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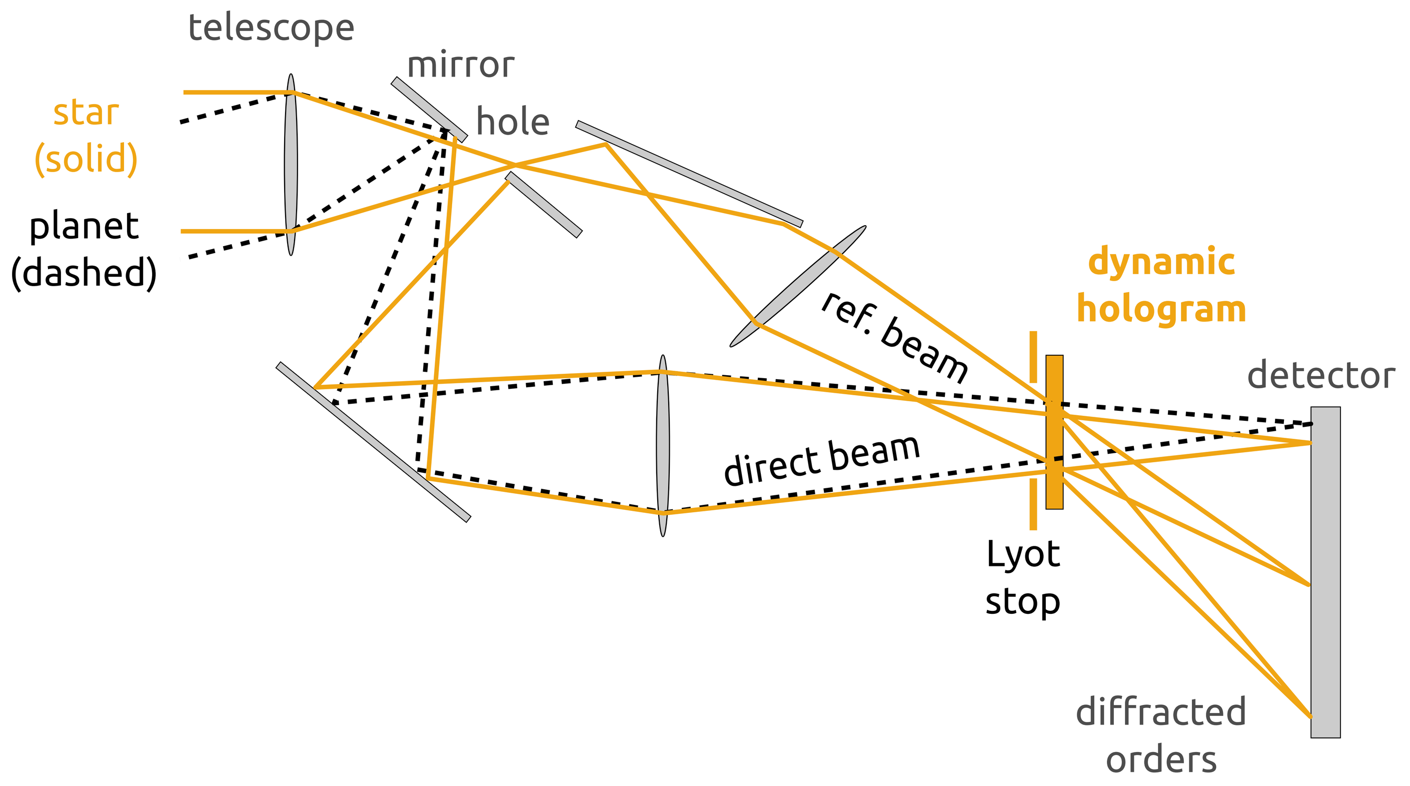
Coronography with a dynamic hologram

We replace the traditional Lyot mask by a flat mirror with a central hole.

Reference beam: the light of the star is not absorbed but it is recuperated.

