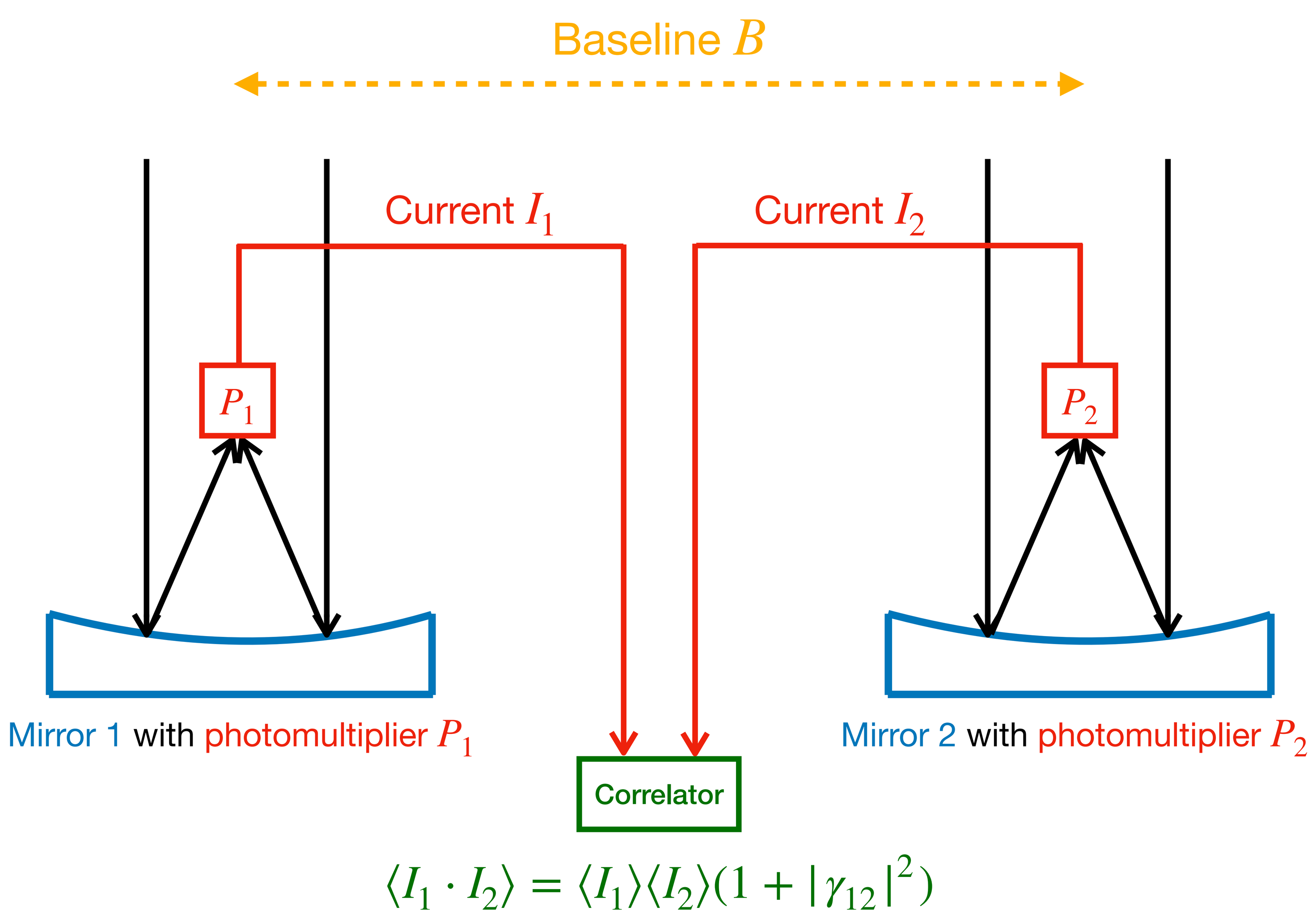
Exoplanet Science with Intensity Interferometry

