Differential Delay Lines

IMT
EPFL
NOVA
ASTRON
MPIA Heidelberg
University of Leiden
Observatoire de Genève

Astrometric Survey for Extra-Solar Planets with PRIMA

PRIMA Data Reduction Library: requirements

Doc. No. UL-TRE-AOS-15752-0001
Issue 0.3
Date 27 September, 2004

Prepared	Eric J. Bakker, Sabine Reffert, Jeroen de Jong	27 September, 2004	
	Name	Date	Signature
Approved	TBD		
	Name	Date	Signature
Released	TBD		

Name	Date	Signature

This page was intentionally left blank

Change Record

Issue	Date	Section/Parag. affected	Reason/Initiation/Documents/Remarks
0.3	27 September, 2004	.....	....
0.1	19 August 2004	all	First concept EJB
0.3	27 September 2004	all	Prepared for CDR

This page was intentionally left blank

Contents

List of Figures

List of Tables

This page was intentionally left blank

Chapter 1

Requirements on data reduction software

1.1 Scientific requirements

1.1.1 Introduction

1.1.2 Scientific performance requirements

The most important requirements on the Data Reduction Library (DRL) are those of the scientific performance. The output of the DRL should guarantee a well-defined accuracy of the output, an error analysis, and scientific performance verification criteria. These numbers will be stricter over time as the system matures. To discuss the scientific requirement, it is important to define what astrometric parameters are. Therefore we define that PRIMA astrometric data has the following characteristics:

1. It is the projected angular separation scalar between two sources (separation vector projected on the baseline vector);
2. It is a time series of calibrated astrometric data (possibly as long as the duration of science operations of PRIMA).

The projected angular separation scalar between two sources is not by itself of much interest to detect the reflex motion of an extra-solar planet, as the parallax and the proper motion provide an astrometric signal at least two orders of magnitude larger than the reflex motion (** ask Sabine **) expected for an extra-solar planet with a period of several years. This poses two requirements.

- Science targets should be observed frequently at epochs which places most constraints on the astrometric solution;
- The DRL should solve for at least six parameters (parallax, proper motion (RA and DEC)) for both the science and the reference source;

Two verification techniques will be used to asses the accuracy of the DRL:

1. A set (about 10, evenly spread over the accessible RA-DEC range) of visual binaries should be selected, with well known orbital parameters, to assess the accuracy of the astrometric parameters;
2. A set of baseline calibrators will be identified (up to 100, evenly spread over the accessible RA-DEC range) which will be monitored on a regular basis.

The accuracy on the astrometric parameters will most likely be limited by accurate knowledge of the baseline, and a large number of known and unknown systematic error term on the measured path length difference between the science and reference source (reference to Bobs paper ****) .

Hence, a requirement on the DRL is that an accurate baseline should be computed corresponding to each exposure with an accuracy of 10 cm for a 200 meter baseline (** ask Rudolf **).

To detect the reflex motion of an extra-solar planet, a data-set which spans several years will be required. This poses the requirement on the DRL that the calibration technique must be consistently applied for the whole data-set.

1.2 Technical requirements

1.2.1 Introduction

The system must cope with several years of data and provide full access to all raw and intermediate data in order to give the astronomers the necessary insight for finding the systematic errors. This information base should be flexible enough to allow for the addition of new derived information when a new analysis method is added to the system. Considering the large amount of computations involved in the analysis, the system should be as efficient as possible with recomputations. Therefore, it should keep track on which steps in the analysis have been altered and only recompute these steps and those depending on them. The database model must contain proper relations in order to achieve this. Processing should be possible interactively and non-interactively. The reduction time of a single exposure should be short enough to allow for a reasonable number of parameter modification tests. The package should be self-contained and distribution of the package should be possible after a detailed development phase. Technical requirements from this are that the software package DAF should have an autoinstall procedure, it should run on a standard UNIX based computer, and should not rely on commercial tools (e.g. IDL). In order to guarantee robustness scripting languages should only be used for peripheral user interface related code.

1.2.2 Req Tech 01: standarization document

The DRL should be designed and implemented within the boundary of the technical requirements. These are different than requirements on the software standards (which are discussed in a separate section).

1.2.3 Req Tech 02: processing time

An important technical performance requirement is that processing of a single exposure should be possible, and should not take more than 5 minutes. Processing should be possible interactively and non-interactively.