Direct beam: the residual light does not pass through the hole.

The beams intersect on a dynamic hologram.



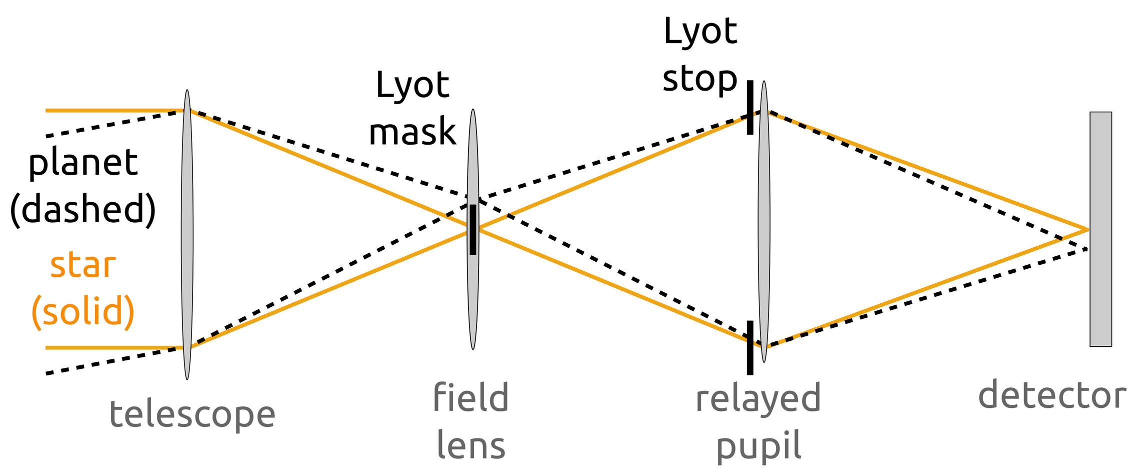
The two beams create fringes in the speckles of the hologram → recording the hologram.

The fringes act like a grating → diffraction of several orders on the detector.

Destructive interference → order 0 of direct beam vs order +1 of the reference beam phase-shifted by π.

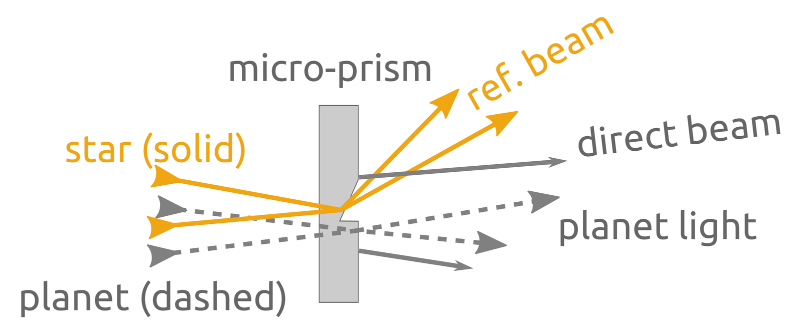
The planet's light is incoherent → no destructive interference.

History: the Classical Lyot coronagraph



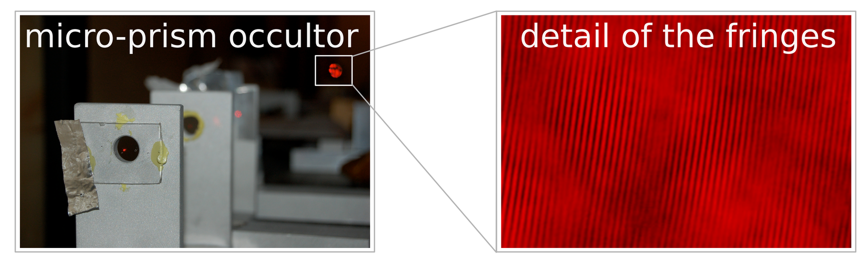
The Lyot mask absorbs only the light of the star.
The Lyot stop masks the residual diffracted light.
The field is re-imaged on the detector.
The planet detection limit can be increased by apodizing the entrance pupil.

