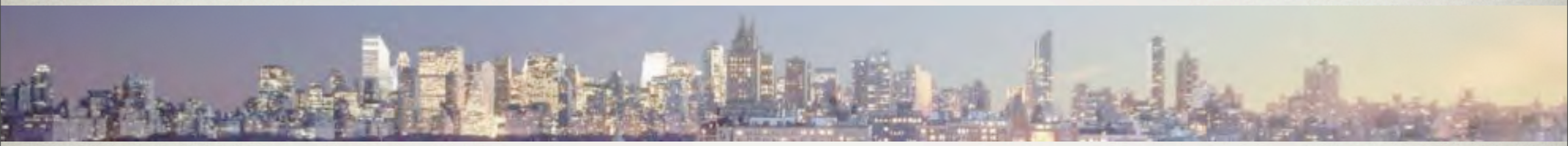

Speckle noise in high contrast imaging, a (rapid) overview

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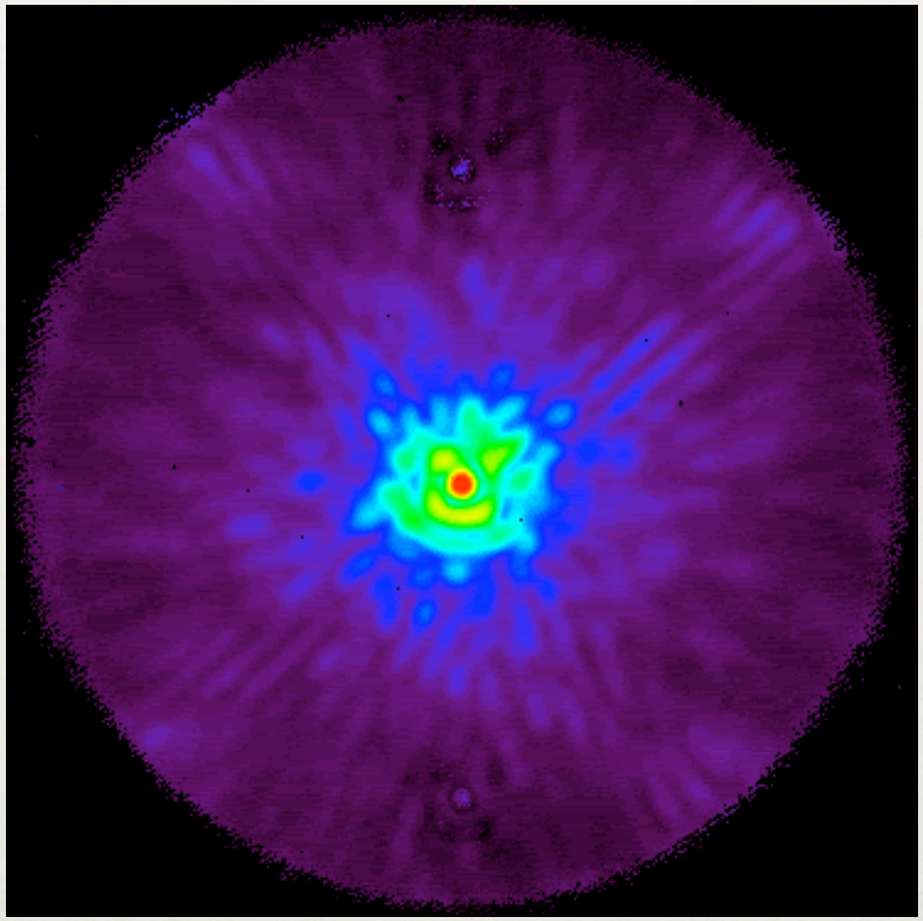
Contributions from the Lyot project team

Acknowledgments: Michelson Fellowship Program, Center For Adaptive Optics

Coronagraphic PSF



Effect of a coronagraphs on speckles?
Effect of quasi-static speckles?
How can we go deeper?

