Documentation of MSAP3-31 for PLATO
Consistency checks

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March 5, 2024

Table 1: Author information

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Table 2: Version history

Issue	Date	№ change description	Page(s)	Paragraph(s)
1.0	March 4, 2023	Initial release	All	All
1.1	January 12, 2024	Updated version	All	All
1.2	March 4, 2024	Added full seismic inputs	All	All

Contents

1 Introduction

1.1 Scope of the document

This document aims to provide a description of the consistency checking algorithm for the selection and validation module of the MSAP5. It provides technical details (inputs, outputs, data types) as well as the functional description (implementation). The position of this algorithm within the data processing pipeline is described in [RD1].

1.2 Nomenclature

See 3 and 4.

Table 3: Nomenclature

Term	Description
M	mass of the star in units of the solar mass $M_\odot$
R	radius of the star in units of the solar radius $R_\odot$
A	age of the star in units of Gyr

Table 4: Standard data types

Type	Size	Values
array	arbitrary	floats

1.3 Referenced documents

The following documents are referenced:

RD1 PLATO-LESIA-PSPM-DD-0021, Work and data flows of the stellar L1/L2 processing pipeline

1.4 Abbreviations

HSD Tukey's Honestly Significantly Different statistical test

2 General overview

2.1 Name of the algorithm and status

The algorithm is MSAP5-31, *Consistency checks*. The baseline algorithm has been implemented and the prototype is complete with only minor revisions expected.

2.2 Synopsis

The objective of MSAP5-31 is to determine whether different measurements of mass (M), radius (R), and age (A) from different modules of the PLATO pipeline are consistent with one another on a star-by-star basis.

We test for consistency using the Honestly Significantly Different (HSD) algorithm proposed by Tukey [1949]. The documentation from `scipy` [Virtanen et al., 2020] summarizes the HSD algorithm as:

"a pairwise comparison of means for a set of samples... The null hypothesis is that the distributions underlying the samples all have the same mean. The test statistic, which is computed for every possible pairing of samples, is simply the difference between the sample means. For each pair, the p-value is the probability under the null hypothesis of observing such an extreme value of the statistic, considering that many pairwise comparisons are being performed... In case of unequal sample sizes, the test uses the Tukey-Kramer method [Kramer, 1956]."

2.3 Model

The algorithm runs on M, R, and A independently. For each of these, the algorithm accepts a variable number of inputs corresponding to the measurements of that quantity from different methods used in the PLATO pipeline. Each input is an array containing samples from the posterior distribution according to that method. The algorithm then computes the HSD on the inputs, and reports whether any of the measurements are inconsistent at a significance level of 0.05. The implementation of HSD used here is from `scipy 1.10.1`.

In the next iteration, this module will be adapted to receive reliability flags from each of the measurement types. Any measurement deemed unreliable will not be used in subsequent processing.

3 Lists of inputs and outputs

3.1 Complete list of inputs

The inputs are tabulated in Table 5.

