EXCALIBUR vs The World:

A Comparative Analysis of HST-WFC3 Data Reduction Pipelines for Exoplanetary Observations

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Pic. credits Lorenzo V Mugnai

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“It all started with a big bang”

The case of GJ 1132b

THE ASTRONOMICAL JOURNAL

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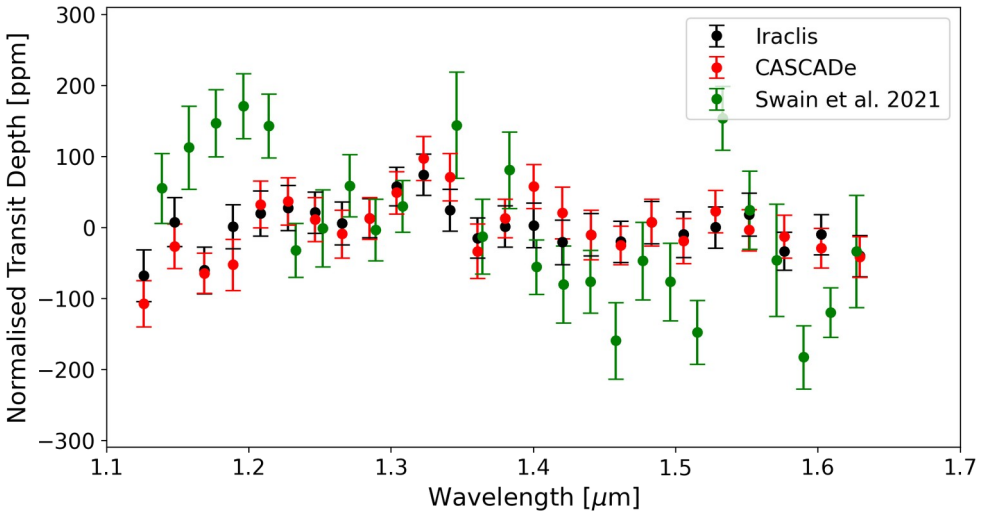

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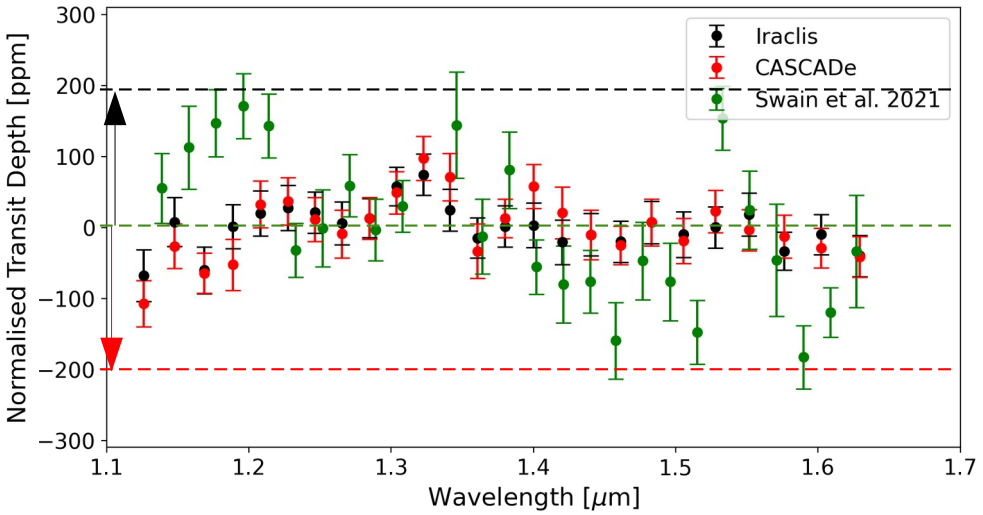

There are offsets in the spectral mean values

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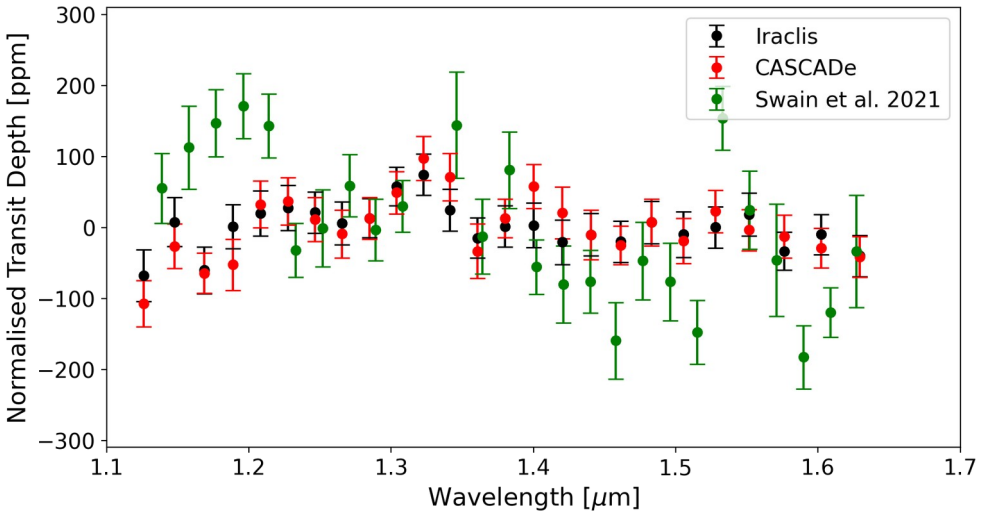