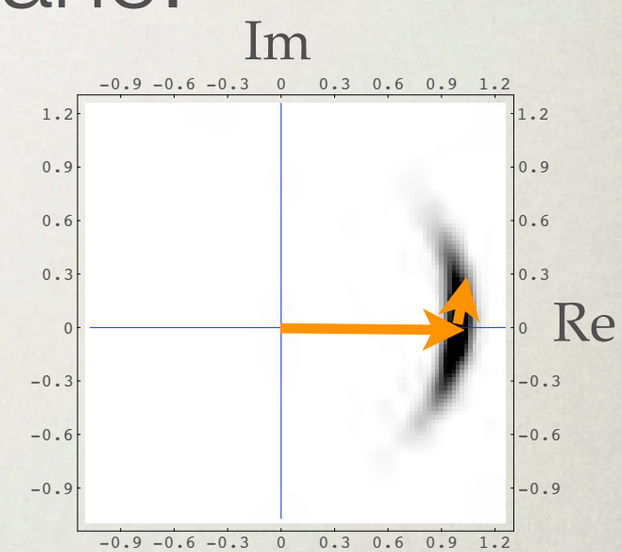
Statistical model for direct images

- Wave amplitude at the pupil plane:

$$\Psi_1(x,y) = [A + a(x,y)]\ P(x,y)$$

Plane wave

uncorrected part of the wavefront

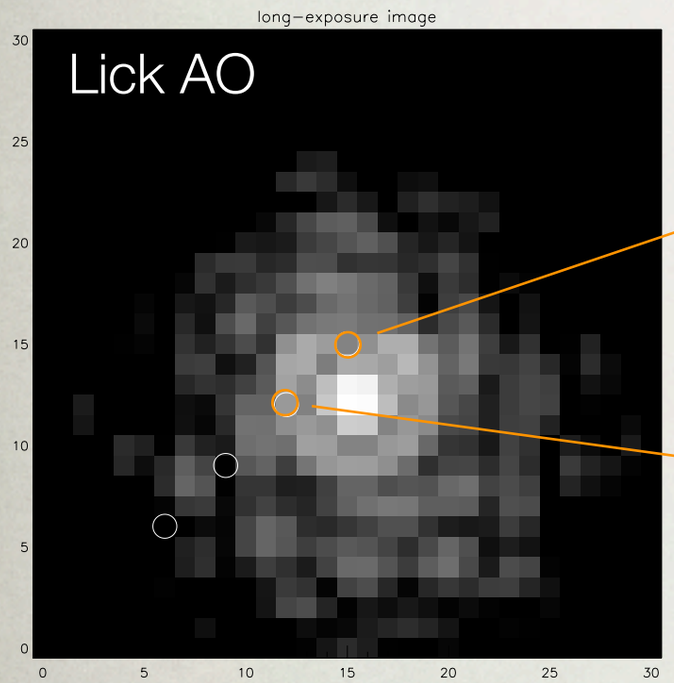


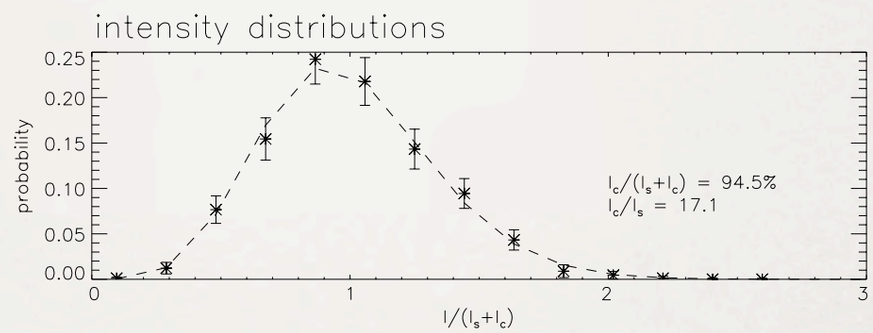
- Focal plane intensity: Rician distribution

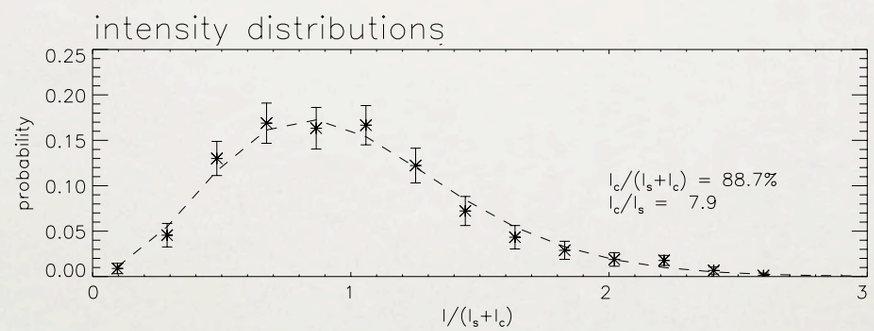
$$\mathcal{P}_I(I) = \frac{1}{I_s} \exp\left(-\frac{I + I_c}{I_s}\right) \mathrm{I}_0\left(\frac{2\sqrt{I}\sqrt{I_c}}{I_s}\right)$$

