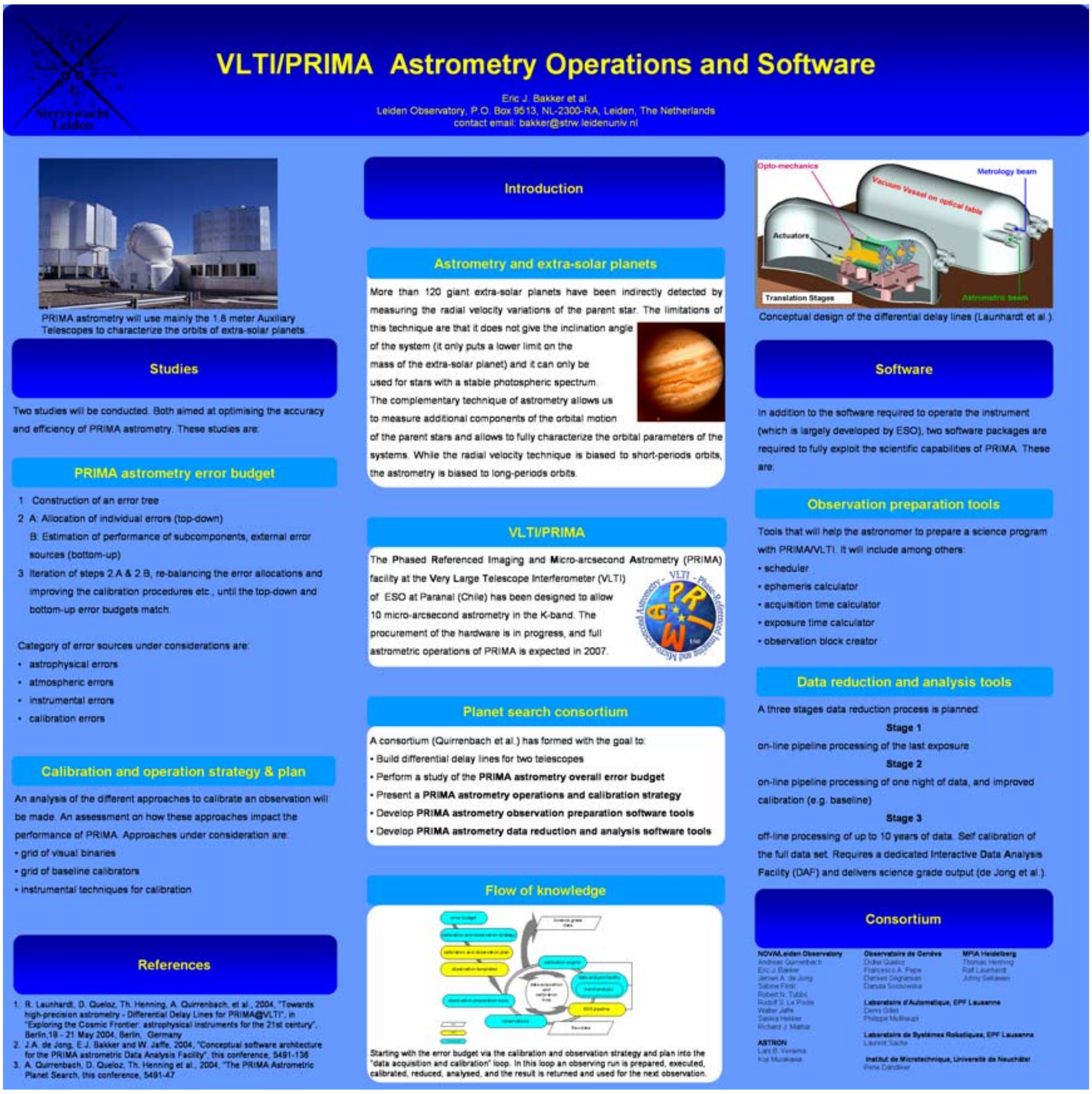

Figure 4: poster as displayed during the conference.