1.2.4 Req Tech 03: installation

The package should be self-contained and distribution of the package should be possible after a detailed development phase. Technical requirements from this are that the software package IDAF should have an auto-install procedure, it should run on a standard UNIX based computer, and should not rely on commercial tools (e.g. IDL).

1.2.5 Req Tech 04: documentation

Sufficient documentation should be available such that others can install, upgrade, and operate the IDAF independent of the developers.

1.3 Requirements on user interfaces

1.3.1 Introduction

User interface It is clear that the requirements on both flexibility and robustness pose a considerable challenge to the user interface design. The user interface needs to provide a uniform and comprehensive view on all the available data in graphical and tabular form. However, it should also provide the flexibility for adding easily new views and analysis steps on the data. These additions should always be integrated through uniform APIs (application programmers' interfaces) in order to maintain a consistent codebase. The number of APIs should be as small as possible and they should be available as abstract base classes. APIs will be provided for creating plugin panels to the user interface and adding an accompanying step to the reduction chain. The user interface plugins will include tabular and graphical visualizations and input forms, as well as interactive GUI components where needed.

1.3.2 Req UserI 01: flexibility

For the trend analysis and initial system debugging, the data analysis facility should have a flexible environment in allows to manipulate the data and display the data interactively (analogue to an IDL environment).

1.3.3 Req UserI 01: calibration

The IDAF should allow the user to place firm constraints on the calibration solution through the input of outside information on the program sources. For example, the user should be able to provide the magnitude, a spectrum, know orbital parameters from radial velocity observations, to the system.

1.3.4 Req UserI 02: errors

In order to identify calibration errors, ad-hoc events during the exposure which effects the astrometric observables, the system should provide information to the user, and request direction for the user. Hence visualization tools should be available. Given the extensive period over which the IDAF should operate (maybe up to 10 years).

1.4 Requirements on data and algorithm interfaces

1.4.1 Introduction

The input data will be provided as FITS files of which the format has to be specified by the PRIMA consortium. The software must be able to handle all standard IAU FITS format data (including ESO extensions). The internal data of the DAF will be stored in a database and XML files in case of saved configuration and snapshots. Data products and calibration files will be exported as FITS files. Algorithms will be kept strictly separate from the infrastructure in order to be able to share them between the DAF and the pipeline. All algorithms will be written in ANSI C.

1.4.2 Req DataI 01: IAU standard

FITS formats according to the IAU standard. If the standard is not available, efforts should be made to define an IAU standard.

1.5 Requirements on quality control

1.5.1 Introduction

The DAF should verify the performance of each PRIMA subsystem as far as the data available in the FITS files allow. It should make an assessment of the performance of these subsystems, and possible systematic errors. For example, the performance of the Fringe Sensor Unit (FSU) should be assessed by taking into account the spectrum of the star, the correlation between the fringe tracking parameters for both FSUs, and whether the observed signal from the FSU is consistent with that expected for the program stars (e.g. the ABCD signal of the FSU should be compared with the predicted signal given the angular size of the program star).

1.5.2 Req QC 01: quantify

The quality control should be quantified.

1.6 Requirements on simulations

1.6.1 Introduction

Each software module should have a simulation mode. A PRIMA astrometry data simulator should be available to allow to test the DAF before PRIMA astrometry data will be available. This simulator should be sophisticated enough to test the data ow and algorithms. Especially the trend analysis procedures (see Sect. 3.3) should be tested by providing data with combinations of multiple known systematic errors. This should provide limits on how well the algorithms can disentangle these errors.

1.6.2 Req Sim 01: 5 sets of simulated data should be produced

1.7 Requirements on trend analysis

1.7.1 Introduction

Remove astrometric motion parameters of science-reference source: alpha #1, delta #1, pm alpha #1, pm delta #1, parallax #1 (5 parameters)
alpha #2, delta #2, pm alpha #2, pm delta #2, parallax #2 (5 parameters)
fit for orbit
period #1, eccentricity #1, inclination #1, time of periastron passage #1, longitude of periastron #1, mass function #1, ascending node #1 (7 parameters)
period #2, eccentricity #2, inclination #2, time of periastron passage #2, longitude of periastron #2, mass function #2, ascending node #2 (7 parameters)

1.7.2 Req Trend 01: parallax

For those sources which have been observed for a period longer than one year, the trend analysis should make a best estimate of the parallax for both the science source as the reference source.

1.7.3 Req Trend 02: proper motion

For those sources which have sufficient astrometric data, the trend analysis should make a best estimate of the proper motion of the science source and the reference source.

