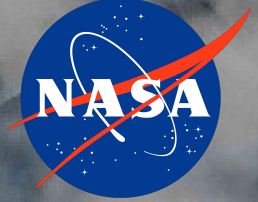
Pushing ELT's sensitivity through PCA background subtraction

Hélène Rousseau
PhD student, University of Liège
Research Technologist, LBT Observatory, University of Arizona

Working with:
Steve Ertel, Denis Defrère, Virginie Faramaz, Kevin Wagner



Large Binocular Telescope Interferometer

- Mont Graham
- Two 8m telescopes
- 23 m baseline
- H,K,L and M band with LMircam
- N band with NOMIC

Large Binocular Telescope Interferometer

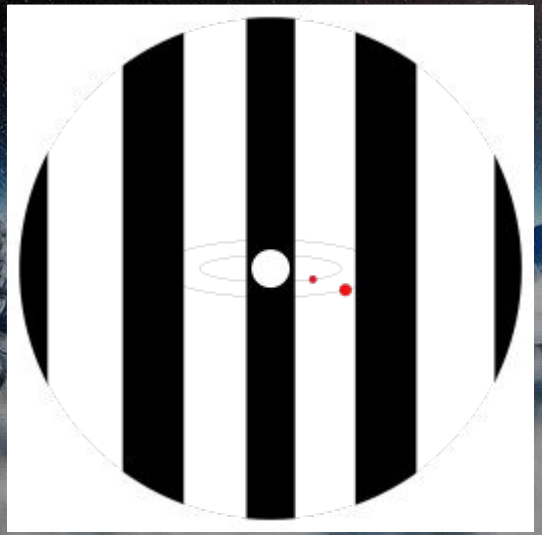
- Mont Graham
- Two 8m telescopes
- 23 m baseline
- H,K,L and M band with LMircam
- N band with NOMIC