More to this planet’s story:

Libby-Roberts et al. 2022

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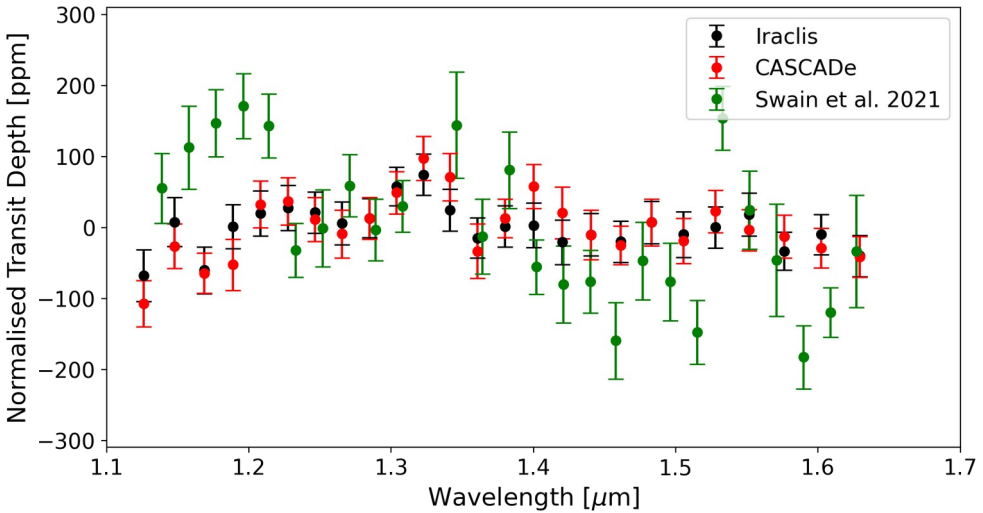

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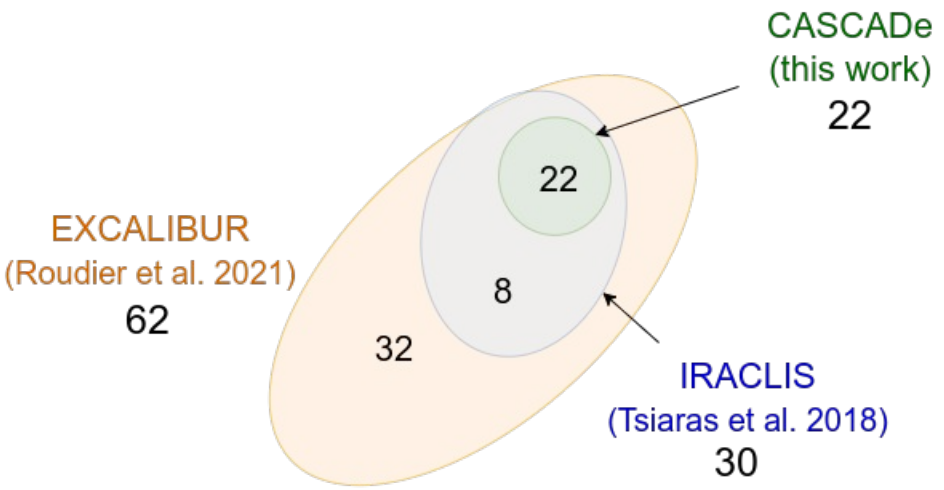
Katherine Bennet’s poster

The other pipelines

- Iraclis (Tsiaras et al. 2016):
  - starts from RAW data;
  - executes multiple corrective and calibrative steps, culminating in the extraction of flux from spatially scanned images to produce transit light curves;
  - applies Kreidberg's divide-white method for spectral light curve fitting and normalization.

- CASCADe (Carone et al. 2021):
  - starts with the "ima" intermediate data product from the CALWFC3 pipeline, skipping direct data calibration;
  - implements a data-driven method enhancing data reduction accuracy by leveraging causal connections within the dataset;
  - completely automatic.

