Exoplanet imaging: From equations to telescopes

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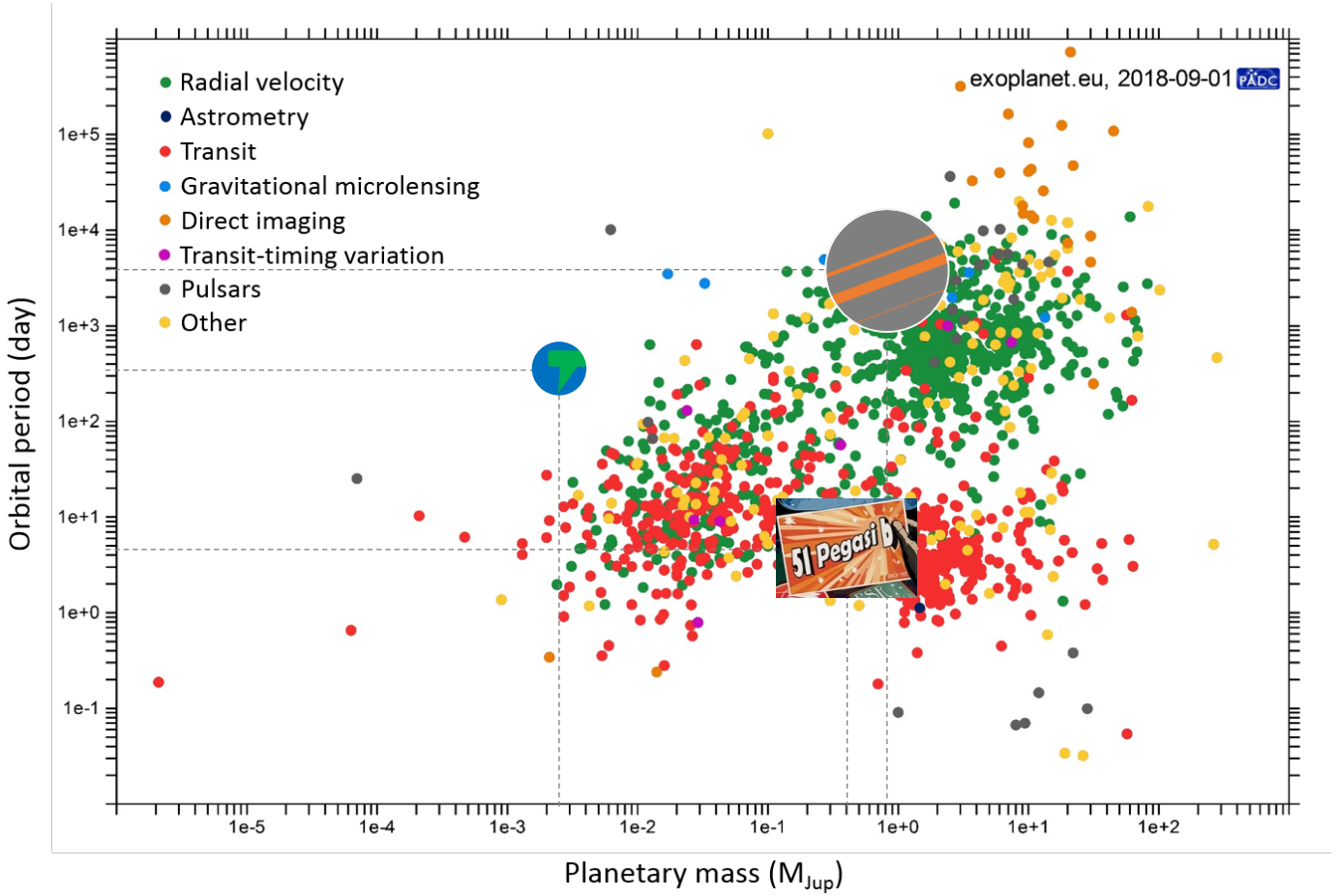
Exoplanet detection map

1995

First detection of a planet around a Sun–like star

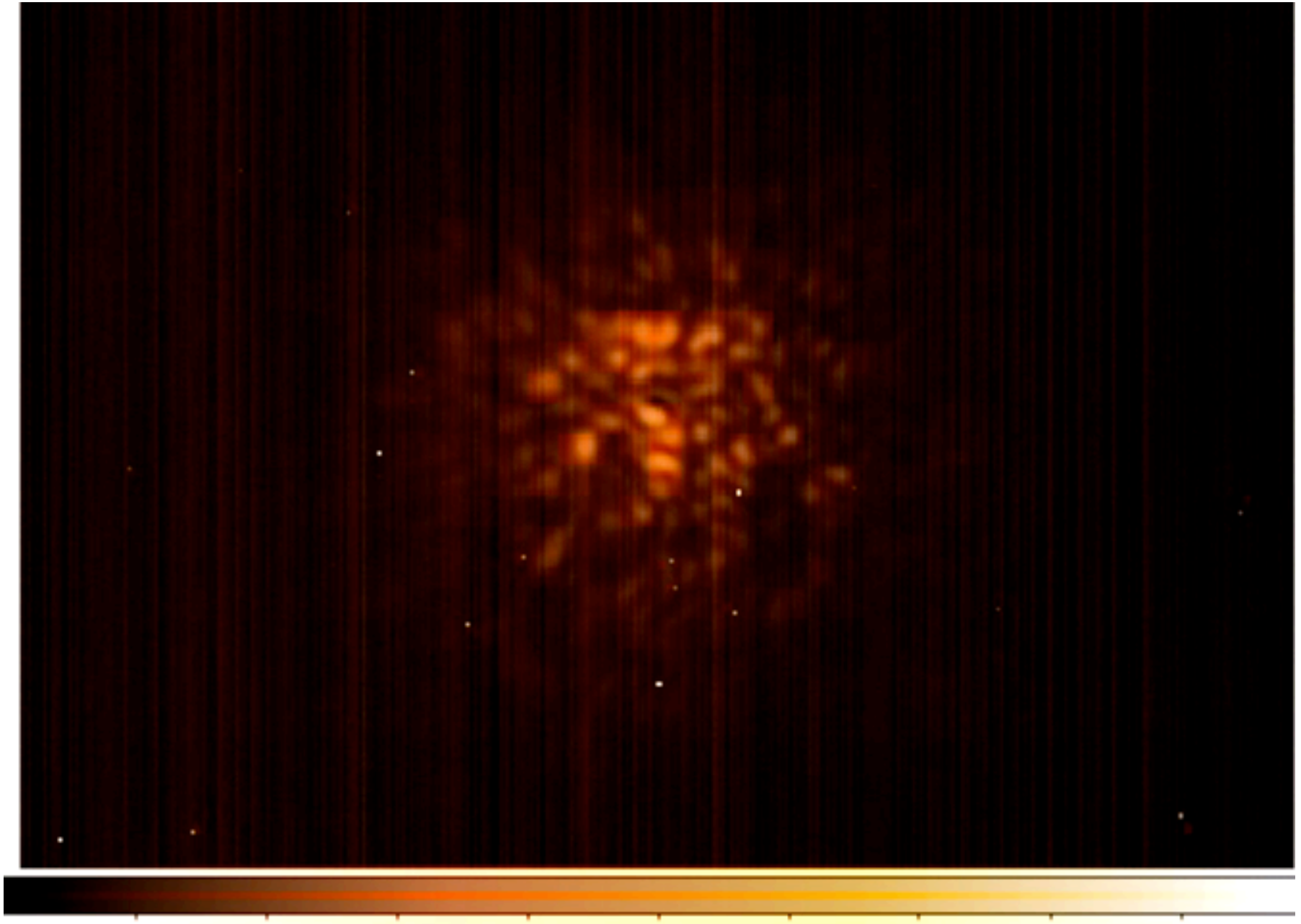
2020

More than 4000 confirmed exoplanets



Simulation of long exposure images

Turbulence



Singh et al.

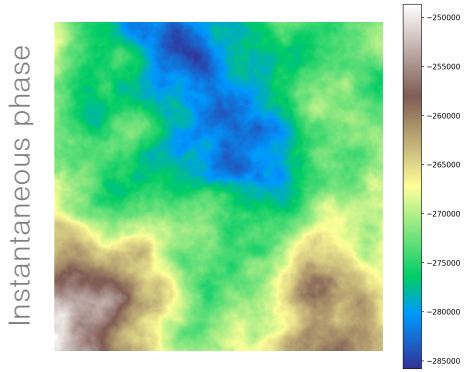
PSF numerical simulation

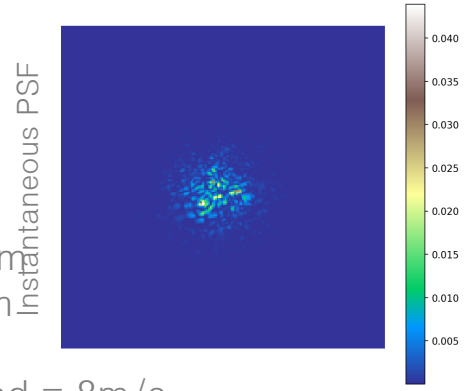
Short exposure time	Long but finite exposure time	Infinite exposure time