HOSTS Survey september 2016 - may 2018

Hunt for Observable Signature of Terrestrial planetary Systems

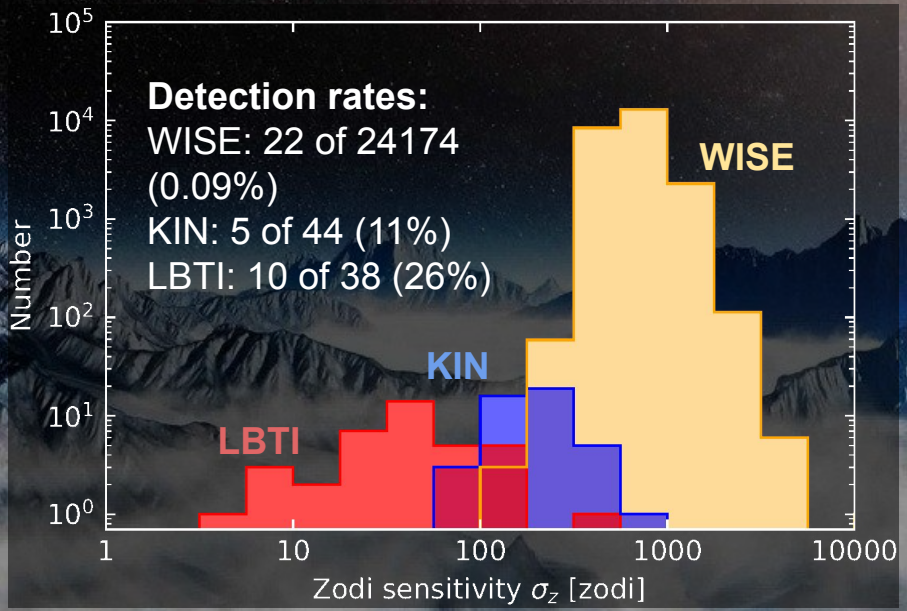
- Exozodiacal dust

Hunt for Observable Signature of Terrestrial planetary Systems



- Exozodiacal dust
- N-band nulling interferometry

Hunt for Observable Signature of Terrestrial planetary Systems

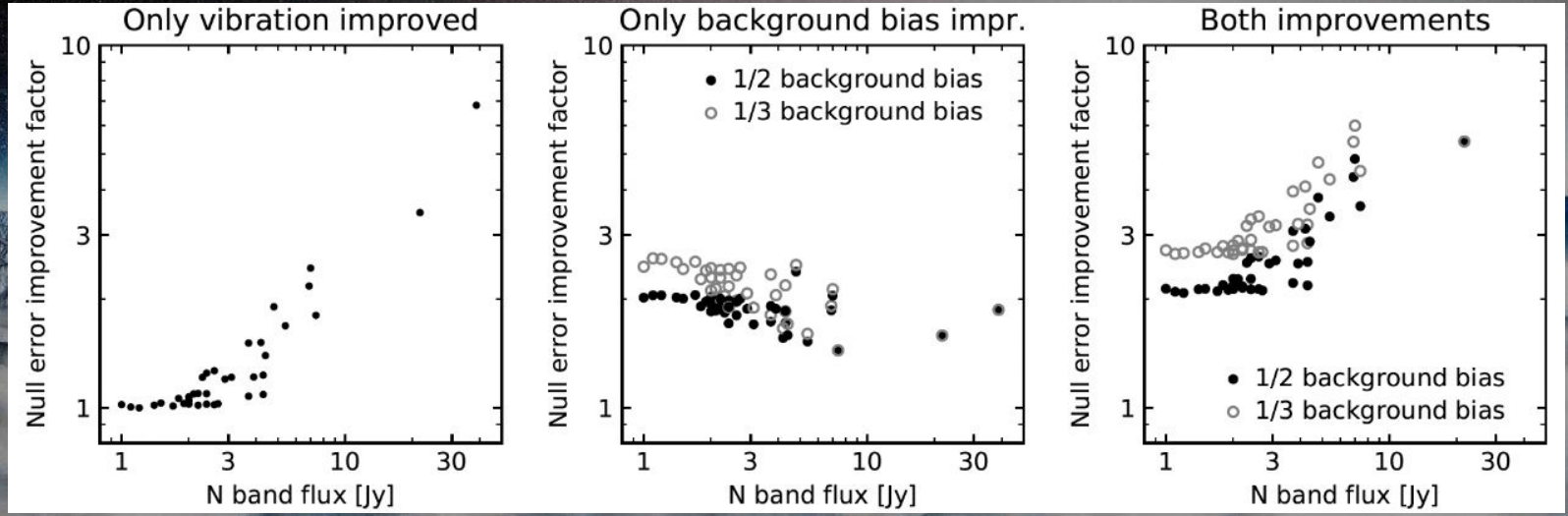


Ertel et al.2020

- Exozodiacal dust
- N-band nulling interferometry
- 38 stars / 10 detections
- 1σ upper limit: 9 zodis
- 95% confidence: 27 zodis