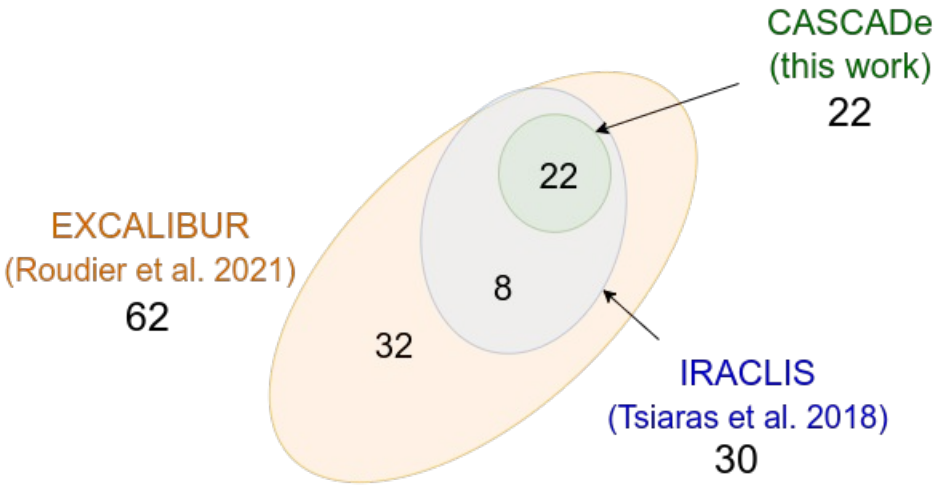
Populations from the literature



Exoplanets observations with HST-WFC3

- Tsiaras et al. 2018: transmission spectra for 30 gasseos exoplanets processed with Iraclis pipeline;
- Roudier et al. 2021: spectra for 62 exoplanets, processed with EXCALIBUR pipeline;
- This work: 22 transmission spectra obtained with the automatic CASCADe pipeline. Roudier et al. 2021 system parameters used as inputs.

Intersections in the data sets



- **Intersections** are exoplanets observations (same dataset) that have been analyzed with different pipelines.
- **22** HST-WFC3 observation analyzed with **all the pipelines**.
- Other **8** datasets processed with both EXCALIBUR and Iraclis.