PSF numerical simulation

Short exposure time

"Short" = shorter than t_0, the turbulence lifetime





D = 8m
λ = 800nm
r0 = 50cm
L0 = 50m
Windspeed = 8m/s

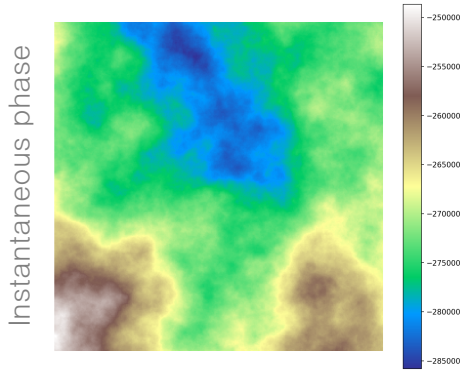
Long but finite exposure time

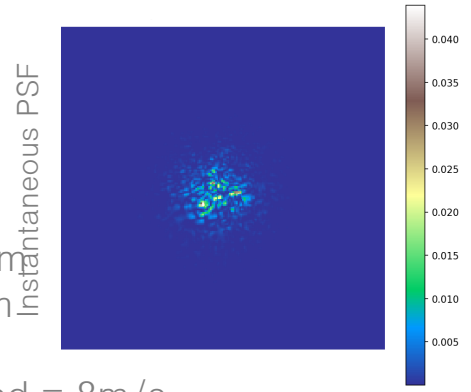
Infinite exposure time

PSF numerical simulation

Short exposure time

"Short" = shorter than t_0, the turbulence lifetime





D = 8m
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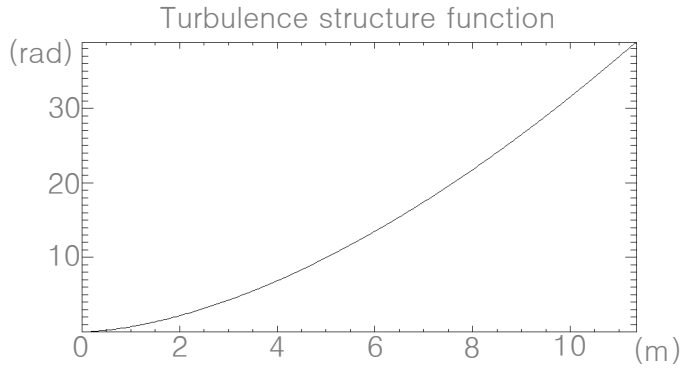
Long but finite exposure time

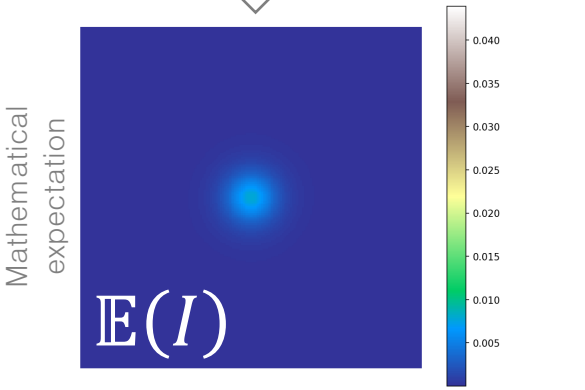
Infinite exposure time



$$\prod$$

$$\mathrm{TF}((\mathrm{P}\otimes P)(\vec{\zeta}) \times e^{-0.5 D_\varphi(\vec{\zeta})})$$

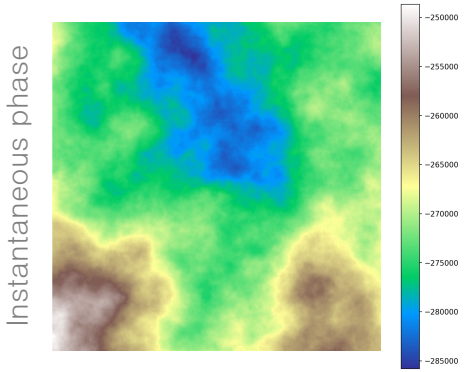
$$\Downarrow$$

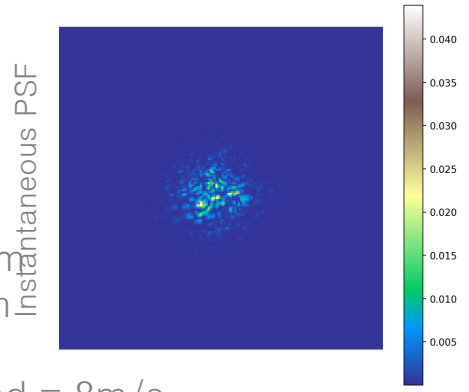


PSF numerical simulation

Short exposure time

"Short" = shorter than t_0, the turbulence lifetime



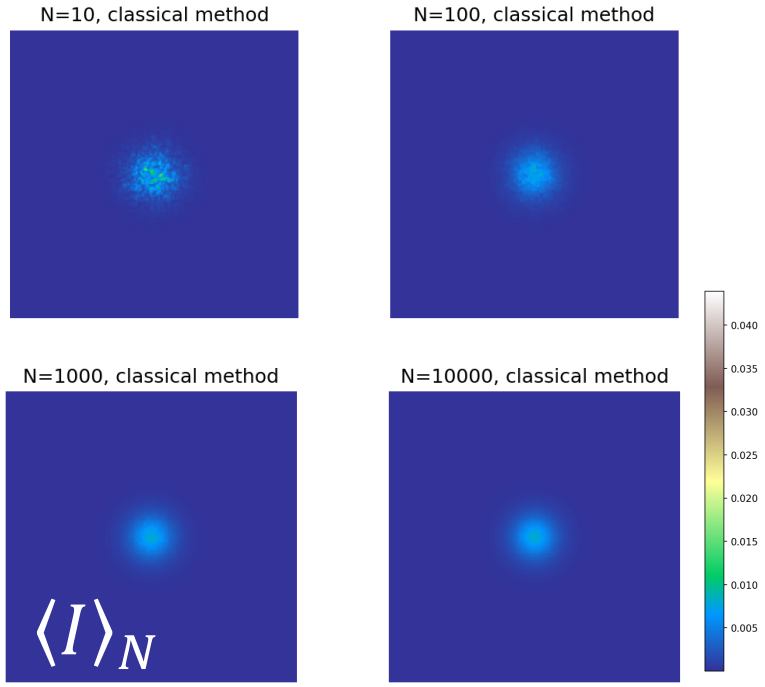


D = 8m
λ = 800nm
r0 = 50cm
L0 = 50m
Windspeed = 8m/s

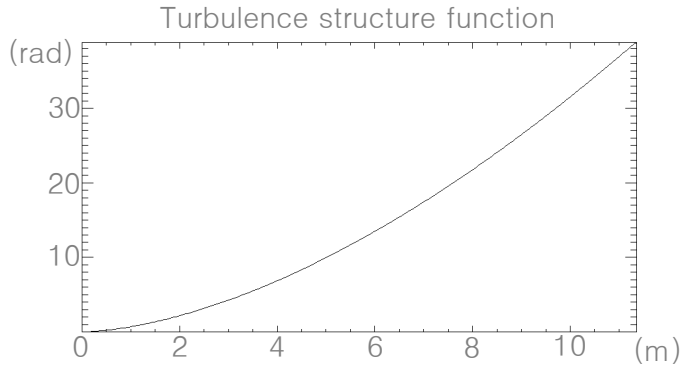
Long but finite exposure time

→ More realistic (on-sky observations)

→ Point out patterns due to dynamic effects (turbulence)



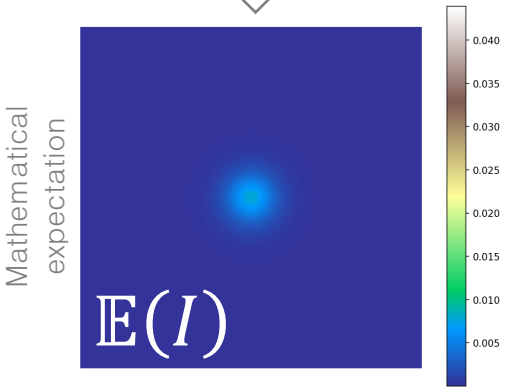
Infinite exposure time



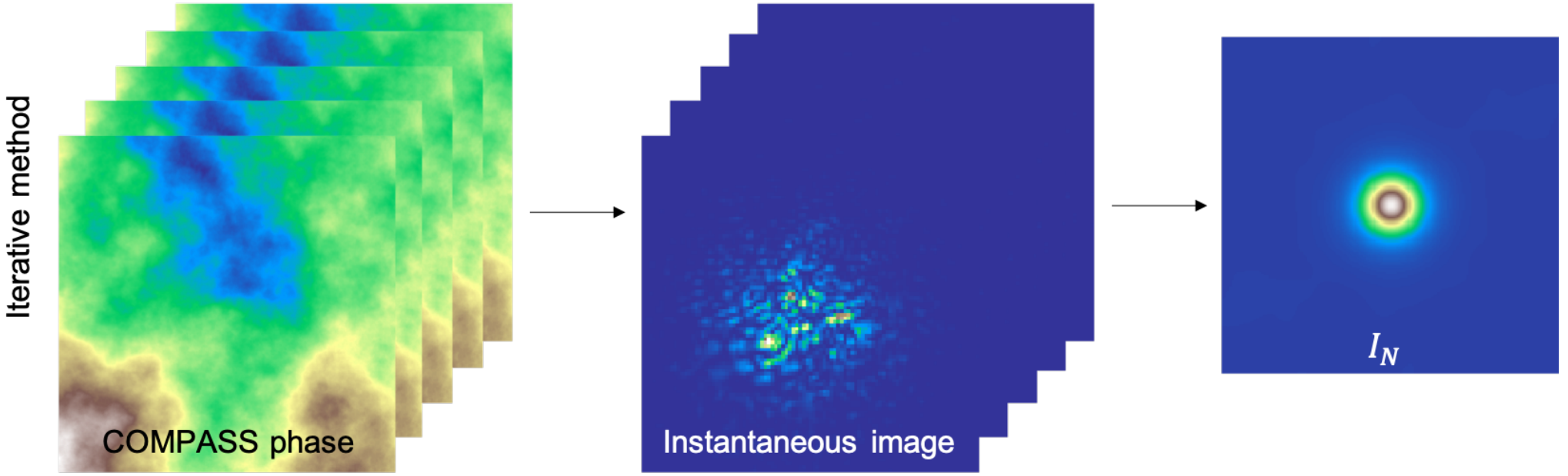
$$\prod$$

$$\mathrm{TF}((\mathrm{P}\otimes P)(\vec{\zeta}) \times e^{-0.5 D_\varphi(\vec{\zeta})})$$

