Differential Delay Lines

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Astrometric Survey for Extra-Solar Planets with PRIMA

PRIMA Astrometry Object and Reference Selection

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Fehler! Es konnten keine Einträge für ein Abbildungsverzeichnis gefunden werden.

Chapter 1: Introduction

1.0 Scope of the document

This document shall provide a guideline for observers who want to use PRIMA for high-precision differential astrometric measurements on how to select and characterize their target and phase reference stars. Unlike for radio interferometers, where phase reference stars can be several degrees away from the science target, it is therefore impossible to provide users with a list of standard phase calibrators.

The scope of this document is to enable observers to select and characterize their own science target and reference star pairs so that they are both suitable for the specific observing mode and ensure the achievement of the anticipated astrometric accuracy.

The document describes the top level requirements on target and phase reference stars derived from the characteristics of the instrument and the specific observing mode. It further describes qualitatively and quantitatively (based on extensive modeling) all astrophysical effects, related to the stars and their location on the sky, that can affect the astrometric stability of the pair (triple) and thus may prevent the observer from reaching the anticipated astrometric accuracy and missing the science goal of the observations.

The document also gives a guideline on how to pre-select potential reference stars from existing data bases, including quantified selection criteria. Since in most cases existing data bases cannot provide the information needed to characterize the astrometric stability of the pre-selected stars to the required accuracy, this document also provides both models and diagrams that help to further characterize the pre-selected stars and recommendations for specific preparatory observations.

This first draft contains only the Table of contents and keywords on the. Many sections could already be filled with content, others need further investigation. However, at this stage it is more important to elaborate on the logical structure of the document.

1.0.1 Applicable Documents

AD-1	VLT-???			
AD-2				

1.0.2 Reference Documents

RD-1	VLT-???			
RD-2				

1.1 Acronyms

AD	Applicable Document
AC	AOS Coordinator
AOS	Astrometry Operation and Software
CIDL	Configurated Item Data List
DDL	Differential Delay Line
DICD	Data Interface Control Dictionary
DRS	Data-reduction Software
EPF(L)	Ecole Polytechnique Fédérale (Lausanne)
ESO	European Southern Observatory
ETC	Exposure-Time Calculator
EUR	Euro
FTE	Full-Time Equivalent (1 FTE = 1 person during one year, full time)
HW	HardWare
IMT	Institut de MircoTechnique (Neuchâtel)
ISR	Institut Systèmes Robotiques
IST	Instrument Science Team
LA	Laboratoire d'Automatique (EPFL)
MPIA	Max-Planck-Institut für Astronomie (Heidelberg, D)
NOVA	Netherlands Research School for Astronomy
OG	Observatoire de Genève
PI	Principal Investigator
PM	Project Manager
PRICS	PRIMA Instrument Control Software
PRIMA	Phase Referenced Imaging and Microarcsecond Astrometry
PS	Project Scientists
RD	Reference Document
RIX	Review Item Comment/Question/Discrepancy
SE	System Engineer
SSE	Software System Engineer
SOW	Statement Of Work
SW	Software
TBC	To be Confirmed
TBD	To Be Defined
TLR	Top Level Requirement
TRS	Technical Requirements Specification
UL	University of Leiden
VLT(I)	Very Large Telescope (Interferometer)
VM	Verification Matrix
WBS	Work-Breakdown Structure
WP	Work Package
WPM	Work-Package Manager
WPD	Work-Package Description

Chapter 2: High-precision differential astrometry with PRIMA

This chapter is the introduction. It provides the reader/user with the basic insides that are necessary to understand the tight requirements on target and reference stars. References for more detailed reading are given in each subsection.

2.0 Interferometry with the VLTI

Short summary of principle and VLTI particulars. As an introduction to the next section.

2.1 PRIMA and its subsystems

Short summary, only as background to understand the measurement principle, the need for and requirements on reference stars.

2.2 High-precision differential astrometry with PRIMA

Short summary of principle of PRIMA astrometry, to understand the need for and the requirements on reference stars.

2.3 The need for phase reference stars

While the science target will usually be one star, the target of the interferometric differential astrometric observations is always a pair (or triple) consisting of the science target and one or more nearby phase reference stars that have to be selected specially for the particular science target and science goal.
What is a reference star, why is it needed, why such tight constraints.

2.4 From the observables to astrometric data

Short summary of the data reduction principle, to understand what is actually observed and how the astrometric data are derived from these observables. Also describe that absolute positions of reference stars are not known accurately, and that parallax and proper motion have to part of the solution to whatever astrometric measurements involving galactic reference stars are made.

Chapter 3: Requirements on PRIMA astrometric target and reference stars

3.1 Constraints set by the instrument, observing mode, and atmosphere

3.1.1 Introduction

Short summary of effects and constraints and their relative importance.

3.1.2 Declination limitations

Due to telescope site. Recommended standard numbers plus constraints limitations due to airmass, uv coverage, baseline projection changes, etc, as function of declination.

3.1.3 Minimum brightness of target and reference stars

K-magnitude limit for target stars (16 for ATs, 19 for UTs?)
K-magnitude limit for reference stars (10-12 for ATs, 13-15 for UTs?)
Description of gains and losses with brighter or fainter stars

3.1.4 Color difference between target and reference stars

OPD calibration uncertainty (and astrometric accuracy) as function of color difference

3.1.5 Angular separation between target and reference stars

Decorrelation angle (isoplanatic patch), visibility losses, recommended numbers for maximum separation plus diagrams that show correlation between separation, (magnitude), and astrometric accuracy. Also: Minimum angular separation, or draw-backs for very close pairs (due to star separator design).