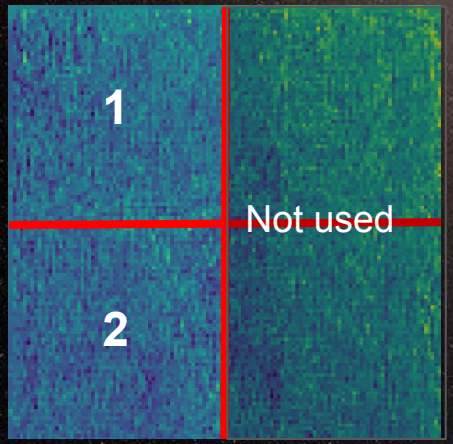
Sensitivity limitations for LBTI/HOSTS

Major limitation : Thermal Background Subtraction



Defrère et al 2016
Ertel et al.2020

Observational Method



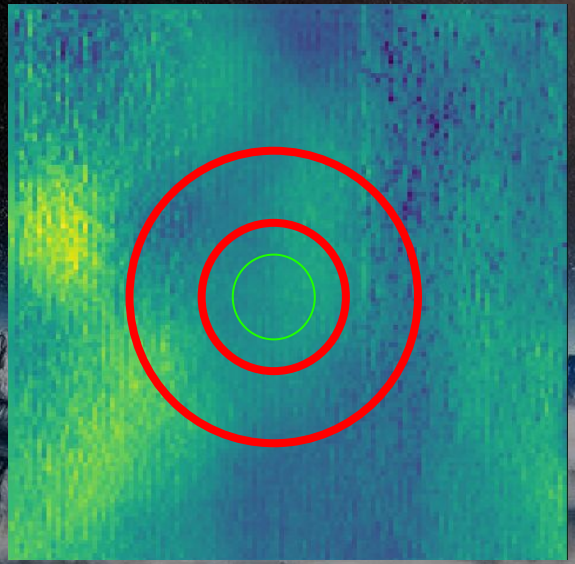
Group of
1000 images

1

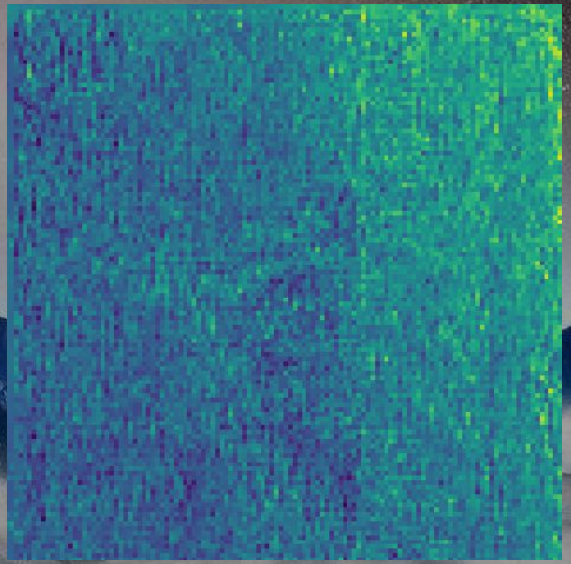
2

Biases

Using background at a different position



Using background at a different time

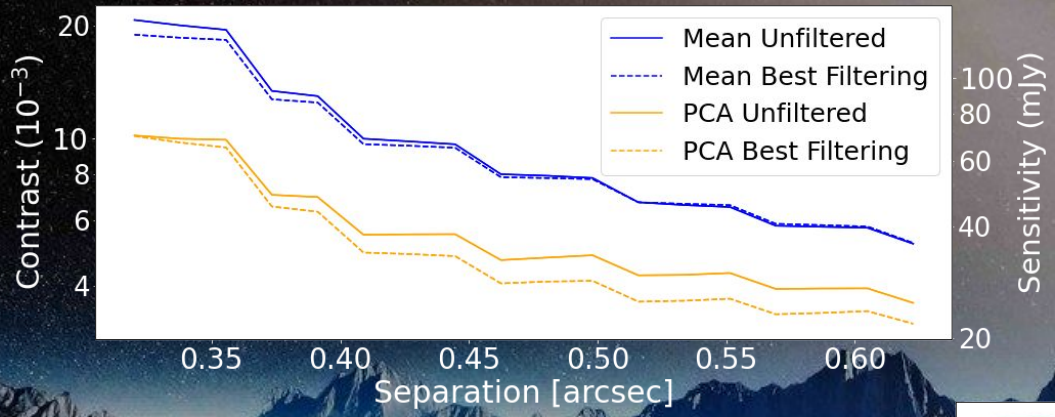


Numerical Method

	Mean Background Subtraction	PCA Background Subtraction
Pre-Subtraction	NO	YES
Correction	Mean image of the background library	Build the principal components on the background library
Mask	NO	YES
Correction image(s)	One correction for all images in one group	One correction per image
Background annulus	YES	NO