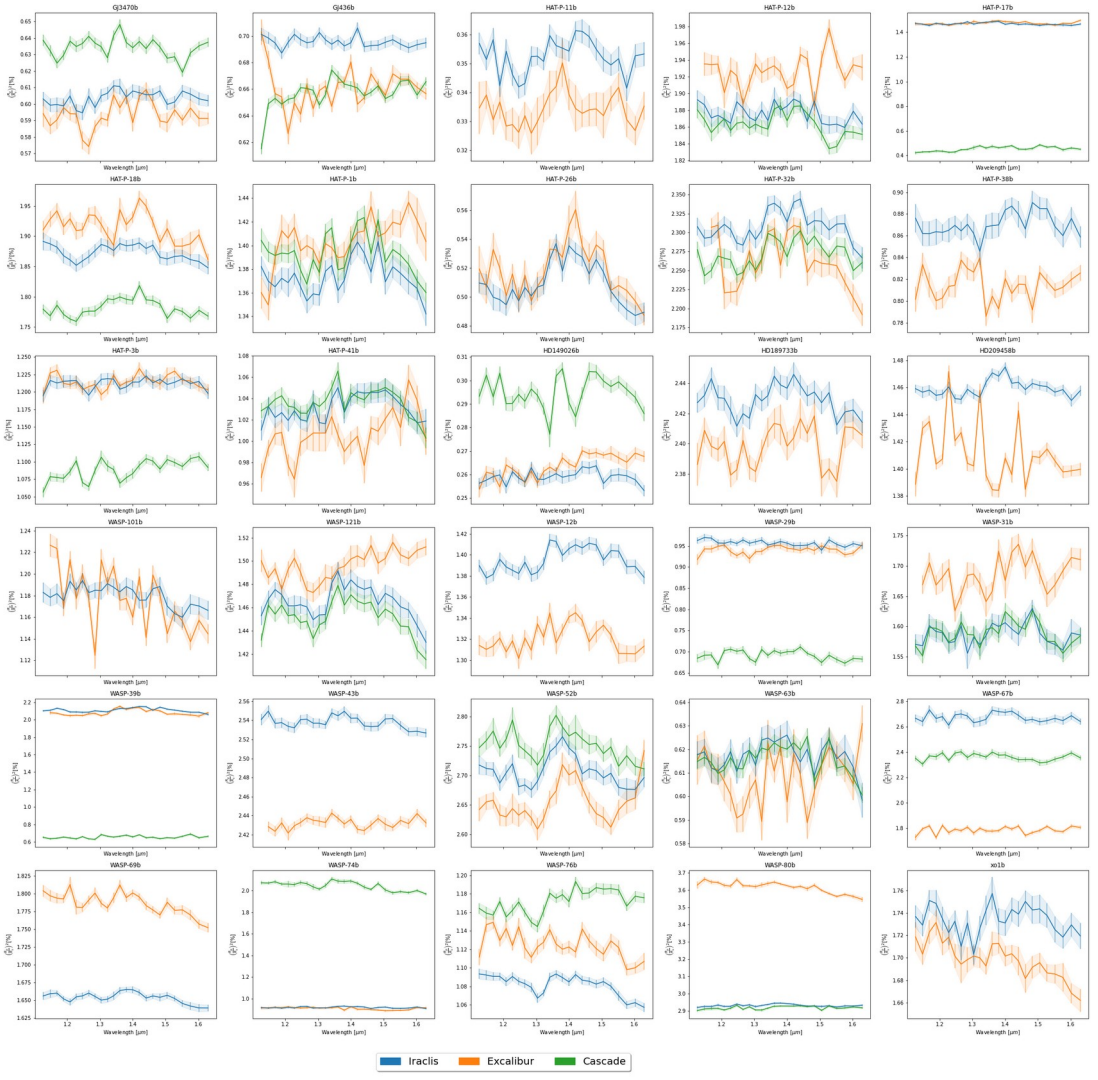
Spectra datasets

Spectra datasets

In the figure are reported all the spectra used for this work.

We notice differences in

- offsets in the data set (mean values)
- Claimed precision (error bars)
- Spectral shapes (channel values)



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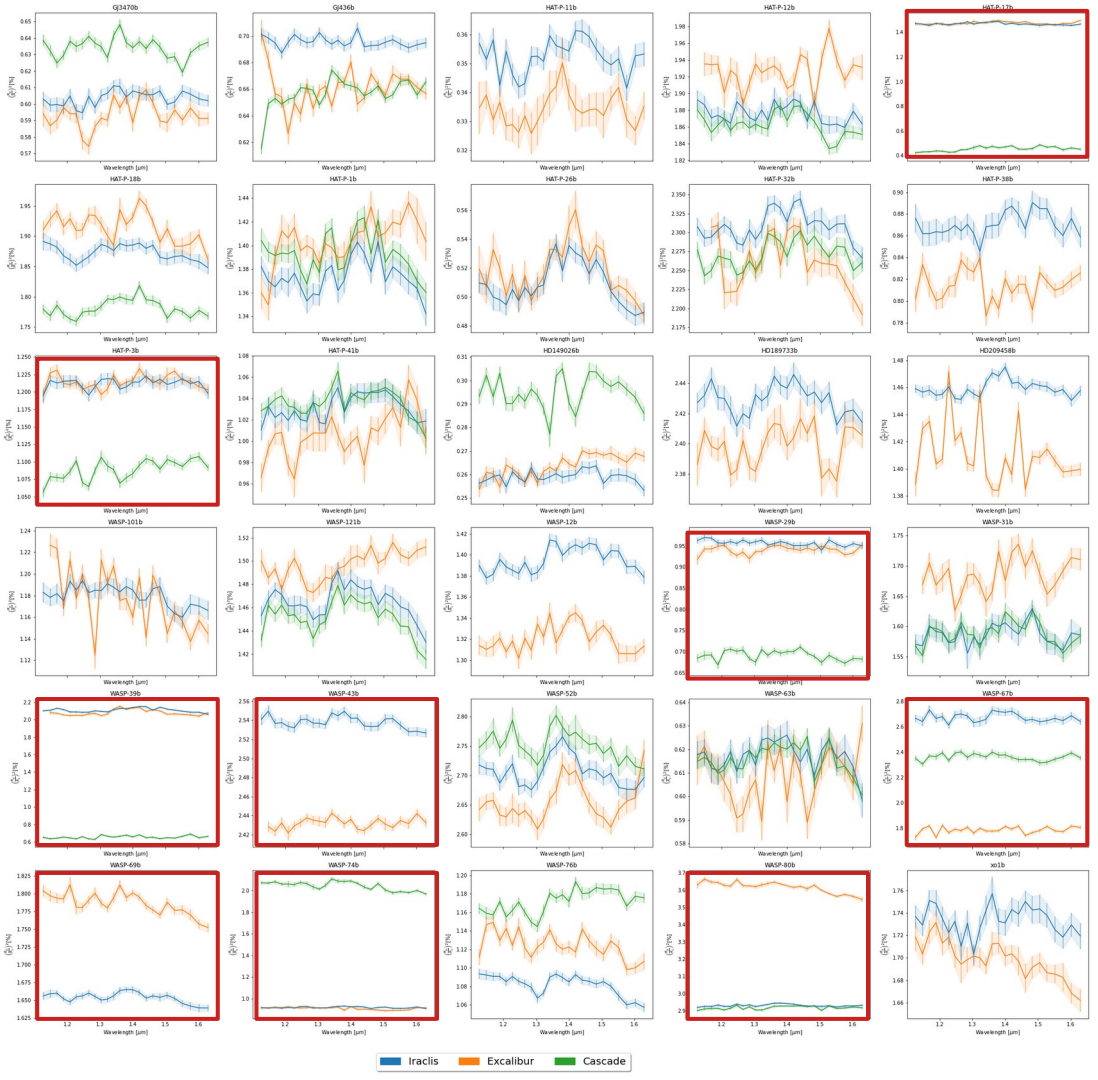