Table 5: Input parameters

Name	Source	Status	Data type	Dimension	Unit
IDP_SAS_AGE_GYRO	IDP_125	optional	array	arbitrary	Gyr
IDP_SAS_AGE_ACTIVITY	IDP_125	optional	array	arbitrary	Gyr
IDP_SAS_MASS_GRANULATION	IDP_125	optional	array	arbitrary	$M_\odot$
IDP_SAS_MASS_GRANULATION_CGBM	IDP_125	optional	array	arbitrary	$M_\odot$
IDP_SAS_RADIUS_GRANULATION_CGBM	IDP_125	optional	array	arbitrary	$R_\odot$
IDP_SAS_AGE_GRANULATION_CGBM	IDP_125	optional	array	arbitrary	Gyr
IDP_SAS_MASS_SCALING_ONLY	IDP_124	optional	array	arbitrary	$M_\odot$
IDP_SAS_RADIUS_SCALING_ONLY	IDP_124	optional	array	arbitrary	$R_\odot$
IDP_SAS_MASS_SCALING_GRIDS	IDP_124	optional	array	arbitrary	$M_\odot$
IDP_SAS_RADIUS_SCALING_GRIDS	IDP_124	optional	array	arbitrary	$R_\odot$
IDP_SAS_AGE_SCALING_GRIDS	IDP_124	optional	array	arbitrary	Gyr
IDP_SAS_MASS_GRID_MIXED	IDP_124	optional	array	arbitrary	$M_\odot$
IDP_SAS_RADIUS_GRID_MIXED	IDP_124	optional	array	arbitrary	$R_\odot$
IDP_SAS_AGE_GRID_MIXED	IDP_124	optional	array	arbitrary	Gyr
IDP_SAS_MASS_GRID_SURF_IND	IDP_124	optional	array	arbitrary	$M_\odot$
IDP_SAS_RADIUS_GRID_SURF_IND	IDP_124	optional	array	arbitrary	$R_\odot$
IDP_SAS_AGE_GRID_SURF_IND	IDP_124	optional	array	arbitrary	Gyr
IDP_SAS_MASS_FREQS	IDP_124	optional	array	arbitrary	$M_\odot$
IDP_SAS_RADIUS_FREQS	IDP_124	optional	array	arbitrary	$R_\odot$
IDP_SAS_AGE_FREQS	IDP_124	optional	array	arbitrary	Gyr
IDP_SAS_METADATA_SCALING_ONLY	IDP_124	optional	string	arbitrary	
IDP_SAS_METADATA_SCALING_GRIDS	IDP_124	optional	string	arbitrary	
IDP_SAS_METADATA_GRID_MIXED	IDP_124	optional	string	arbitrary	
IDP_SAS_METADATA_GRID_SURF_IND	IDP_124	optional	string	arbitrary	
IDP_SAS_METADATA_GRID_FREQS	IDP_124	optional	string	arbitrary	

3.2 Complete list of outputs

Table 6: Output parameters

Name	Status	Data type	Dimension	Unit
IDP_SAS_CONSISTENCY_FLAGS	MSAP5_31	boolean array	3	

4 Processing description

4.1 Type of delivery

Prototype

4.2 Algorithm maturity

Algorithm concept defined, but interfaces (inputs/outputs) unstable. Has been tested with randomly-generated pseudo inputs, but needs to be tested with actual inputs from all of the PLATO modules.

4.3 Algorithm source

The implemented algorithm and test cases are shipped directly to WP12 office alongside this document as a compressed archive.

4.4 Pseudo-code

N/A

4.5 Flow diagram

N/A

5 Test case(s)

5.1 Implementation test case(s)

We test four cases using simulated data. The default inputs we adopt are 100 random samples from a truncated normal distribution for each measurement method. We use default mean values corresponding to those of the present Sun: 1 $M_\odot$, 1 $R_\odot$, 4.57 Gyr. We adopt default standard deviations of 0.04 $M_\odot$, 0.01 $R_\odot$, and 0.5 Gyr. We truncate at [0, 3] $M_\odot$, [0, 3] $R_\odot$, and [0, 15] Gyr. These tests are run in `MSAP5-31-consistency.ipynb`.

Case 1

- All consistent measurements.
- Inputs: Defaults
- Outputs: [True, True, True]

Case 2

- One inconsistent mass measurement. Additionally, in this case, the seismic radius measurement is missing.
- Inputs: Defaults, except 1 is added to all the samples from the first mass method
- Outputs: [False, True, True]

Case 3

- Two inconsistent radius measurements. Additionally, in this case, the seismic and granulation mass measurements are missing.
- Inputs: Defaults, except 0.5 is added to all the samples from the first radius method, and 1 is added to all the samples from the second radius method
- Outputs: [True, False, True]

Case 4

- Three inconsistent age measurements.
- Inputs: Defaults, except $2, 4, 6$ are added to the first, second, third age methods
- Outputs: [True, True, False]

Case 5

- Consistent but invalid measurements.
- Inputs: Defaults, except the radii are 10 solar radii larger
- Outputs: [True, True, True]

5.2 Scientific test case(s)

Simulated data would be highly valuable in testing the algorithm.

Bibliography

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