$$< I >= I_c + I_s \qquad \sigma_I^2 = I_s^2 + 2 I_s I_c$$

Verification on real data

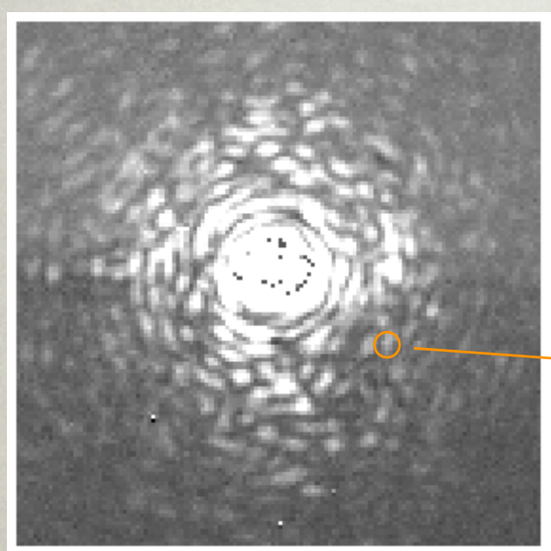


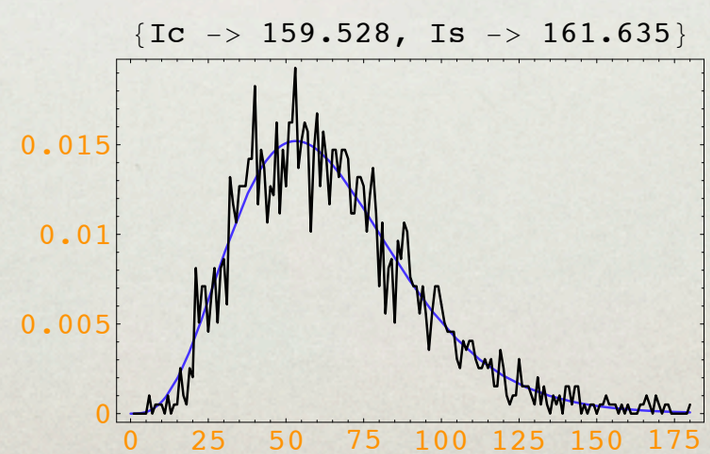




First verification on sky of speckles rician statistics:

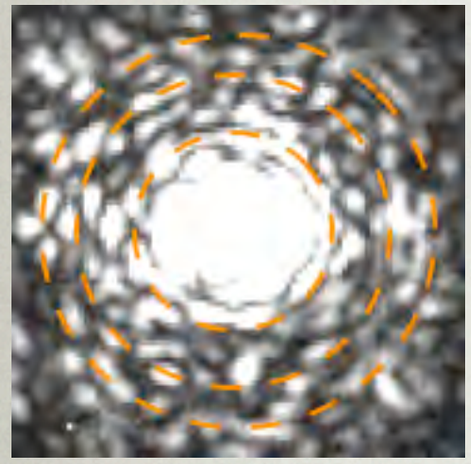
Fitzgerald & Graham (2005)