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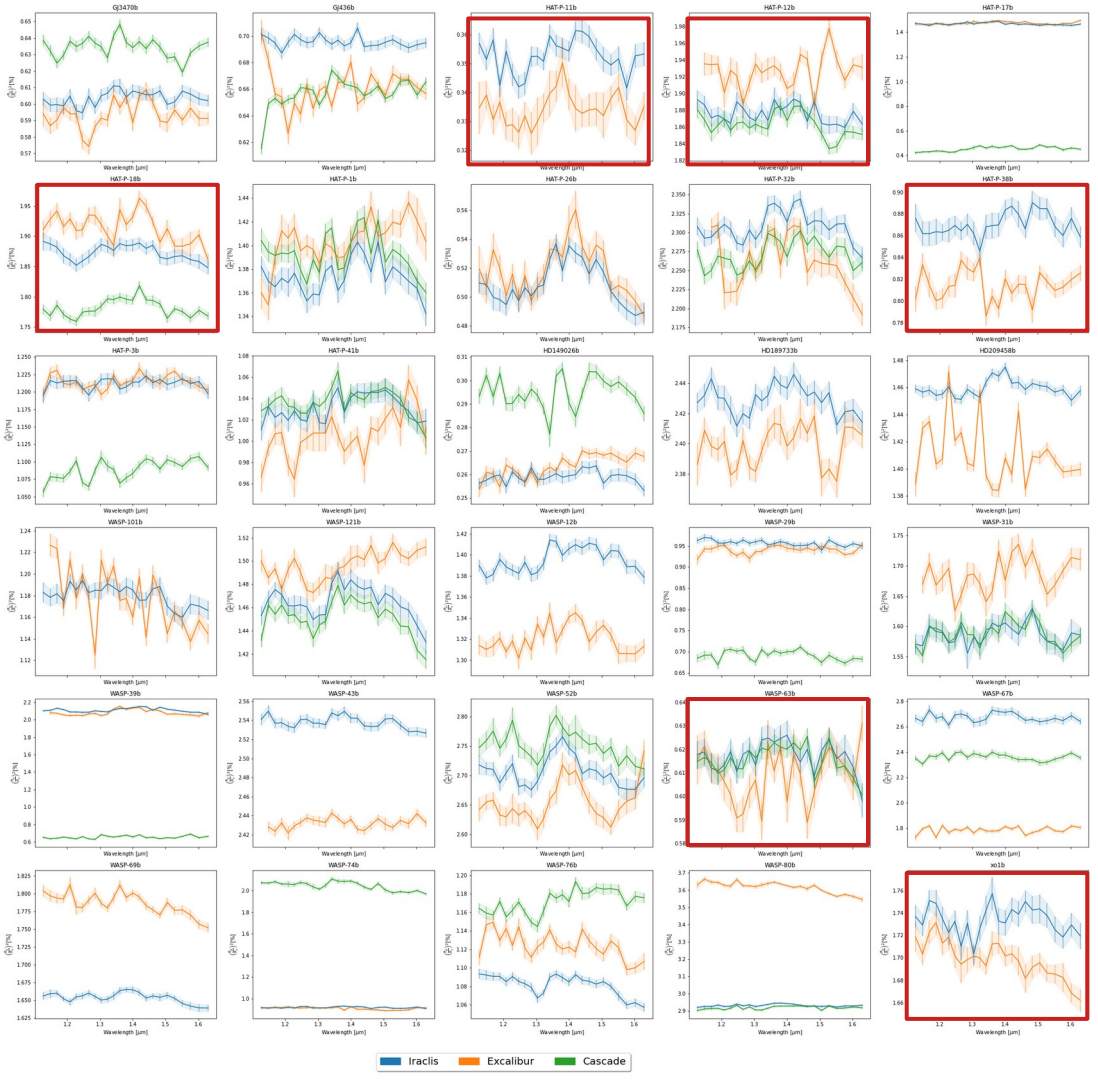