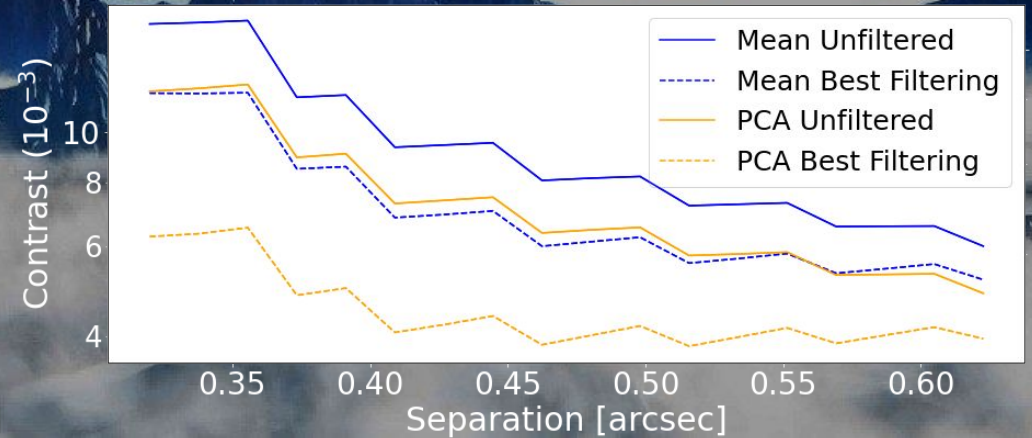
High Contrast Imaging

ADI



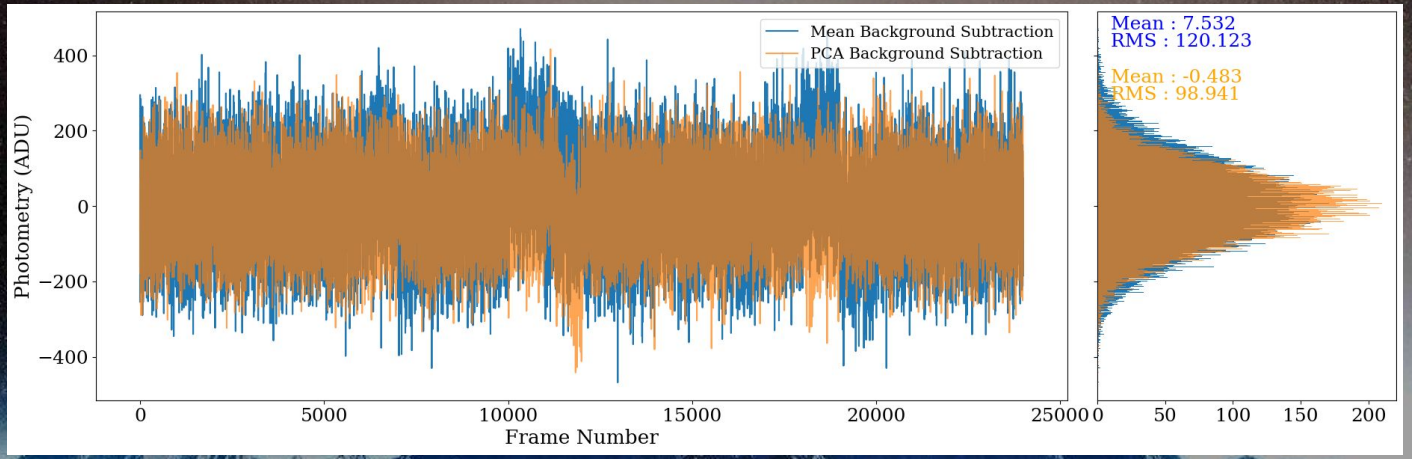
Improvement by a factor 1.5-2

RDI



Background-limited regime

Aperture Photometry

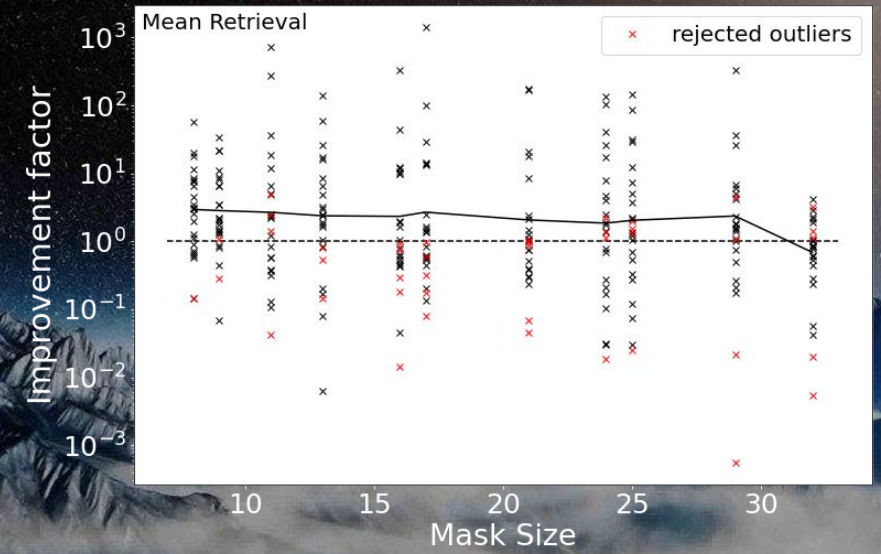


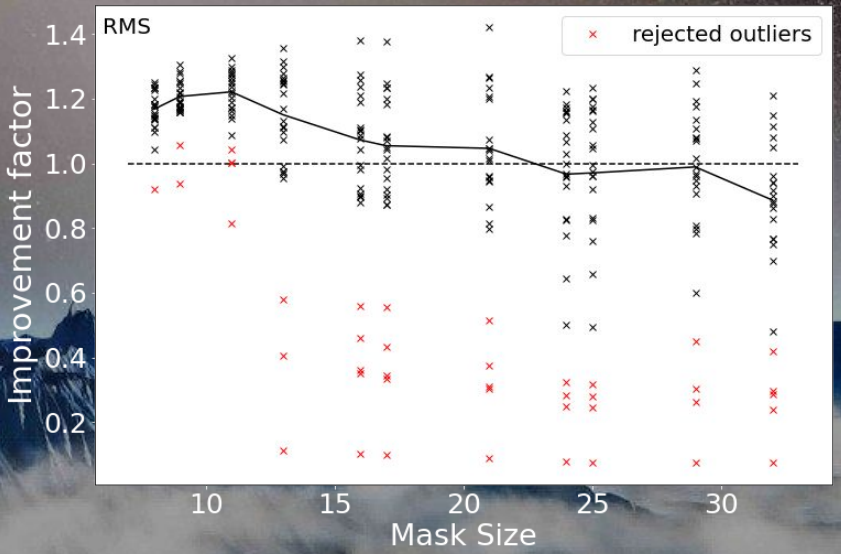
Mean Background Subtraction: 1σ = 0.8 ⇒ 10σ off