$$\Downarrow$$

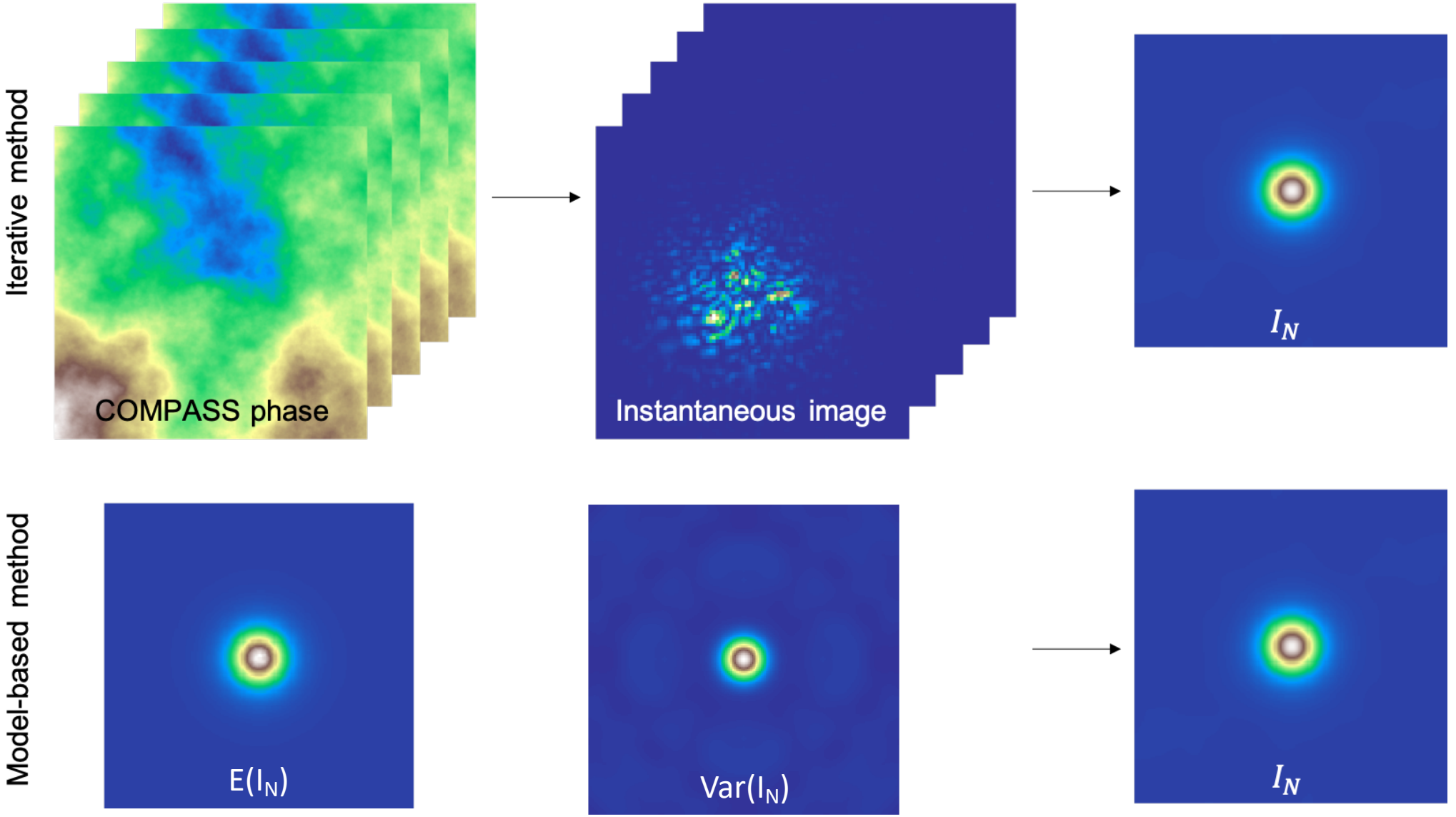


Classical method

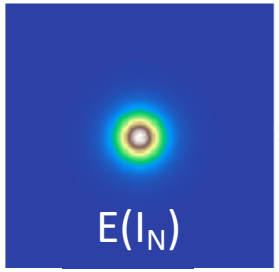


Exposure time = 60sec
$t_0 \sim 2ms$
→ N ~ 30000 !!!

Alternative method

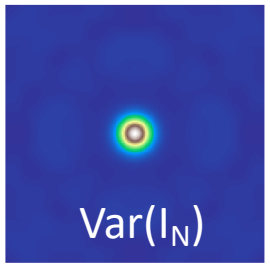


Alternative method



$$= \mathscr{F}\left[P \otimes P \times e^{-0.5 D_\phi}\right]$$

- Fourier Transform
- Telescope-dependant factor
- Statistics of atmospheric turbulence



$$= \frac{\mathrm{E}\left[I^2\right] - \mathrm{E}[I]^2}{N}$$

$$\mathrm{E}\left[I^2\right](\vec{x}) = \int\int\int\int P(\vec{\xi_1})P(\vec{\xi_2})P^*(\vec{\xi_3})P^*(\vec{\xi_4}) e^{-\frac{1}{2}\alpha} e^{-ik\vec{x}.(\vec{\xi_1}+\vec{\xi_2}-\vec{\xi_3}-\vec{\xi_4})} d\vec{\xi_1} d\vec{\xi_2} d\vec{\xi_3} d\vec{\xi_4},$$

$$\alpha = D_\phi\left(\vec{\xi_3} - \vec{\xi_1}\right) + D_\phi\left(\vec{\xi_4} - \vec{\xi_1}\right) + D_\phi\left(\vec{\xi_3} - \vec{\xi_2}\right) + D_\phi\left(\vec{\xi_4} - \vec{\xi_2}\right) - D_\phi\left(\vec{\xi_2} - \vec{\xi_1}\right) - D_\phi\left(\vec{\xi_4} - \vec{\xi_3}\right)$$

