Documentation of MSAP3-34 for PLATO
Validation

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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 validation 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). Moreover, the exact 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

MSAP3-31 PLATO-MSAP3-31, Consistency checks

MSAP3-32 PLATO-MSAP3-32, Selection

1.4 Abbreviations

2 General overview

2.1 Name of the algorithm and status

The algorithm is MSAP5-34, *Validation*. The baseline algorithm has been implemented, but revisions are expected. In particular, this algorithm currently works with the publically available MIST stellar tracks [Dotter, 2016, Choi et al., 2016], but needs to be updated to use the official stellar models used in the PLATO mission.

2.2 Synopsis

The objective of MSAP5-34 is to validate the selected values of mass (M), radius (R), and age (A). In particular, we check whether these values are physically consistent with stellar models. We achieve this with a χ^2 statistical test in which we reject the null hypothesis at a significance level of 0.01. If the validation check succeeds (i.e., we fail to reject the null hypothesis), then we return the mean, standard deviation, and source of each measurement.

2.3 Model

We find the model in the grid with the smallest χ^2, defined as:

$$\chi^2 = \frac{(M - \hat{M})^2}{\sigma_M^2} + \frac{(R - \hat{R})^2}{\sigma_R^2} + \frac{(A - \hat{A})^2}{\sigma_A^2}. \tag{1}$$

Here M, R, A are the mean values of the selected measurements provided by MSAP5-32; $\sigma_M, \sigma_R, \sigma_A$ are their standard deviations; and $\hat{M}, \hat{R}, \hat{A}$ are the theoretical values from the grid of models. We then use `scipy 1.10.1` to compute the χ^2 test statistic.

The module outputs None for each measurement if they are either inconsistent (from the previous module) or invalid (as determined by this module).

3 Lists of inputs and outputs

3.1 Complete list of inputs

See documentation for MSAP5-31.

3.2 Complete list of outputs

Table 5: Output parameters

Name	Status	Data type	Dimension	Unit
DP5_SAS_MASS	mandatory	float	0	$M_\odot$
DP5_SAS_MASS_STD	mandatory	float	0	$M_\odot$
DP5_SAS_MASS_METADATA	mandatory	string	1	N/A
DP5_SAS_RADIUS	mandatory	float	0	$R_\odot$
DP5_SAS_RADIUS_STD	mandatory	float	0	$R_\odot$
DP5_SAS_RADIUS_METADATA	mandatory	string	1	N/A
DP5_SAS_AGE	mandatory	float	0	Gyr
DP5_SAS_AGE_STD	mandatory	float	0	Gyr
DP5_SAS_AGE_METADATA	mandatory	string	1	N/A

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)

The test cases are the same as MSAP5_31 and MSAP5_32. These tests are run in `MSAP5-34-validation.ipynb`.

Case 1

- All consistent measurements.
- Inputs: Defaults
- Outputs: [(1.0, 0.04, 'IDP_SAS_MASS_GRID_MIXED'), (0.999, 0.011, 'IDP_SAS_MASS_GRID_MIXED'), (4.6, 0.5, 'IDP_SAS_MASS_GRID_MIXED')]

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 in order to artificially create an inconsistent measurement
- Outputs: [None, (1.0005, 0.0092, None), (4.6, 0.5, None)]

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: [(1.002, 0.042, 'IDP_SAS_MASS_FREQS'), None, (4.6, 0.5, 'IDP_SAS_MASS_FREQS')]

Case 4

- Three inconsistent age measurements.
- Inputs: Defaults, except $2, 4, 6$ are added to the first, second, third age methods
- Outputs: [(1.0, 0.04, 'IDP_SAS_MASS_GRID_MIXED'), (0.999, 0.011, 'IDP_SAS_MASS_GRID_MIXED'), None]

Case 5

- Consistent but invalid measurements.
- Inputs: Defaults, except the radii are 10 solar radii larger
- Outputs: [None, None, None]

5.2 Scientific test case(s)

Simulated data would be highly valuable in testing the algorithm.

Bibliography

Aaron Dotter. MESA Isochrones and Stellar Tracks (MIST) 0: Methods for the Construction of Stellar Isochrones. , 222(1):8, January 2016. doi: 10.3847/0067-0049/222/1/8.

Jieun Choi, Aaron Dotter, Charlie Conroy, Matteo Cantiello, Bill Paxton, and Benjamin D. Johnson. Mesa Isochrones and Stellar Tracks (MIST). I. Solar-scaled Models. , 823(2):102, June 2016. doi: 10.3847/0004-637X/823/2/102.