PCA Background Subtraction: 1σ = 0.6 ⇒ Within 1 σ range

Aperture Photometry

General case: Aperture size = Mask size

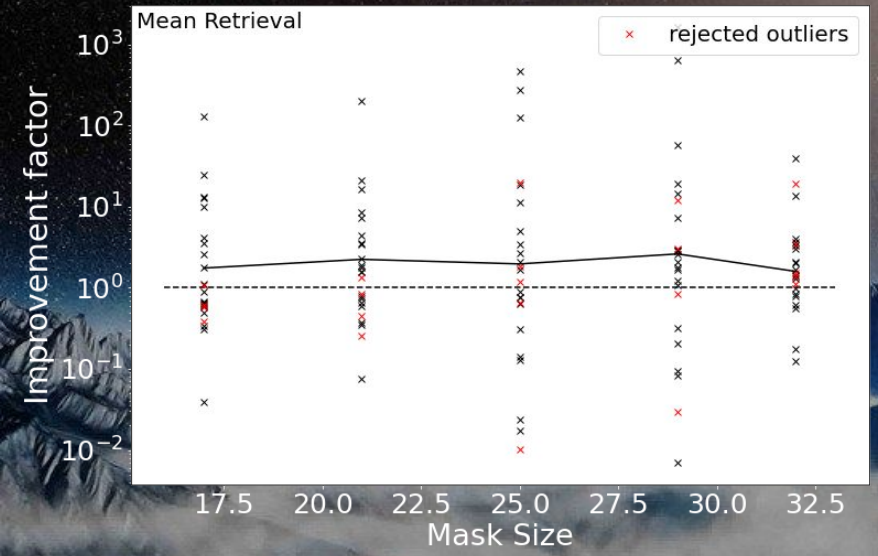


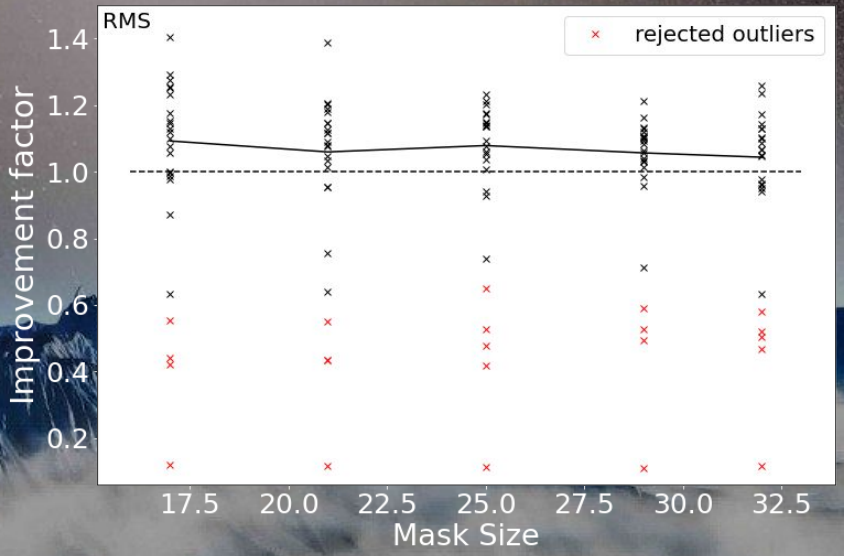


Factor 2 to 3 improvement on the mean retrieval

Aperture Photometry

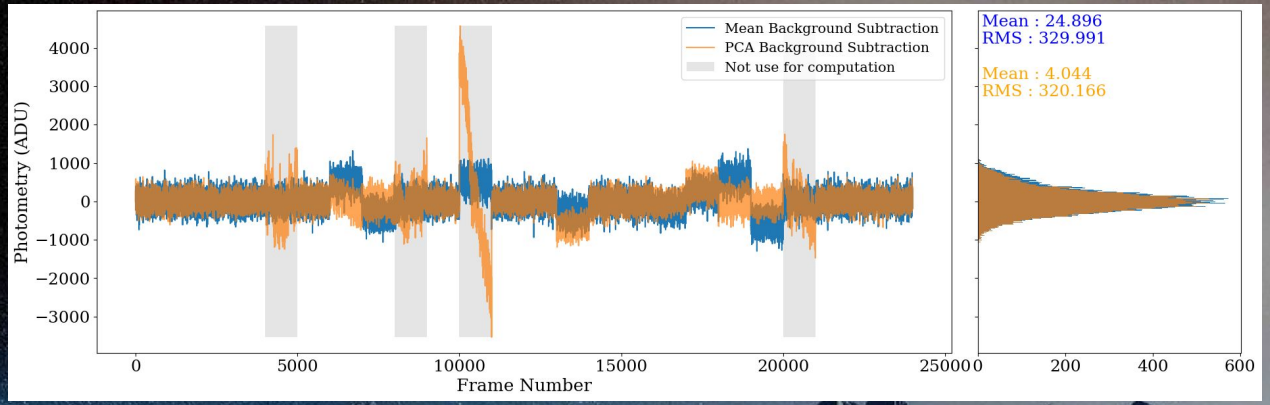