Roberto Cuissa, Lorenz Zwick, Deniz Soyuer, Timothée Scheaffer, Prasenjit Saha
Institute for Computational Science, University of Zurich

Basics of Intensity Interferometry

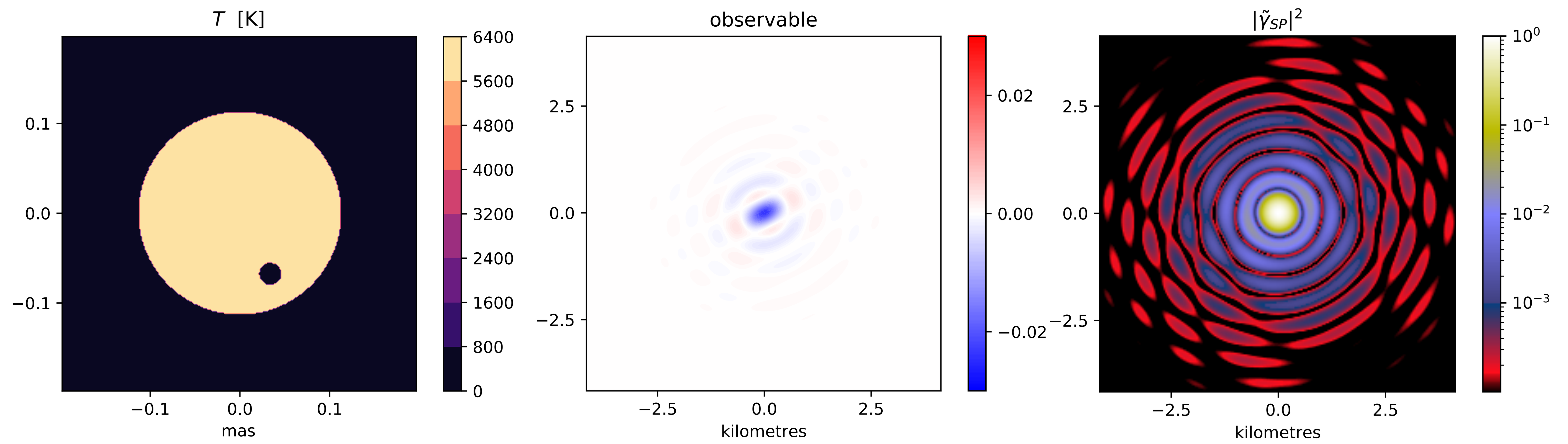
- *The main idea behind intensity interferometry involves **temporally correlating** the light signals received by a **pair of telescopes**, separated by a baseline.*
- *The measured intensities in both telescopes $\langle I_1 \rangle$ and $\langle I_2 \rangle$ (which are averaged over the resolution time) will have a cross correlation profile $\langle I_1 \cdot I_2 \rangle \mathbf{B}$ dependent on the projected baseline $\mathbf{B}$.*
- *One can relate the **cross correlation of the intensities** $\langle I_1 \cdot I_2 \rangle$ to the absolute square of the **spatial correlation function** $|\gamma_{12}|^2$ between the two telescopes.*
- *For a chaotic source, **the intensity fluctuations will average out over timescales which are much longer than the coherence time of light.** Thus, $\langle \Delta I_1 \cdot \Delta I_2 \rangle = \langle I_1 \rangle \langle I_2 \rangle |\gamma_{12}|^2$.*
- *If one has a continuous source, then $|\gamma_{12}|^2$ corresponds to the **correlation of photons coming from different small elements of the sources image on the sky.** It will be identical to the Fourier magnitude of the source distribution Σ. Thus, $|\gamma_{12}|^2 = \left(\mathcal{F}[\Sigma]\right)^2$.*