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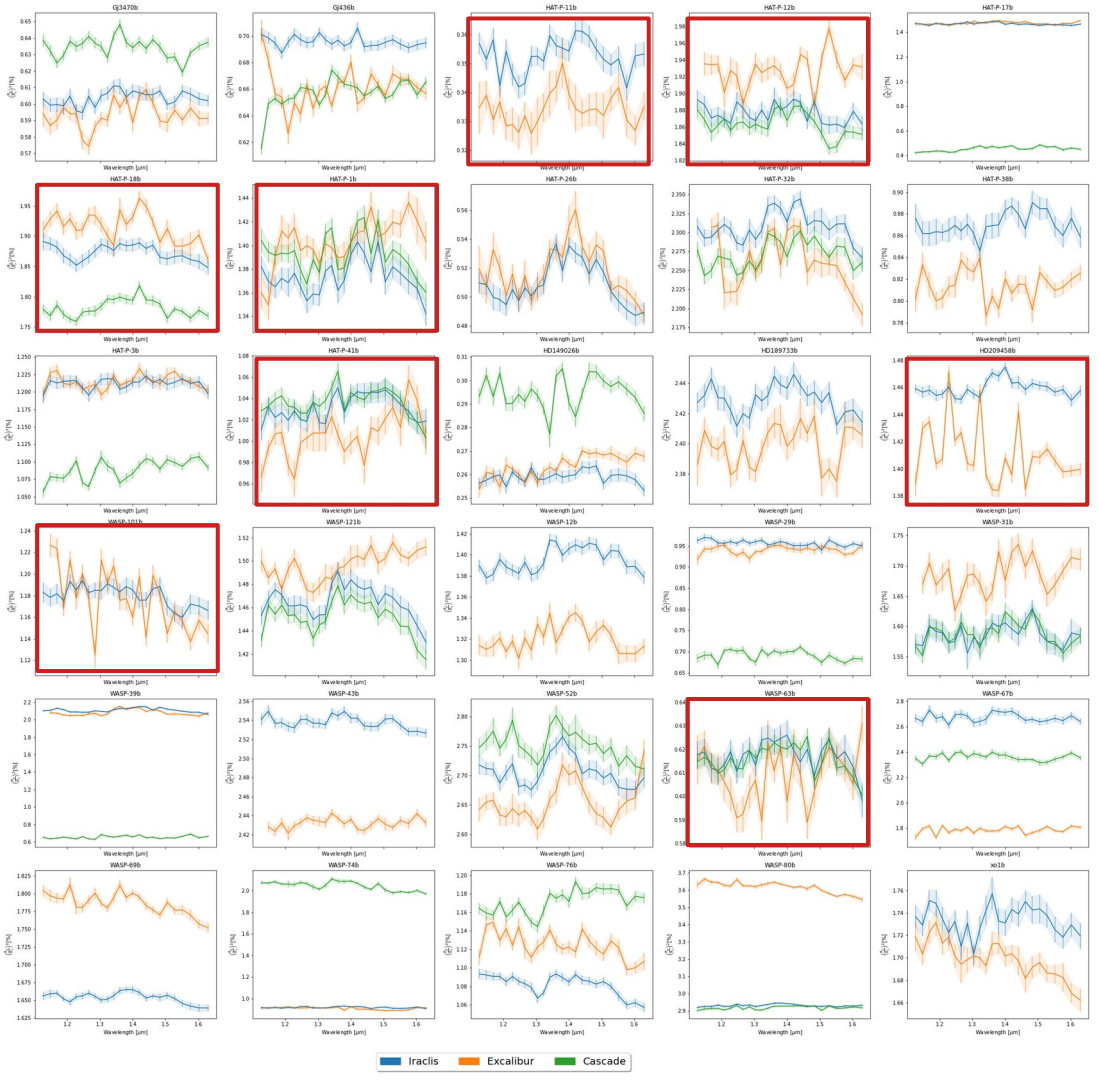