HOSTS case: Aperture radius = 13 pixel, Mask size varying

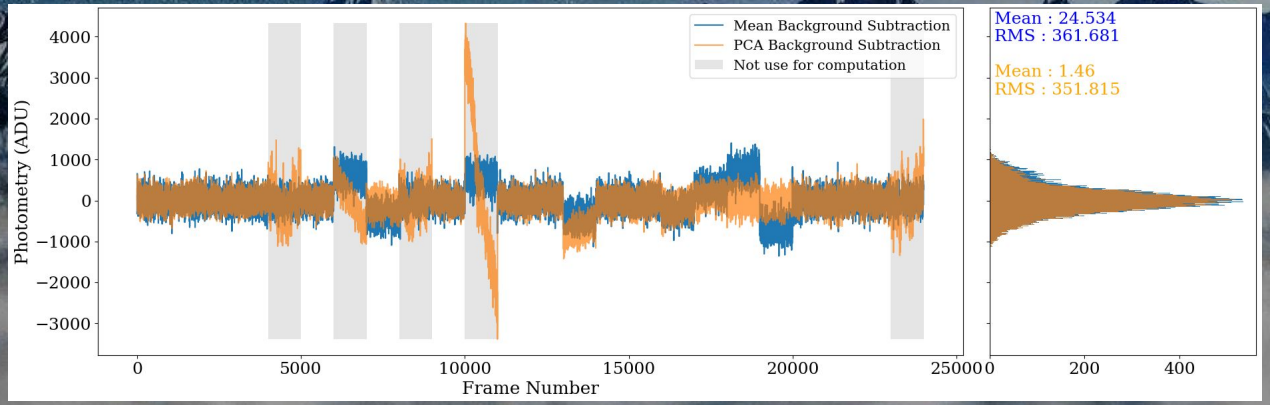




Factor 2 to 3 improvement on the mean retrieval

Limitations and future improvements





Limitations:

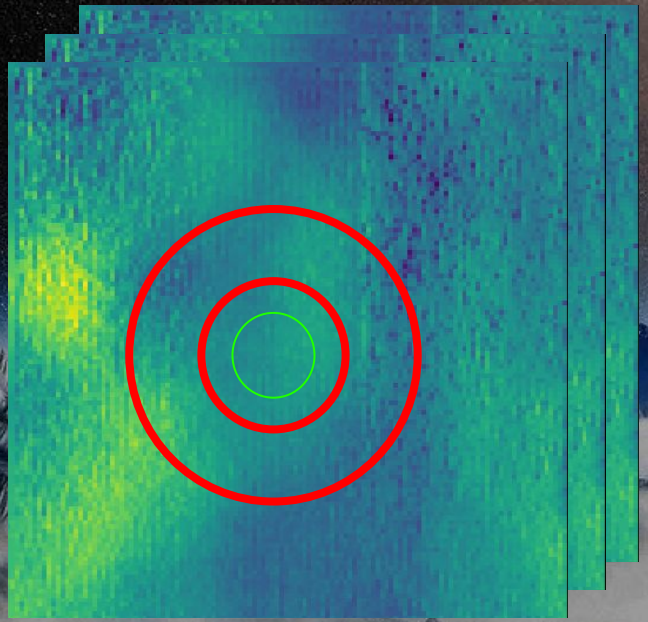
- Large spikes in the photometry
- Remove the groups concerned