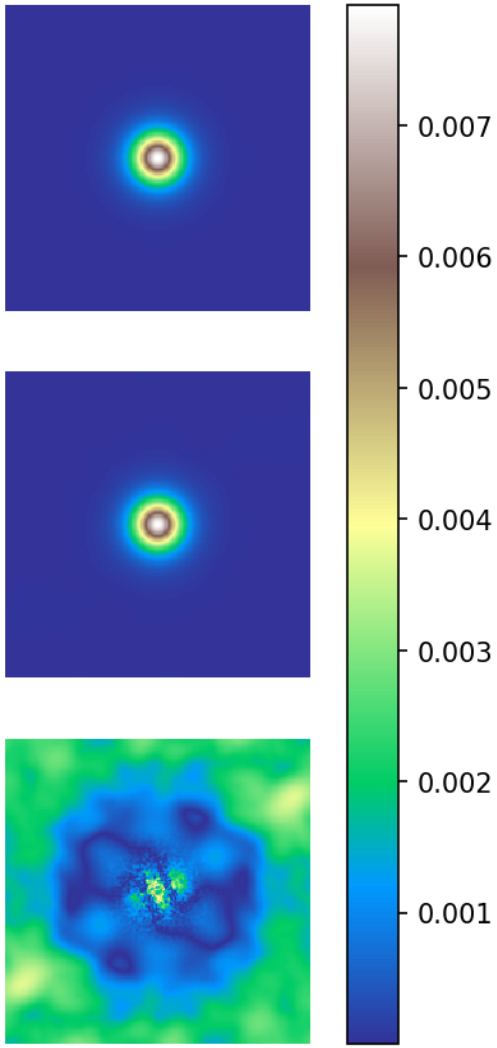
Validation – mathematical expectation

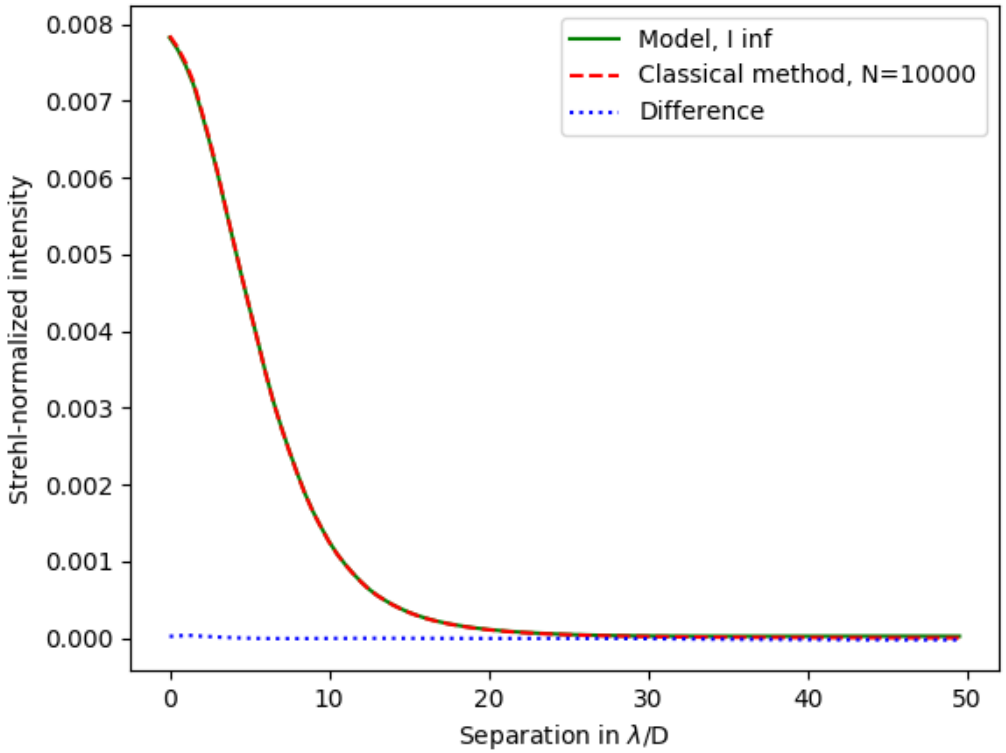
Roddier 1981, 1999	Turbulent wavefront
Jolissaint & Veran 2002	Post-adaptive optics system
Conan et al. 2005	
Fétick et al. 2018, 2019	
Sauvage et al. 2010	Coronagraphic instrument
Herscovici-Schiller et al. 2016, 2017	