Alternative design



More performing design: the hole in the flat mirror is replaced by a micro-prism. This approach is presented in our recent papers:
Ricci, D. et al., "Extreme coronagraphy with an adaptive hologram. Simulations of exo-planet imaging", A&A 503, 301–308 (Aug. 2009).

Laboratory tests



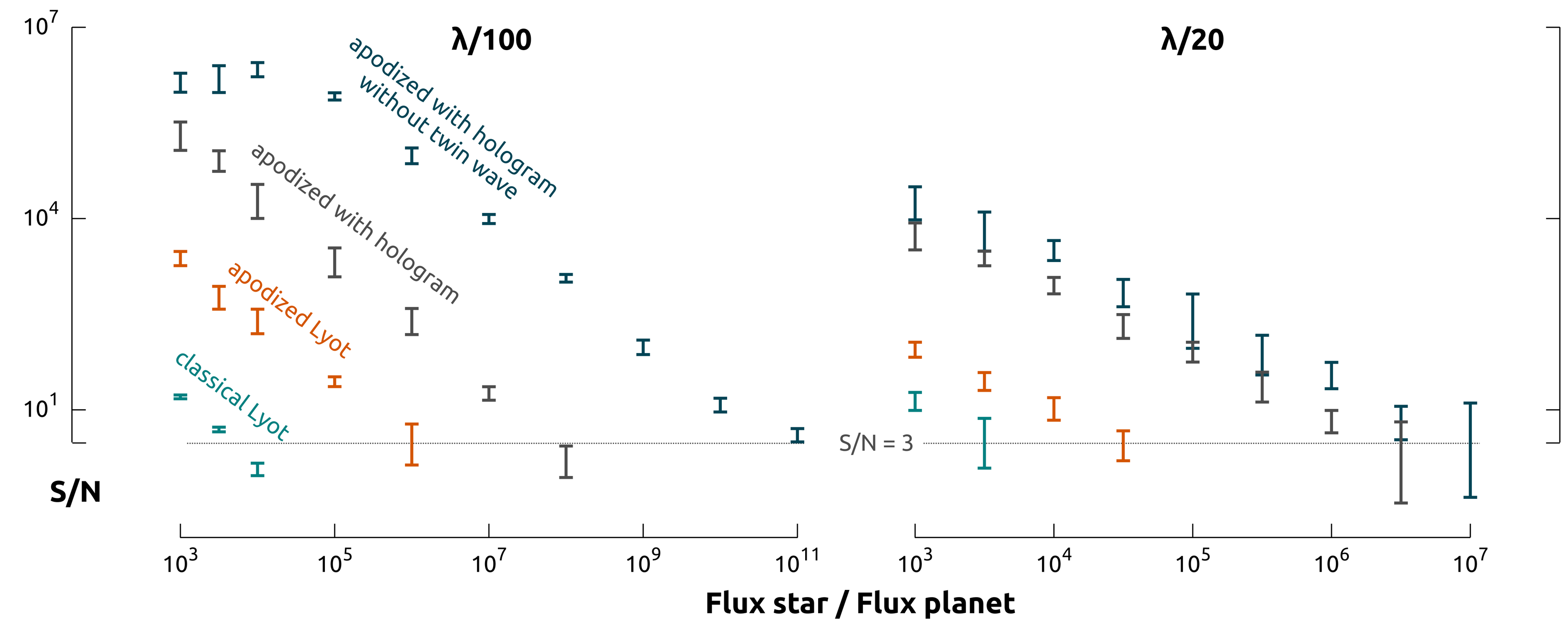
A preliminary laboratory test by Labeyrie, A. et al. is progressing in Calern, France.

Numerical simulations: a 6.5m observing a Sun-Earth system at 11pc

Perfect conditions

comparing several coronagraphs ($\lambda/100$ and $\lambda/20$ mirror bumpiness).