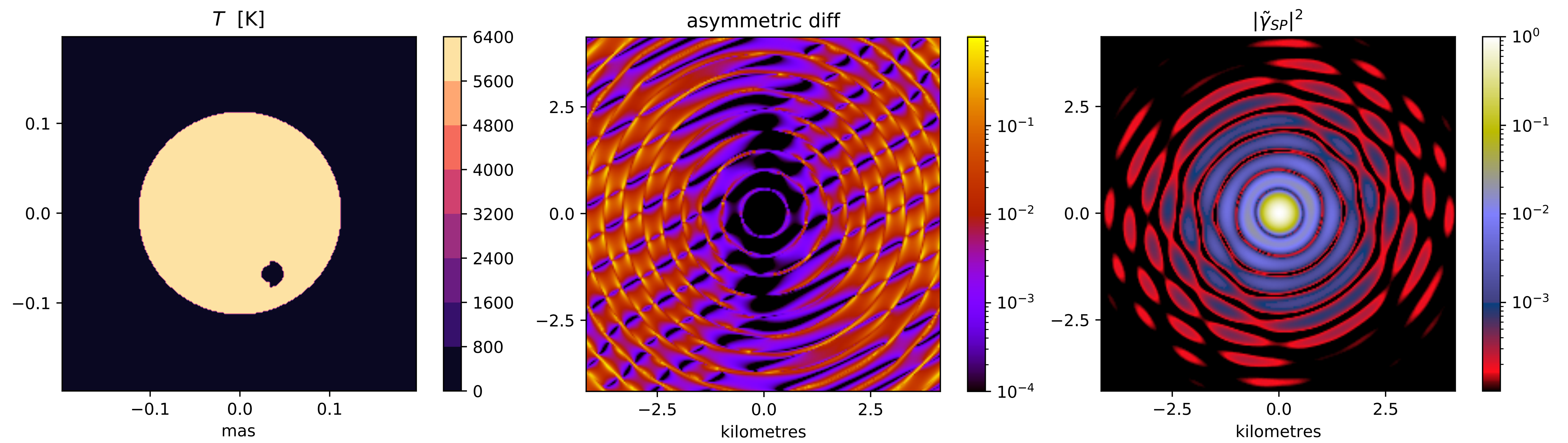
Intensity interferometry** can reach resolutions **far beyond the capabilities of conventional telescopes** and can potentially **resolve features on exoplanets!

Prescription for Transit Events

- *The spatial correlation function **for the star** γ_S is related to the **Fourier transform** of its **light intensity distribution**. Thus, $\gamma_S(\mathbf{k}) = \mathcal{F}[I(r)]_S = \int_0^1 \mathrm{d}r\, 2\pi r J_0(2\pi r k) I(r)$.*
- *A transiting planet will appear as a **hole** of radius r_P centered at coordinates $x_P = (x, y)$ in the light intensity distribution of the star: $\gamma(\mathbf{k},, \mathbf{x}_P, r_P) = \mathcal{F}[I(r)]_S - \mathcal{F}[I(r)]_P$.*
- *Assuming spherical symmetry of the transiting planet, the **observable** difference between the normalized spatial correlation function of the star with and without transiting planet, $(|\tilde{\gamma}_{SP}|^2 - \tilde{\gamma}_S^2 \Sigma_S^2 / \Sigma_{SP}^2)/\tilde{\gamma}_S$, where Σ_{SP} and Σ_S are the normalization values, can be very well approximated by the **analytical formula** $-2\pi \cos(2\pi \mathbf{k} \cdot \mathbf{x}_P)\, I(r)\, r_P^2 \frac{\Sigma_S}{\Sigma_{SP}^2} + \mathcal{O}(r_P^4)$. Therefore, simple analytical formulas can be used to **infer symmetric properties** of the system via **MCMC methods**. Panels show a snapshot of a **transit** in **physical** space, baseline space and the spatial correlation function $|\tilde{\gamma}_{SP}|^2$*



- *For more complicated profiles (e.g. asymmetries relating to wind profiles, molecular abundances etc.) we currently resort to **numerical fits**. Panels show the imprint of a **lopsided shape**, and the **difference between a lopsided and spherical shape.***



References

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[2] Baumgartner, S. et al. 2020: Towards a polarization prediction for LISA via intensity interferometry, *MNRAS*

Email: zwicklo@ics.uzh.ch, soyuerd@ics.uzh.ch