Classical method

Analytical model

100*difference



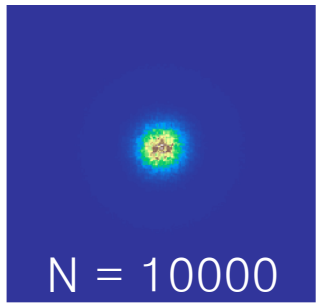


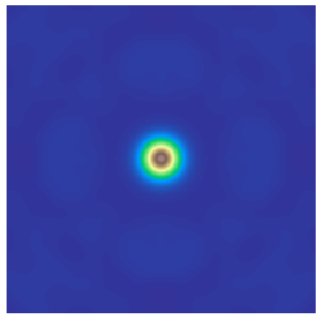
Validation – variance

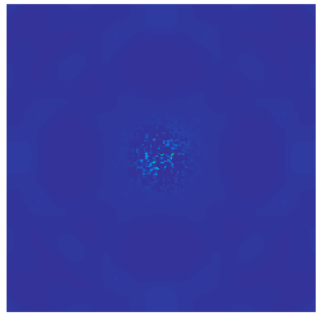
Classical method

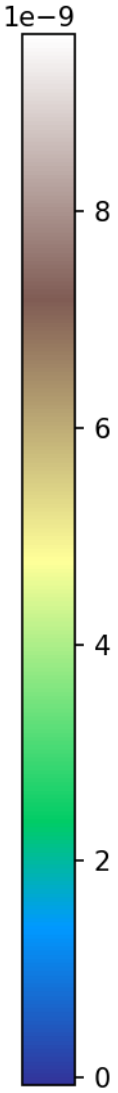
Analytical model

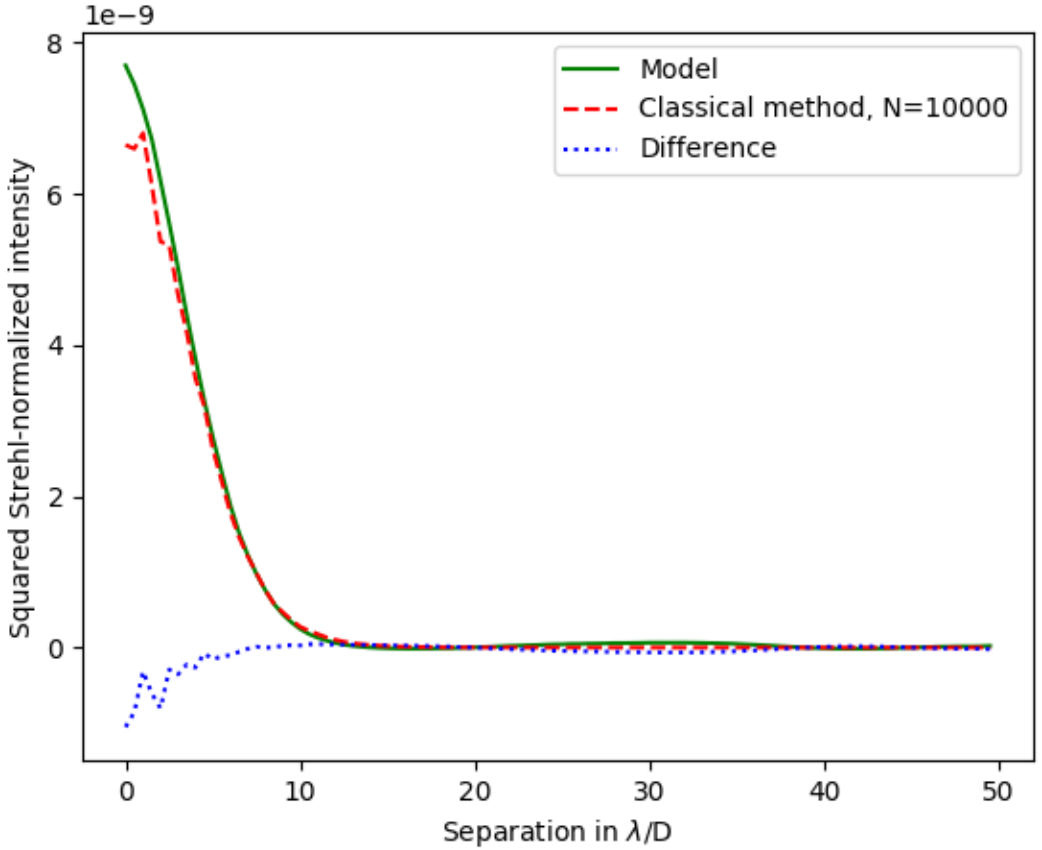
Difference



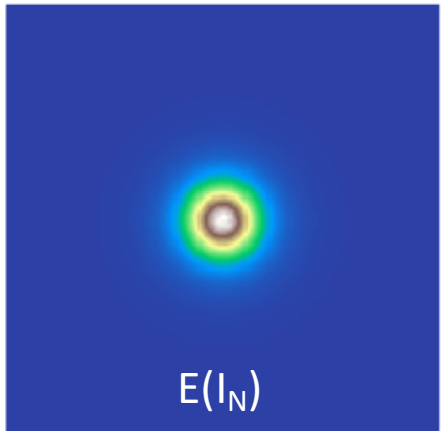


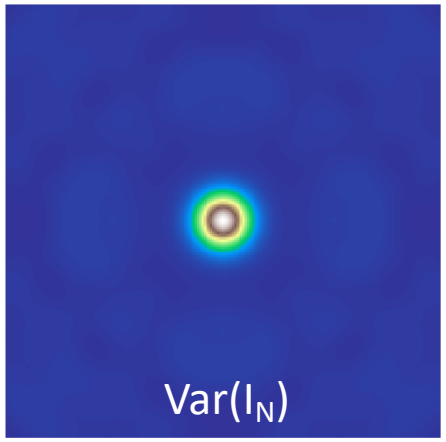


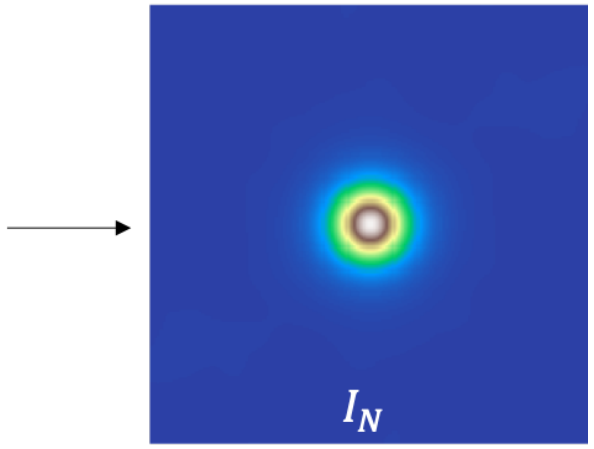




Model-based method

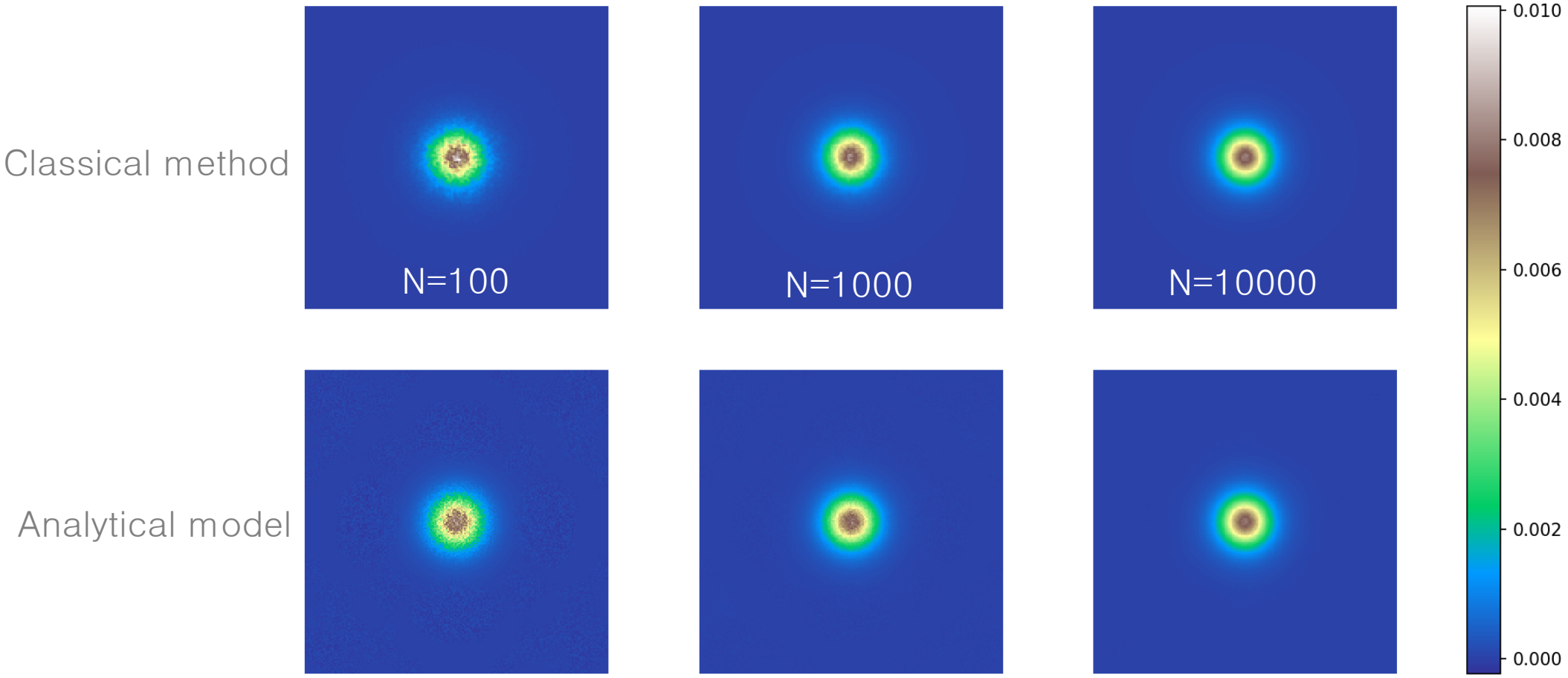






PSF numerical simulation

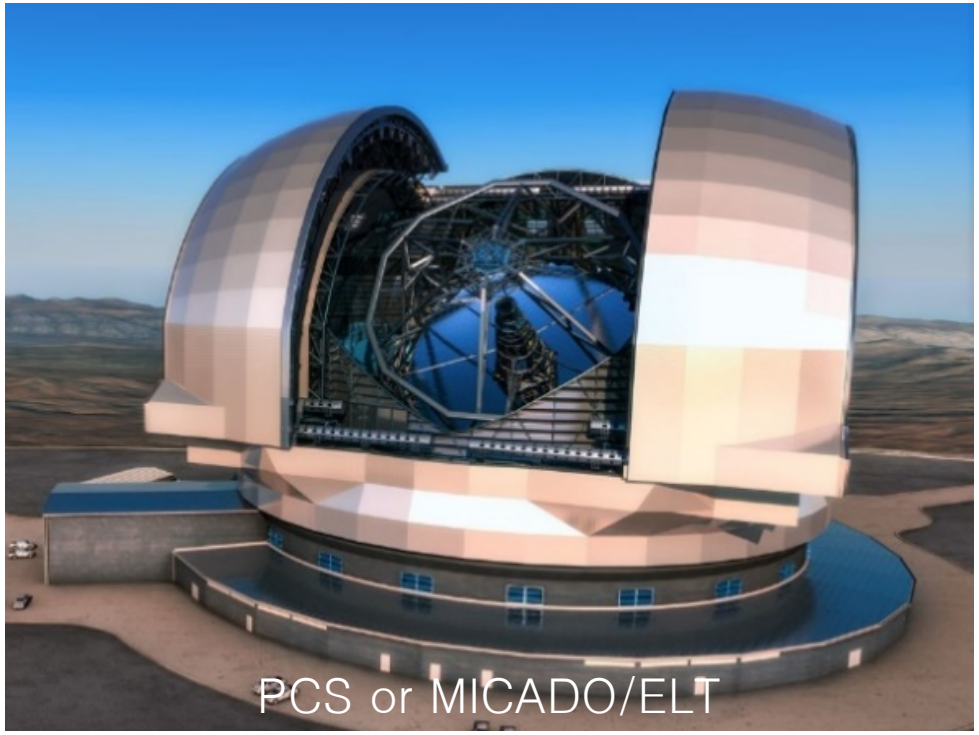
Examples of long exposure PSFs



→ Each image requires N = 1 random array with the model-based method

Application cases

Leboulleux et al.(SPIE)
Leboulleux et al. (in prep.)



What does the high-contrast imaging community look like?

Socio-demographic study of the exoplanet direct imaging community,
Leboulleux, Choquet, Huby, Singh, Cantalloube (submitted, BAAS)

Origin of the project – state of the art

Inequalities faced by women in access to permanent positions in astronomy in France

A recent national survey on behalf of the French Society of Astronomy and Astrophysics highlights the elitism and gender discrimination faced by women — particularly women educated in universities rather than *grandes écoles* — when applying for permanent positions in astronomy in France.

Olivier Berné and Alexia Hilaire

We are all made of (un-twinkling) stars: establishing gender equity in the Adaptive Optics community

Céline d'Orgeville[a], Benoit Neichel[b], Elena Masciadri[c], François Rigaut[a]

The Nonbinary Fraction: Looking Towards the Future of Gender Equity in Astronomy

A State of the Profession Consideration

Kaitlin C. Rasmussen[1,2,*] (she/they), Erin Maier[3] (they/them), Beck E. Strauss[4,**] (they/them), Meredith Durbin[5] (they/them), Luc Riesbeck[6] (they/them), Aislynn Wallach[5] (they/them), Vic Zamloot[7] (they/them), Allison Erena[8] (they/them)

STUDYING GENDER IN CONFERENCE TALKS – DATA FROM THE 223RD MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY

James R. A. Davenport[1,2], Morgan Fouesneau[1], Erin Grand[3], Alex Hagen[4], Katja Poppenhaeger[5], and Laura L. Watkins[6]

March 14, 2014

Diversifying the next generation of Astronomers One institution at a time

Antonella Nota (Space Telescope Science Institute/European Space Agency), Sheryl Bruff (STScI), Bernice Durand (Univ. Wisconsin - Madison), Kathy Flanagan (STScI), Matt Mountain (STScI), Meg Urry (Yale)

Enhancing Conference Participation to Bridge the Diversity Gap

Laura Prichard[1]*, Cristina Oliveira[1], Alessandra Aloisi[1], Julia Roman-Duval[1], Svea Hernandez[1], Camilla Pacifici[1], Ivelina Momcheva[1], Space Telescope Science Institute Women in Astronomy Forum

[1]Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA

Gender-Correlated Systematics in HST Proposal Selection

I. Neill Reid

Gender equity issues in astronomy: facts, fiction, and what the adaptive optics community can do to close the gap

Céline d'Orgeville*[a1], François Rigaut[a], Sarah Maddison[b], Elena Masciadri[c]
[a]Research School of Astronomy and Astrophysics, Australian National University, Mount Stromlo Observatory, Cotter Road, Weston Creek ACT 2611, Australia; [b]Centre for Astrophysics & Supercomputing, Swinburne University, H30, PO Box 218, Hawthorn, VIC 3122, Australia; [c]INAF Arcetri Astrophysical Observatory, Largo E. Fermi, 5, 50125 Firenze, Italy

Participation of women scientists in ESA solar system missions: an historical trend

Arianna Piccialli (1), Julie A. Rathbun (2), Ann Carine Vandaele (1), Francesca Altieri (3) Anni Määttänen (4) Anna Milillo (3) Alessandra Rotundi (3,5), Miriam Rengel (6), Pierre Drossart (7)

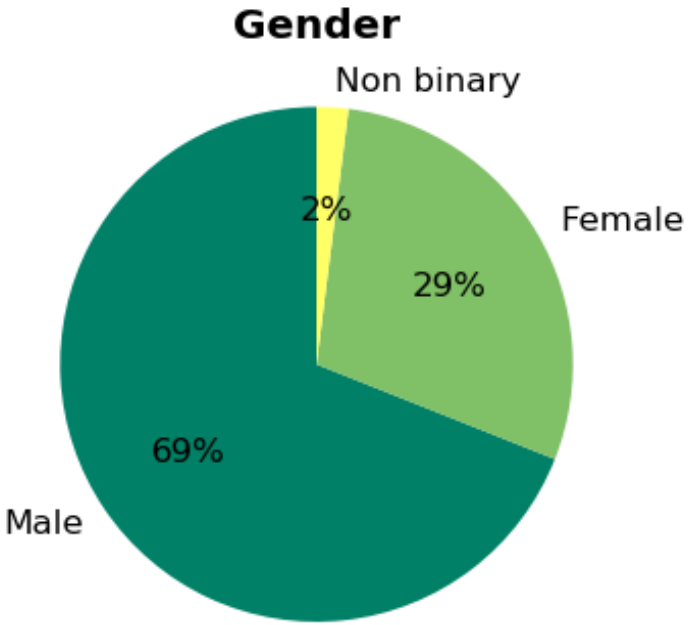
(1) Royal Belgian Institute for Space Aeronomy, Belgium, (2) Planetary Science Institute, Tucson, USA, (3) INAF, Istituto di Astrofisica e Planetologia Spaziali, Italy, (4) LATMOS/IPSL, UVSQ Université Paris-Saclay, Sorbonne université, CNRS, Guyancourt, France, (5) Dip. di Scienze e Tecnologie Università degli Studi di Napoli "Parthenope", (6) Max Planck Institute for Solar System Research, Göttingen, (7) LESIA, Observatoire de Paris, CNRS, Sorbonne université, Univ. Denis Diderot, F-92195 Meudon, France.