3.1.6 Number and relative location of reference stars

Depending on goal: one vs. 2 ro 3 reference stars, preferred separation vectors for certain elevations (if there is a choice), …

3.1.7 Other parameters/effects?

Exposure time ?, Differential refraction (only if this directly affects the selection of suitable reference stars), …
Differential refraction results in a measurable distortion of the reference frame that is very sensitive to zenith angle. Not clear if this has effects only on observing strategy and data reduction, or also on target and reference star selection. To be studied further.

3.2 Astrometric stability of target and reference stars

3.2.1 Introduction

Short summary of different effects on the astrometric stability. Try to create an overview sketch or diagram.
The following sections contain: Verbal description of effects and diagrams or formulae which quantify the effects as function of stellar parameters, distance, … Also included: how can these effects (e.g., companions, activity) be observed and quantified to the required accuracy. Distinguish between stars that are save, stars that should be avoided, and stars that have to be checked more carefully (e.g., by special dedicated preparatory observations).

3.2.2 Parallax

Quantify amplitude for typical target and reference stars. Parallax will part of the astrometric solution.

3.2.3 Proper motions

Quantify amplitude of effects for typical target and reference stars. Parallax will part of the astrometric solution.

3.2.4 Perspective acceleration

Quantify and show for which stars (distance and approximate proper motion), accurate proper motion, absolute RV, and distance have to be known, to what accuracy? (Sabine)

3.2.5 Unseen companions

The information of stellar multiplicity is indispensable in selecting targets and reference stars.
Unseen substellar and stellar companions of the reference stars produce the same kind of astrometric signal in the differential measurement as planetary companions of the target star. For example, a reference star of 1 M_{Sun} at 100 parsec will produce an astrometric signal of 20 µarcsec (twice of PRIMA astrometric precision) if it has a 1 $M_{Jupiter}$ with an orbital period of 1000 days. Stars with high astrometric instability should be rejected in the selection of reference stars. …
Diagrams which quantify the effects and show which kind of companions are a concern, which ones are not, which ones can how be detected easily in preparatory observations, …

3.2.6 Chromospheric activity

Surface inhomogeneities such as starspots produce astrometric signal by changing the photometric center of the star due to the stellar rotation (rotational modulation). Since both stellar rotation periods and spot stability time scales are usually shorter than the time scale for our astrometric observations, this effect will be very difficult to predict accurately. The effects will appear as astrometric noise, thus preventing the detection of certain planets. Diagrams which quantify the effects and show which kind of activity on which stars are of concern, which ones are not, which ones can how be detected easily in preparatory observations, What kind of planets can be detected around stars (and reference stars) with certain activity, and how the activity levels can be predicted a priori or quantitatively derived from preparatory observations … Same for flares …. (Ralf)

3.2.7 Stellar pulsations

Variations of the stellar diameter due to radial/nonradial pulsations will change the luminosity and visibility of a star. Nonradial pulsations will also result in variations of photocenter. It is not clear yet, how significant this effect will be, depending on pulsation modes and which mechanism produces the stellar oscillations. To be studied further. (Sabine)

3.2.8 Circumstellar disks

In particular: scattered light, important for young stars, Zodi disks may also have an effect.
To be studied and quantified (Geoff Bryden for SIM)

3.2.9 Extended/resolved targets

Chapter 4: Selection criteria for astrometric target and reference stars

This section contains practical selection criteria (numbers and diagrams) based on the requirements and effects described in the previous section.

4.1 Top level selection criteria for astrometric targets

Brightness, declination, magnitude and time scale of expected astrometric signal, targets or target groups that are not suitable at all.

4.2 Top level selection criteria and availability of reference stars

Brightness, angular separation, spectral types that should always be avoided (depends on distance). Diagrams that show the statistical probability to find one or more reference stars for a potential target (dependence on ang. separation, galactic latitude and probably longitude, …). List also recommended catalogs to search for reference stars.

4.3 Target and goal-specific refined selection criteria

Anticipated astrometric accuracy vs. angular separation and number of available reference stars, astrometric noise as function activity levels -> translate into RV or brightness variability and strengths of acitivity indicator spectral lines, ….

Chapter 5: Recommended selection strategy

5.0 Setting the goal, accuracy, and strategy of the anticipated astrometric observations

Evaluate if the properties of the target star (e.g., mass, distance, astrometric stability) are consistent with the anticipated astrometric accuracy. The properties of the target star and the anticipated astrometric accuracy determine how many, and at what separation reference stars are needed as well as the requirement on their astrometric stability – see next section

5.1 Defining the specific requirements and selection criteria

Top-level criteria plus number, brightness, separation, astrometric stability, spectral types, activity levels, minimum distance, etc. of reference stars needed

5.2 Pre-selecting reference stars from existing data bases

Recommend catalogs and data bases. 2MASS (not deep enough, problems with faint stars very close to bright ones), USNO and other optical catalogs. Give vis. magnitude limits (depending on spectral type), where to get spectral types, distance, proper motion, etc.

5.3 Defining strategy for preparatory observations

[1] First step may have to be NIR imaging of fields around potential targets to find reference stars that are not seen in 2MASS or that where too red to be seen in optical catalogs, and to measure their K-band magnitude.
[2] Compile list of additional properties that has to be derived from dedicated preparatory observations (e.g., spectral type and color, distance, presence of disk, spot coverage, flaring and other activity, companions of certain mass and period, rotation period, precise absolute RV, …)
[3] Define the observables from which above properties can be derived.
[4] Define time scales, sensitivity, and resolution for RV and/or photometric screening, find suitable instruments, …
[5] AO imaging?

5.4 Final characterization and selection of target and reference star pairs