Solutions:

- Background annulus
- **Temporal PCA**

Temporal PCA

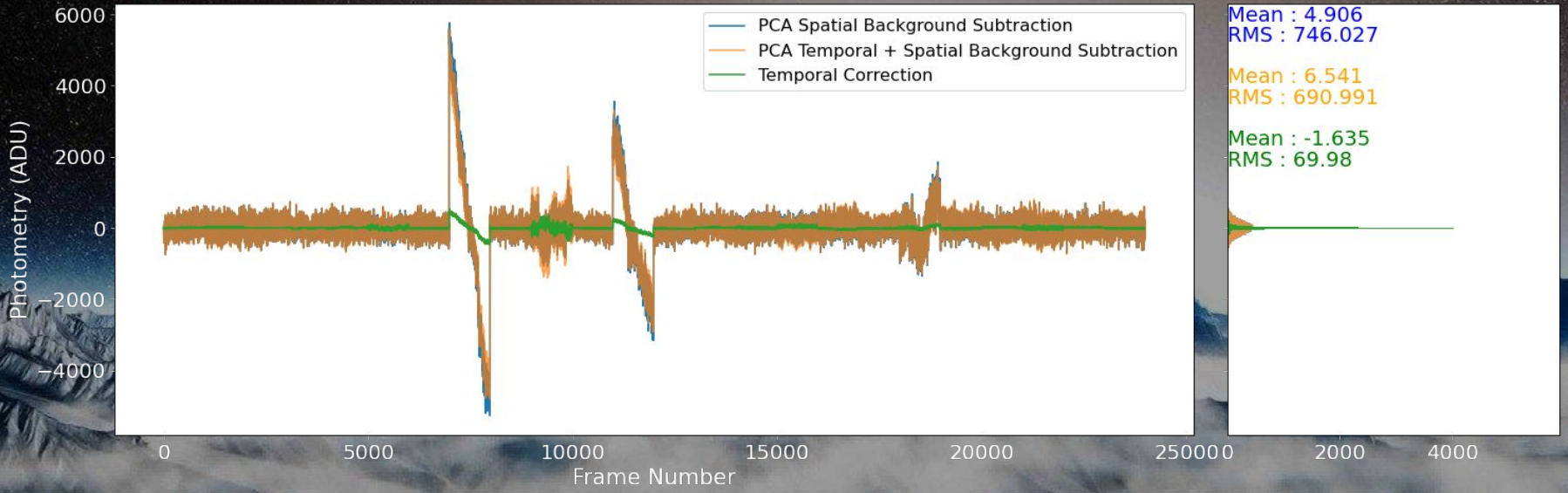
Work in progress



- Remove the spikes in the photometry
- Reduce the spatial bias introduce by the background annulus
- Perform PCA on the temporal dimension instead of the spatial dimension