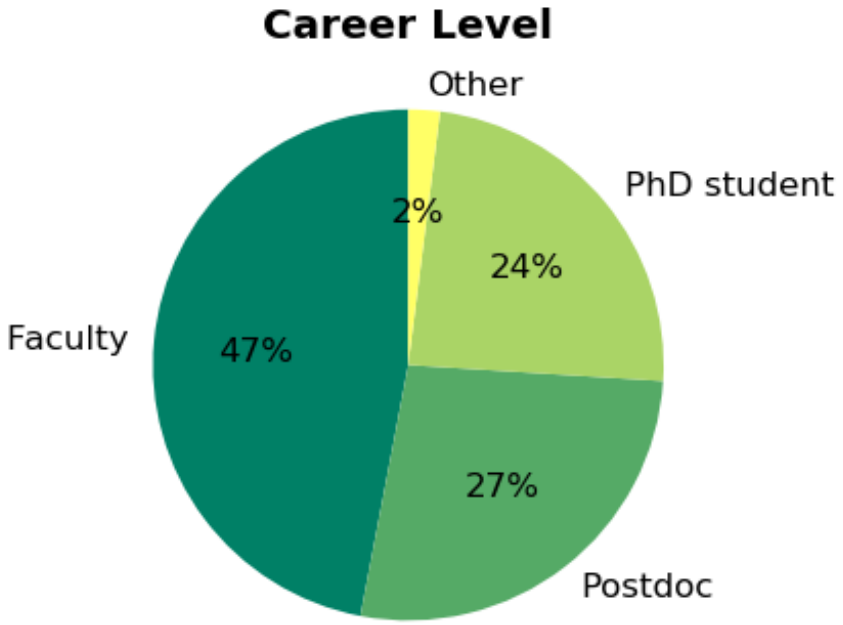
(email: arianna.piccialli@aeronomie.be, Twitter: @apic79)

Survey

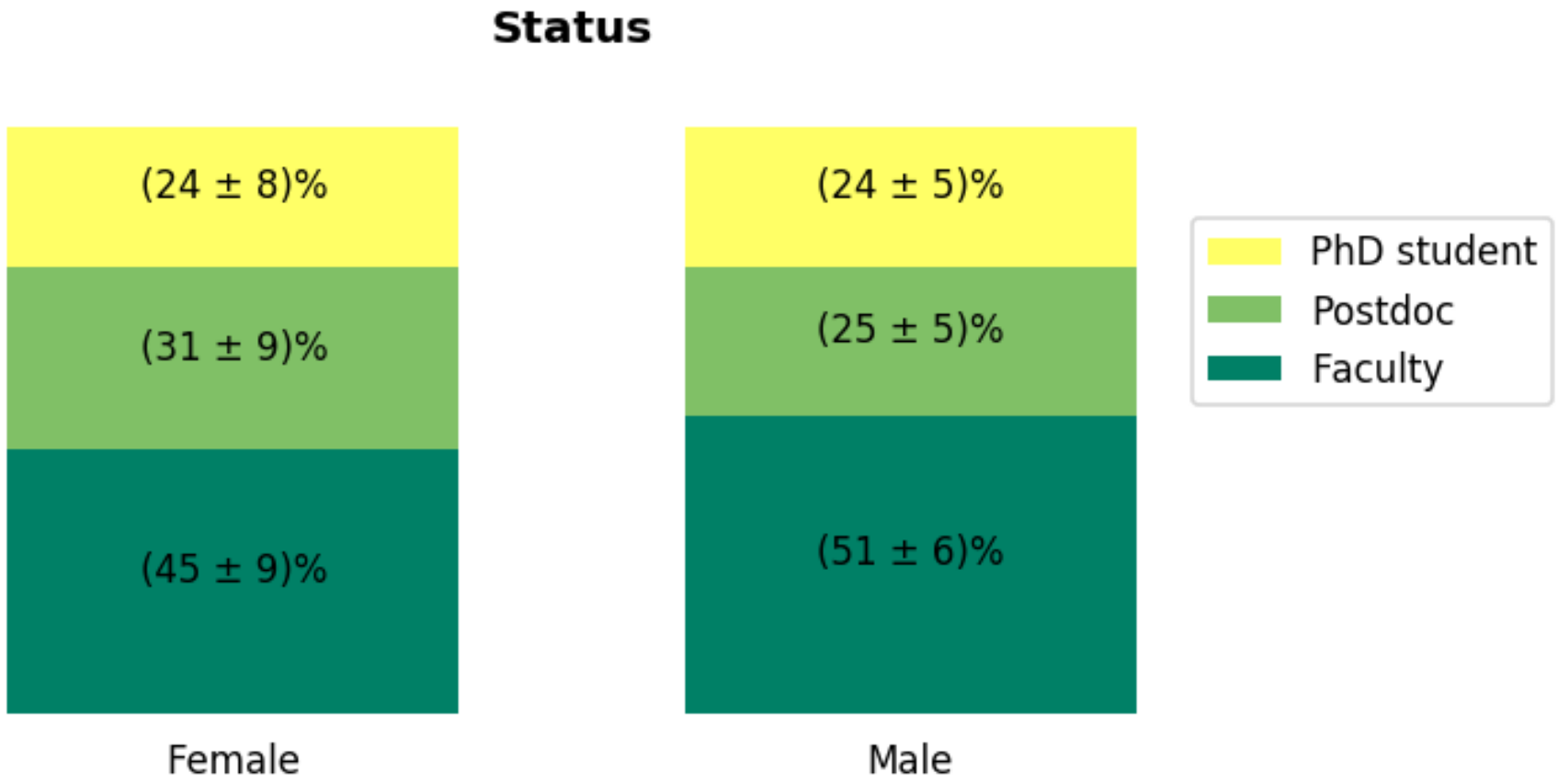
Objective
Setting references for future discussions and actions/decisions to be made in the field of HCI

Support
A survey sent to around 200 people – 100 answers
Spirit of Lyot conference, Tokyo, Japan – October 2019





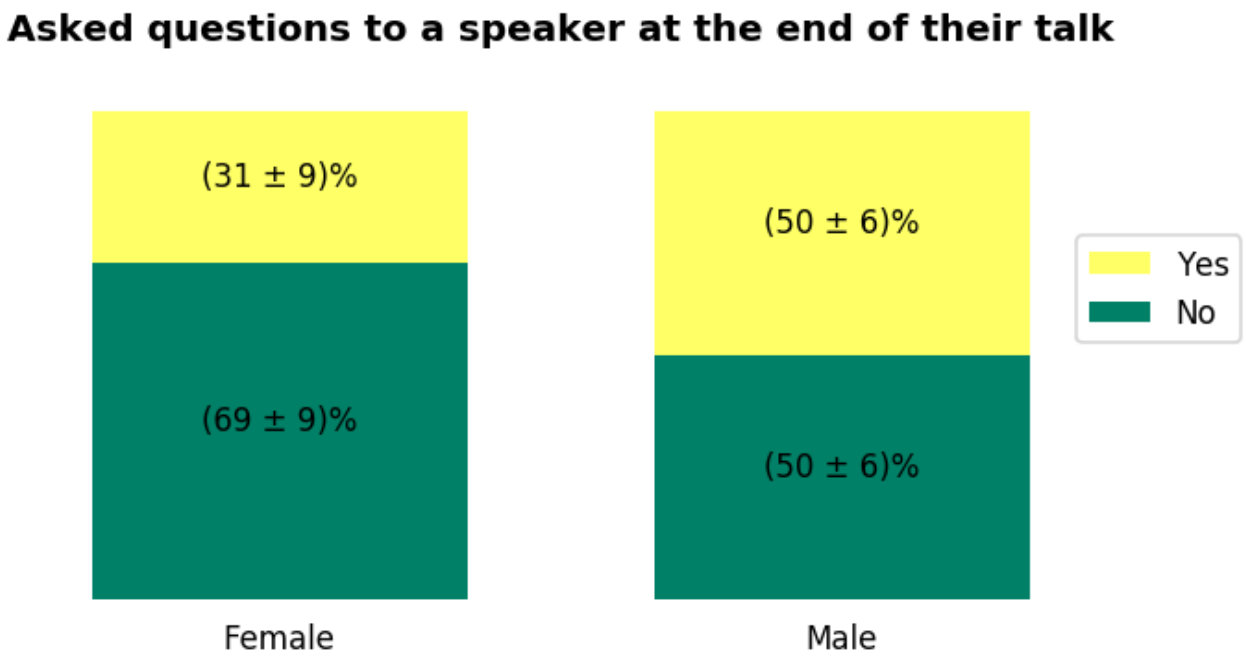
Gender basis – Distribution of career levels