Our system vs apodized coronagraph:
$\lambda/100$ → **100000** times better
$\lambda/20$ → **1000** times better

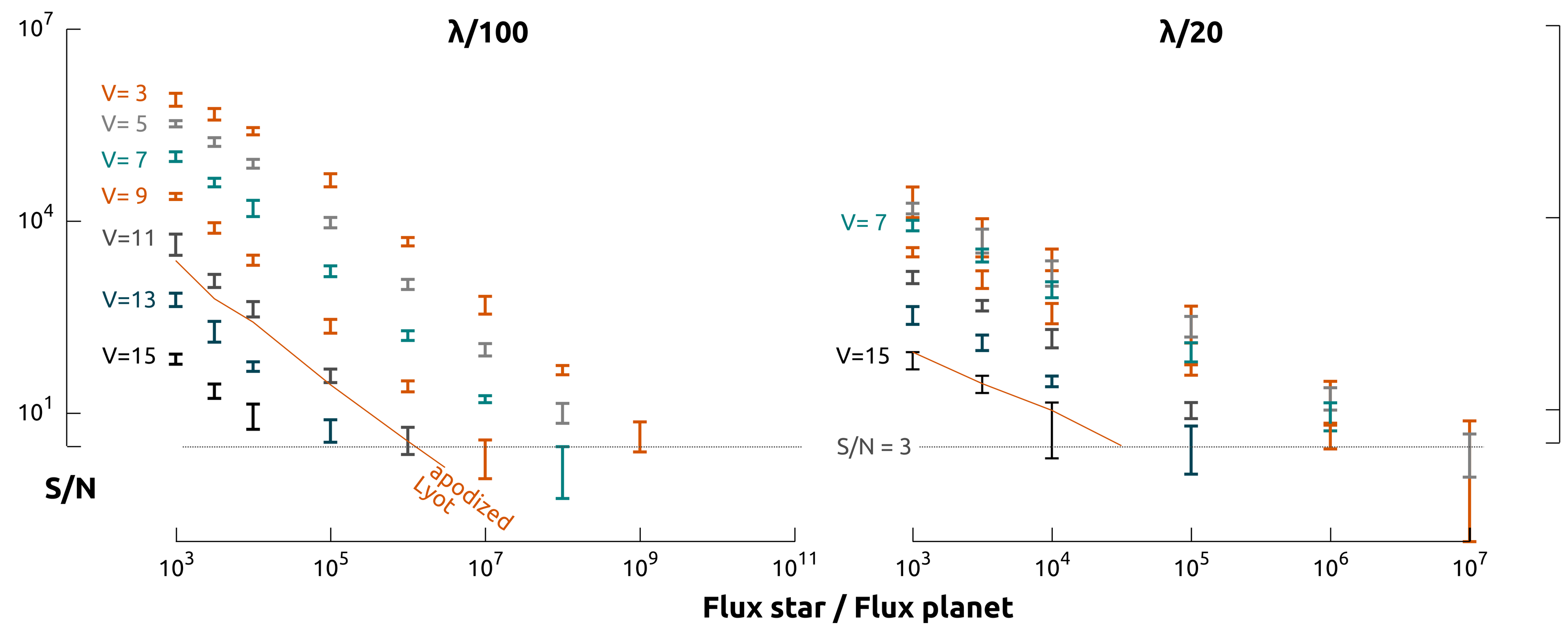


Photon noise

variating the star's **V magnitude.**

Upper limits:
$\lambda/100$ → **V=3** → **10000** times better
$\lambda/20$ → **V=7** → **1000** times better

Lower limits:
$\lambda/100$ → **V=11**
$\lambda/20$ → **V=15**
(match the apodized coronagraph)