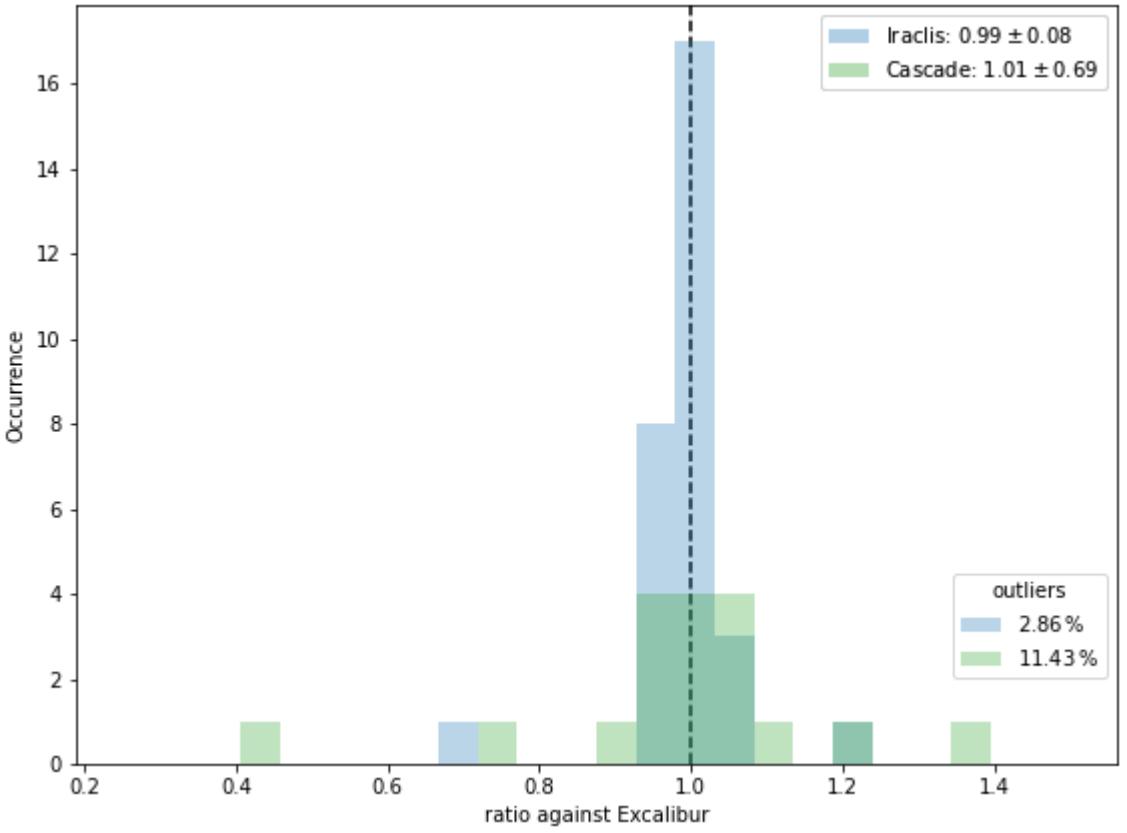
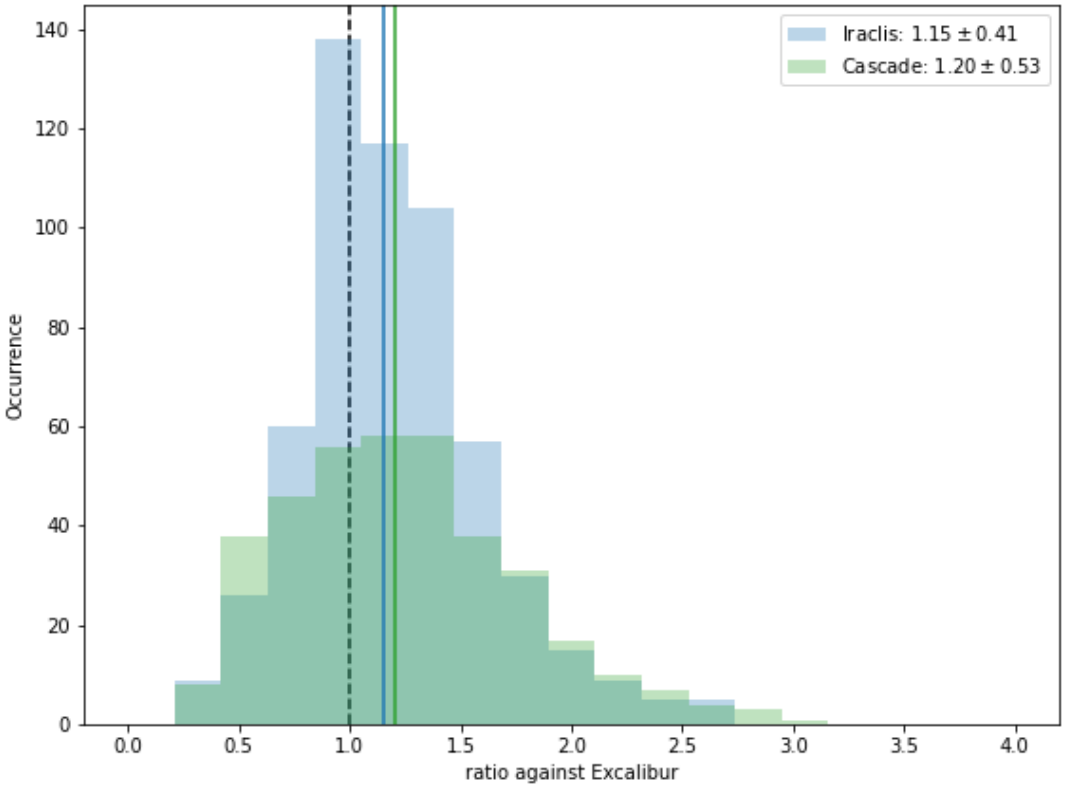