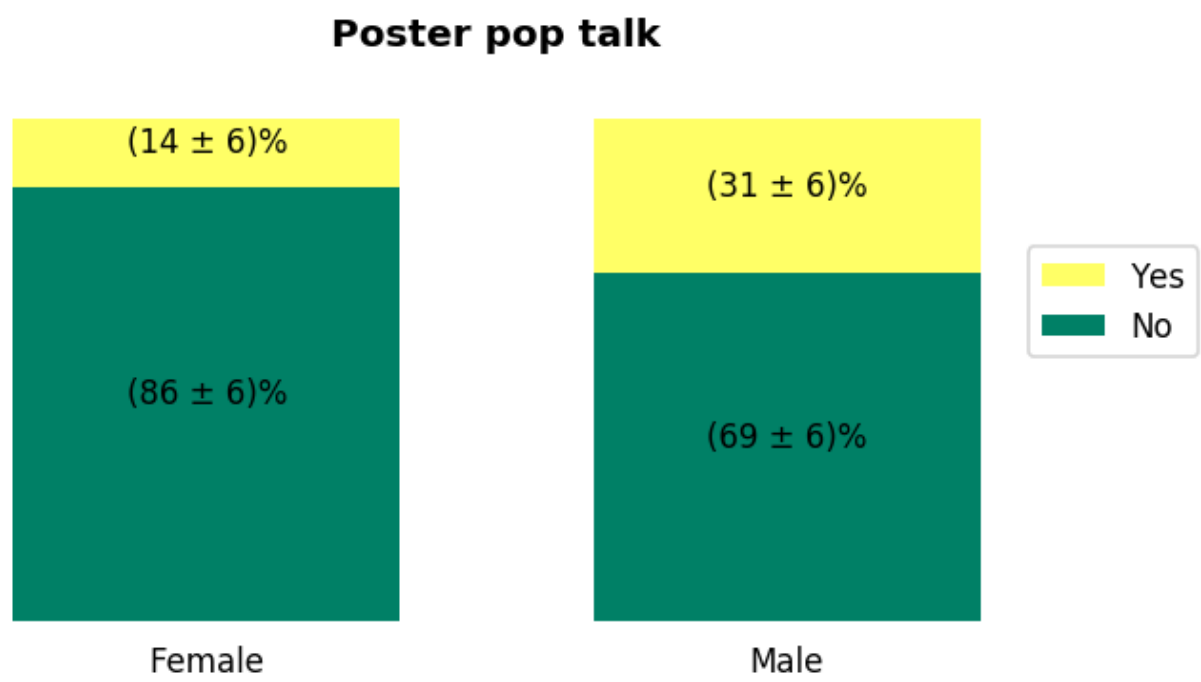


→ No clear variation between genders

→ The % of PhD students per gender indicate no discrimination, but also no coming improvement