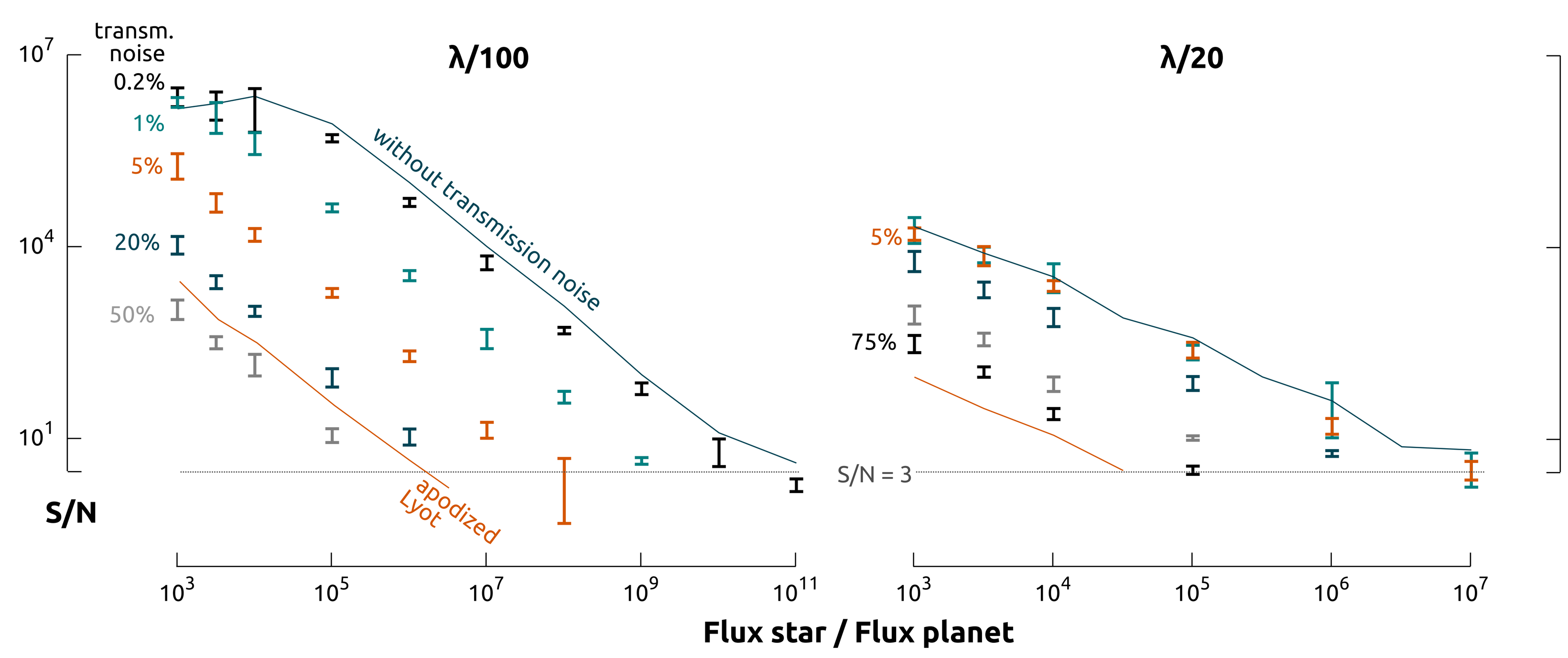


New: Transmission noise

Studying a practical implementation.

Upper limits:
$\lambda/100$ → **0.2%**
$\lambda/20$ → **5.0%**
(performances not degraded with noise of the hologram actuators lower than these limits)

Lower limits:
$\lambda/100$ → **0.2%**
$\lambda/20$ → **75%**
(match the apodized coronagraph)



Conclusions

It is possible to override the current limits of coronagraphic systems with the introduction of a dynamic hologram.

It is sufficient to control the "actuators" with a precision better than 0.2 - 5% in order not to be limited by the transmission noise.

This will improve the performances of the coronagraph by a factor 1000 - 10000.

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