Mean values ratio $\frac{\widehat{S_{A,\lambda}}}{\widehat{S_{B,\lambda}}}$

Excalibur's ratio of the mean values is compatible with 1.
There is not a preference bias toward bigger or smaller radii.



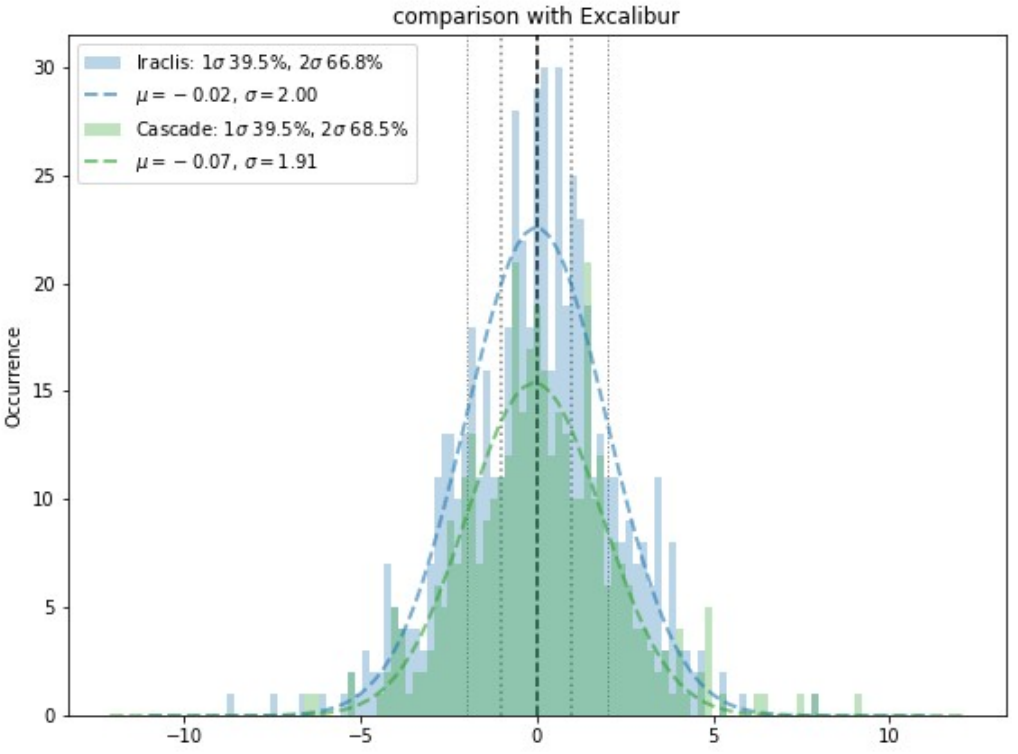
Uncertainties ratio $\frac{\sigma_{A,\lambda}}{\sigma_{B,\lambda}}$



Excalibur returns the **smallest uncertainties**.

Spectral bin comparison $\frac{S_{A,\lambda} - S_{B,\lambda}}{max[\sigma_{A,\lambda}, \sigma_{B,\lambda}]}$

Spectral values are **averagely compatible** with Iraclis and Cascade, but the distribution is twice what expected.



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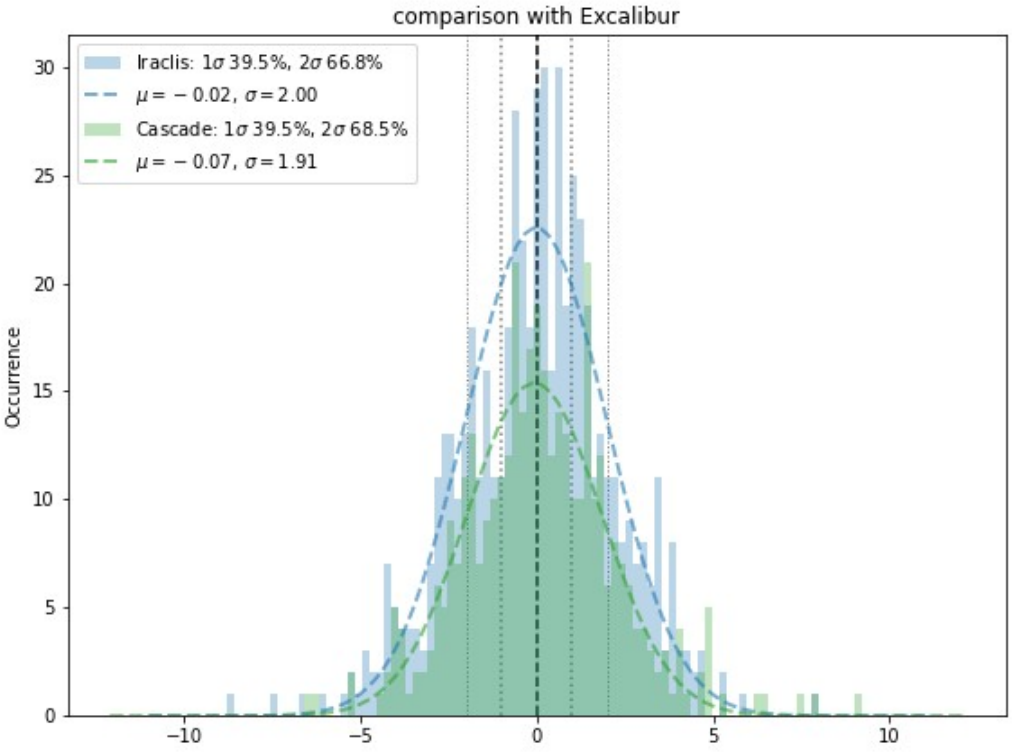
This is true for every pipeline.



Take home messages

- Differences in resulting spectra is a known problem that affects all the pipelines and it is under investigation (drop me an email if curious).
- From a population prospective, EXCALIBUR shows
  - no obvious bias for planetary radius
  - uncertainties ~20% smaller than other pipelines
- This is only a small part of a bigger work: publication is under preparation (stay tuned).

Thank you

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