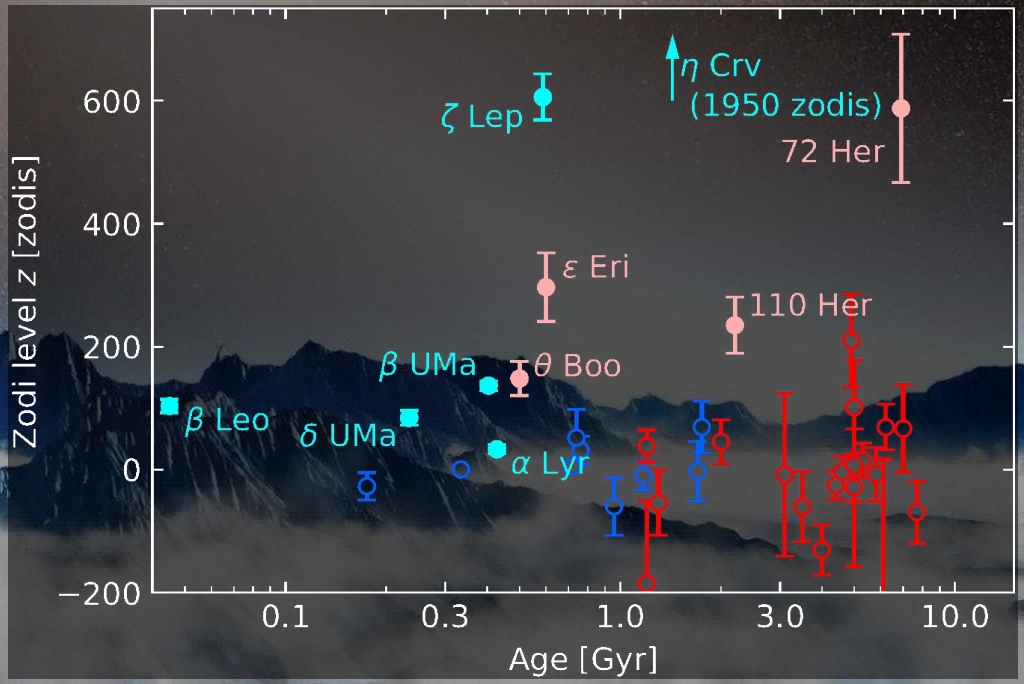
Temporal PCA

Work in progress

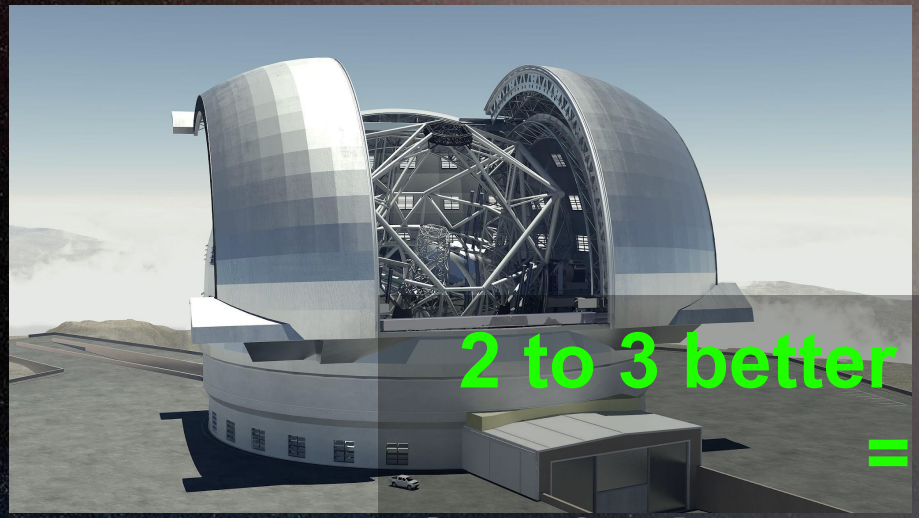


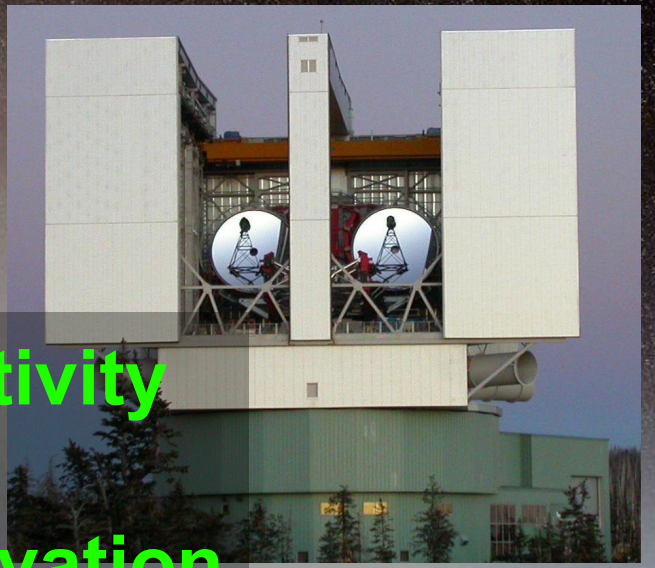
Application to the whole HOSTS survey

- **Factor 2 improvement on errors bars**
- **Better constraints on detection**
- **Better constraints on typical zodi level around other stars**



Ertel et al.2020





2 to 3 better sensitivity

=

4 to 9 shorter observation time needed