1.7.4 Req Trend 02: trending

1.8 Requirements on calibration

1.8.1 Introduction

Calibration of astrometric observables is a key task for the DAF. Many systematic errors are expected and the astrometric observables must be calibrated. Requirements on the calibration are that there should be tools available that allows to:

1. Reduce the data of calibrators (wide binaries, and a set of baseline calibrators);

2. To compute the expected astrometric observables for the calibrators;

3. To correlate the observed versus computed error with a large number of critical (instrumental) parameters and determine the correlation coefficients;

4. Visualization tools to interactively identify trends.

5. Tools for integrating new error correction procedures into the DAF. The DRL should allow calibration of any given exposure which is in the archive, without access to any of the other

data. For this, a calibration engine will need to be developed. Requirements on the calibration engine are among others:

6. It should contain all the necessary calibration parameters such that the ESO pipeline can calibrate any given exposure;

7. It should be sufficiently flexible to allow regular updates of the calibration engine, without needing to update the ESO pipeline.

Calibration of astrometric observables is a key task for the data reduction library. Many systematic errors are expected and the astrometric observables must be calibrated. Requirements on the calibration are that there should be tools available that allows to:

- Reduce the data of calibrators (wide binaries, and a set of baseline calibrators);
- To compute the expected astrometric observables for the calibrators;
- To correlate the observed-computed error versus a large number of critical (instrumental) parameters and determine the correlation coefficients;
- Visualization tools to interactively identify trends.

The DRL should allow calibration of any given exposure which is in the archive, without access to any of of the other data. For this, a calibration engine will need to be developed. Requirements on the calibration engine are among others:

- It should contain all the necessary calibration parameters such that the DRL can calibrate any given exposure;
- It should be sufficient flexible to allow regular updates of the calibration engine, without regular updates of the DRL.
- Data analysis tools (e.g. trend analysis tools) should be available in the IDAF to allow the identification of the source of the error signal.

1.8.2 Req Cal 01: uniformly calibrated

Since the astrometric signal due to the reflex motion of a planet is very small relative to other effects (parallax, proper motion, etc.) the calibration of the data for a single science source needs to be calibrated uniformly for the duration of the time series for the source (this can be up to 5 or 10 years). The data on one single science sources must be regarded as one single data-set.

1.8.3 Req Cal 02: pipeline calibration

The pipeline at Paranal must be able to use calibration parameters from the IDAF. The calibration parameters for the pipeline must be updated every 6 months at Paranal with a minimal amount of overhead.

1.8.4 Req Cal 03: correct for polarization effects

1.8.5 Req Cal 04: correct for elevation effects

Use zenith as reference.

1.8.6 Req Cal 05: correct for color effects

User the Sun as reference.

1.8.7 Req Cal 06: correct for humid air in the optical path

User $T = 293$ K and R.H.=10 % as reference.

1.9 Requirements on software design process

1.9.1 Introduction

These requirements deal with the software programming standards (to allow long-term maintenance), and tools to verify the performance of the system and trace sources of programming error.

1.9.2 Req Design 01: *

Summary

In Table 1.1 a summary is given of the requirements discussed in the previous sections. In the near future for each of these requirements a quantities number will be listed. However, one should realize that certain requirements can only be reached if the available infrastructure does not forbid this.

Table 1.1: Requirements.

Description	Requirement	Comment
Scientific performance requirements		
SC	Compute baseline for each exposure	y
	Compute astrometric parameters for each exposure	y
	For each science-reference source pair, solve for:	
	- proper motion for science source	y
	- proper motion for reference source	y
	- parallax for science source	y
	- parallax for reference source	y
	- error analysis on proper motion	y
	- error analysis on parallax	y
Technical performance requirements		
TE	Processing of single exposure	y
	Processing of all data of a single night	y
	Processing of the full data-set	y
	Interactive mode	y
	Non-interactive mode	y
	Self contained package (for distribution)	y
	Documentation	
	- user manual	y
	- maintenance manual	y
	- installation manual	y
	Use of commercial utilities	n
Calibration requirements		
CA	Calibration engine to allow to calibrated any exposure from the archive	y
	Upgrades of the Calibration engine, independent on upgrades of the other SW modules	y
Interface requirements		
IN	User input	
	- spectrum	y
	- orbital parameters from radial velocity measurements	y
	System output	
	- visualization tools	y
Development standard requirements		
DE	TBD	