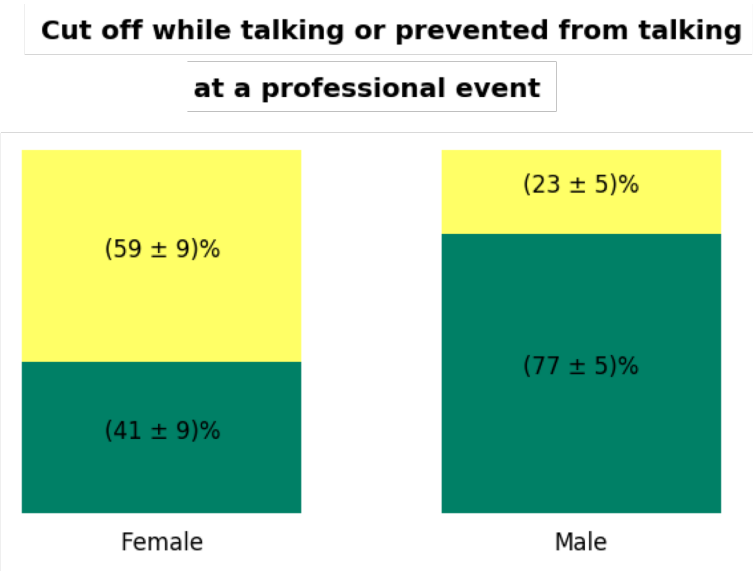
Gender basis – Exposure and visibility

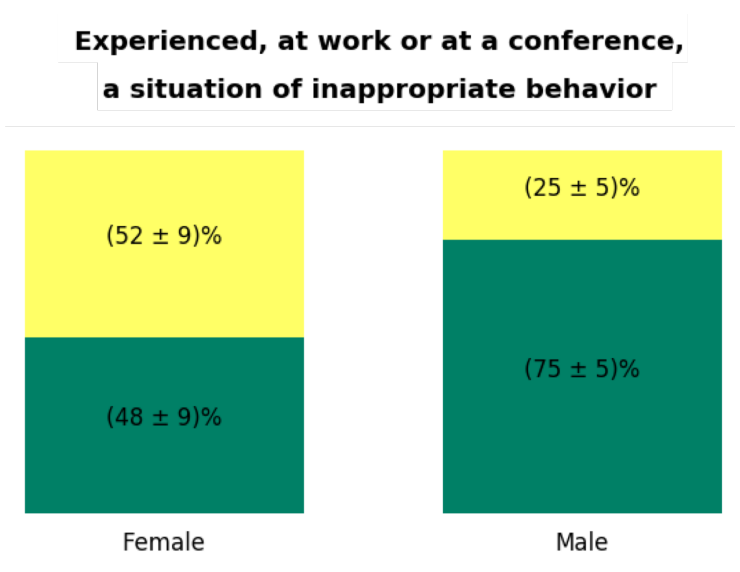


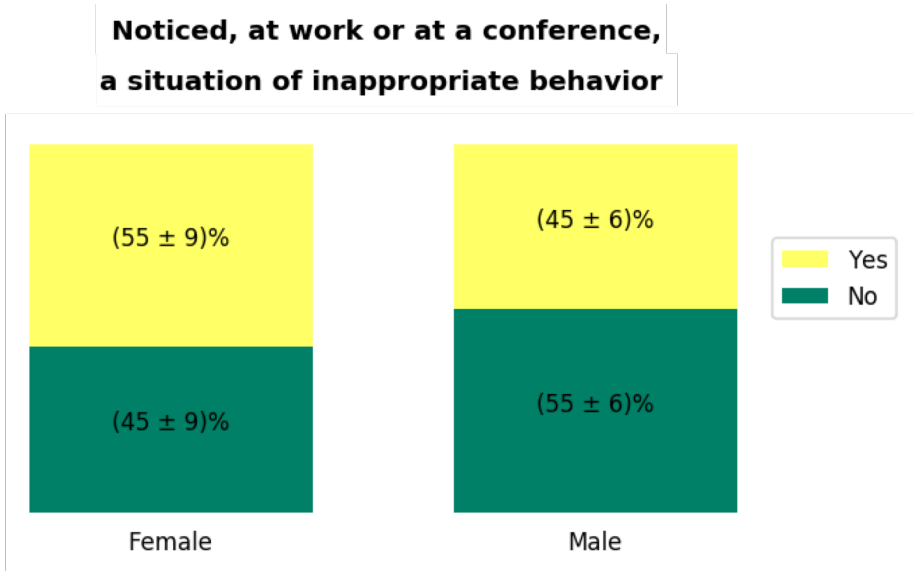


→ Women are more subject to self-censorship than men

Gender basis – Unprofessional behaviors



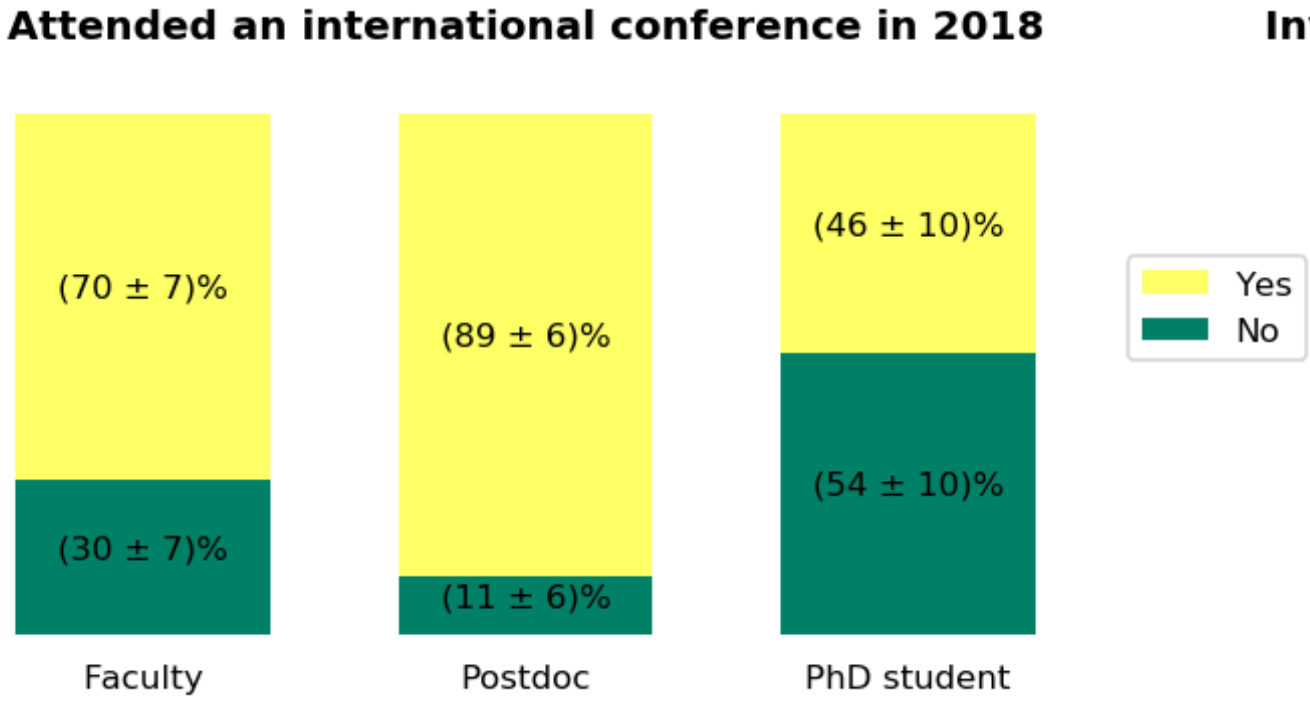


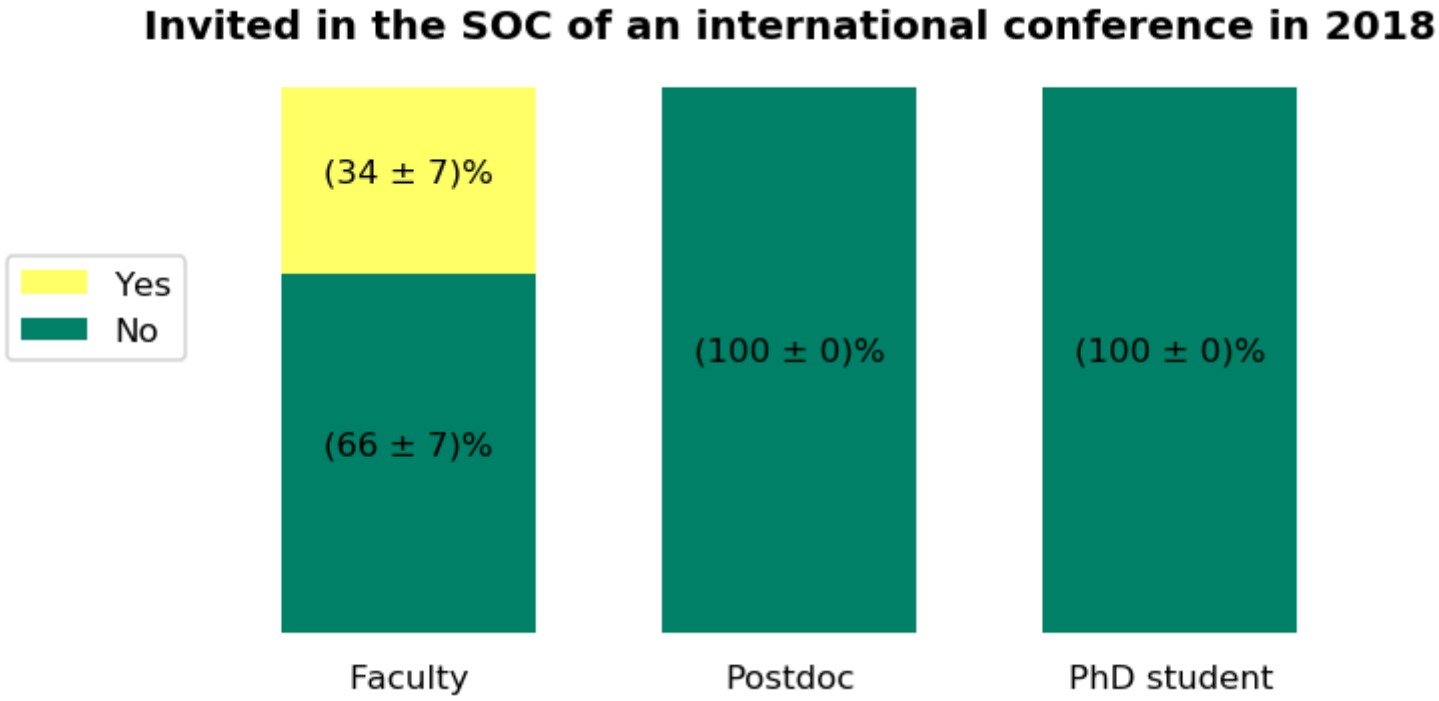


→ Obvious unprofessional behaviors towards women (80% vs 43% for men)

→ The community is overall aware of these issues and can be in a position to intervene when they happen

Status basis – Visibility and recognition by peers

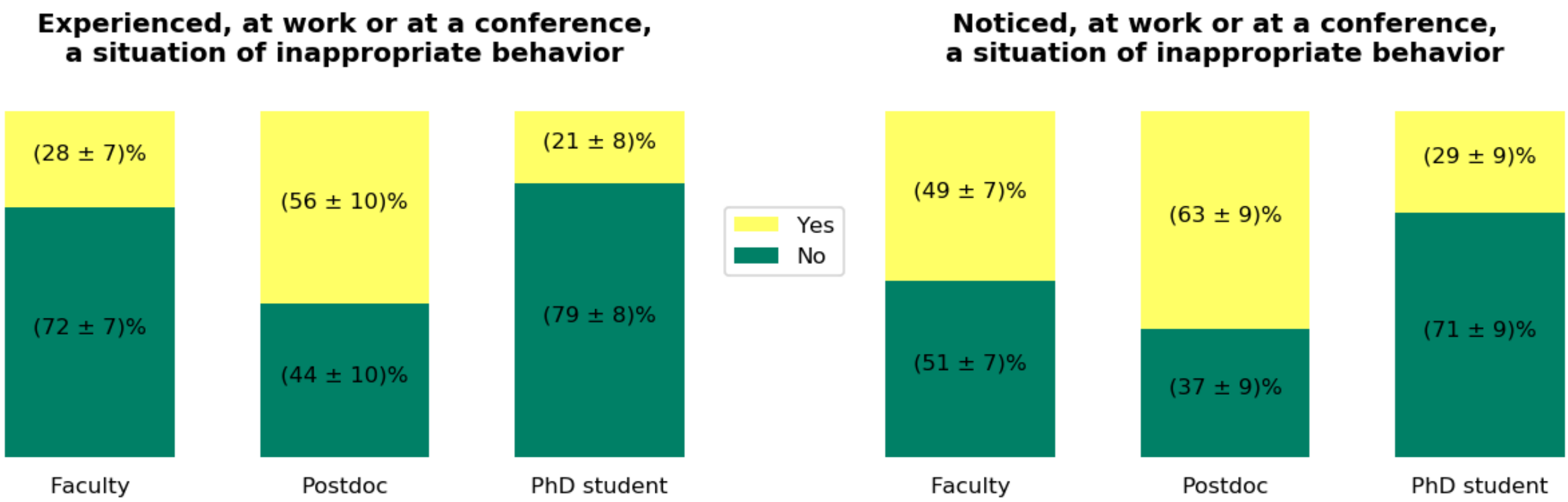




→ Postdocs encouraged to attend international conferences

→ But excluded from SOCs

Status basis – Inappropriate behaviors



→ Female and non binary postdocs are predominantly victims of inappropriate situations (78% of them)

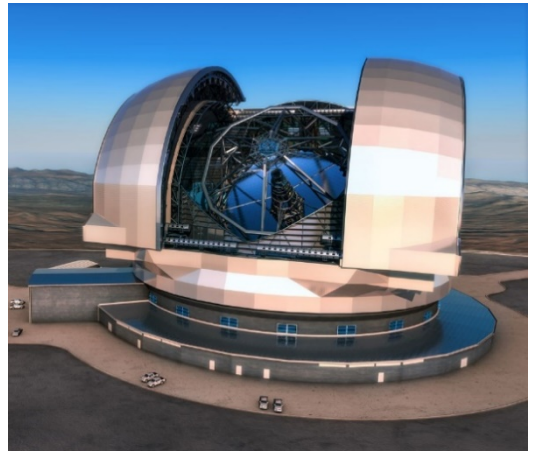
→ And 41% of male postdocs

Conclusions and perspectives

Conclusions & perspectives

→ Long exposure image model:

- Alternative method to multiple end-to-end simulations
- To do: AO and extension to coronagraphic images
- Applications to SPHERE+ and MICADO



ELT

→ Demographic study:

- Systemic behaviors have to be addressed to improve the quality of the work environment
- Reference for future studies to monitor the evolution of demographics and social behaviors in the field of exoplanet imaging

→ Available in open source on GitHub: https://github.com/lleboulleux/socio-demographic-community-survey-in-STEM