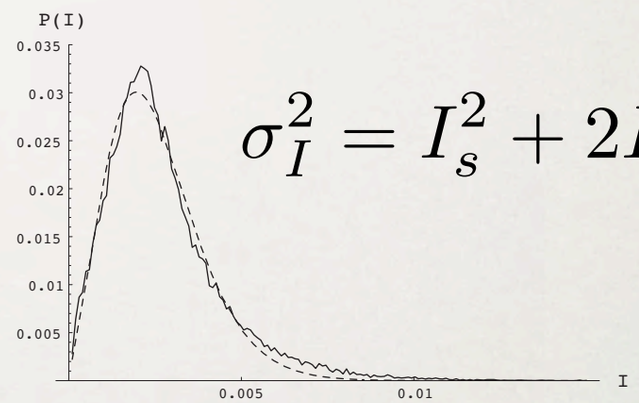




Soummer & Lloyd in prep

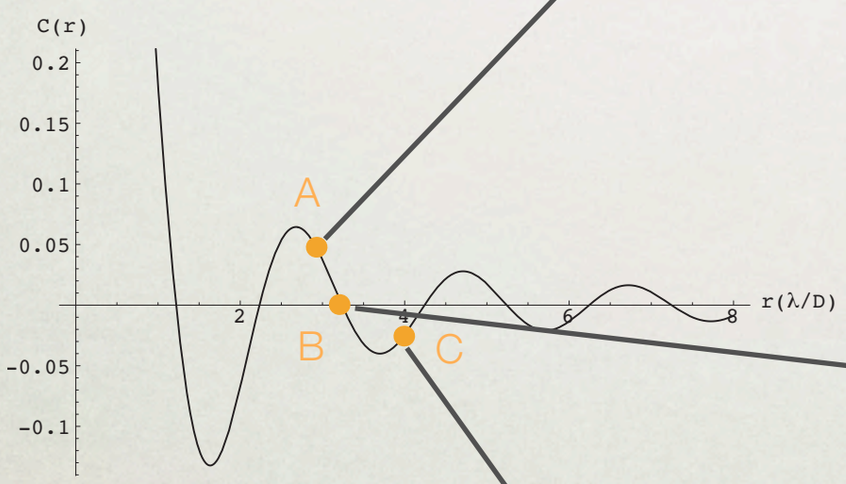
Speckle pinning



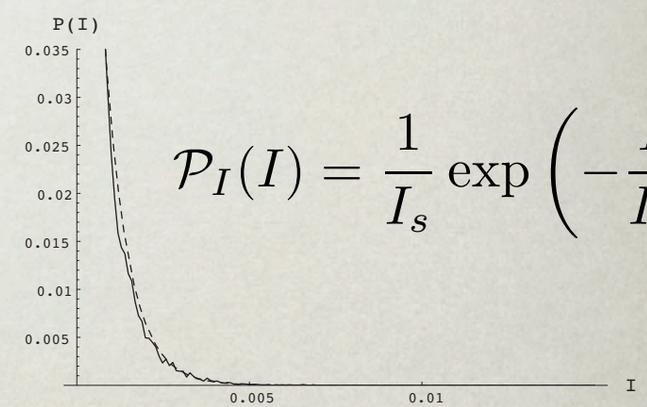


$$\sigma_I^2 = I_s^2 + 2 I_s I_c$$

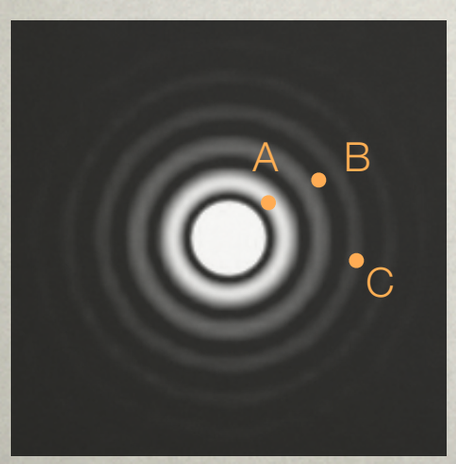
High continuous value amplification of the fluctuation



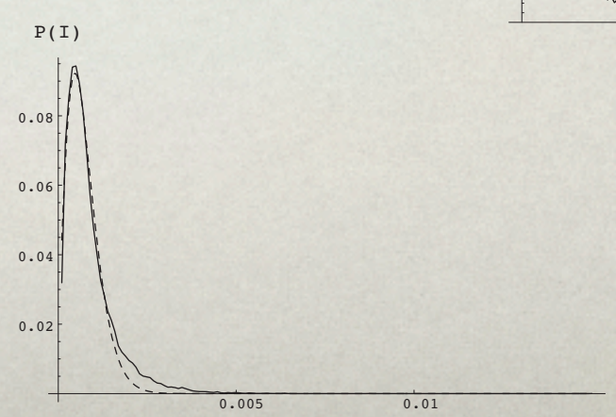
zero of the PSF exponential statistics



$$\mathcal{P}_I(I) = \frac{1}{I_s} \exp\left(-\frac{I}{I_s}\right)$$



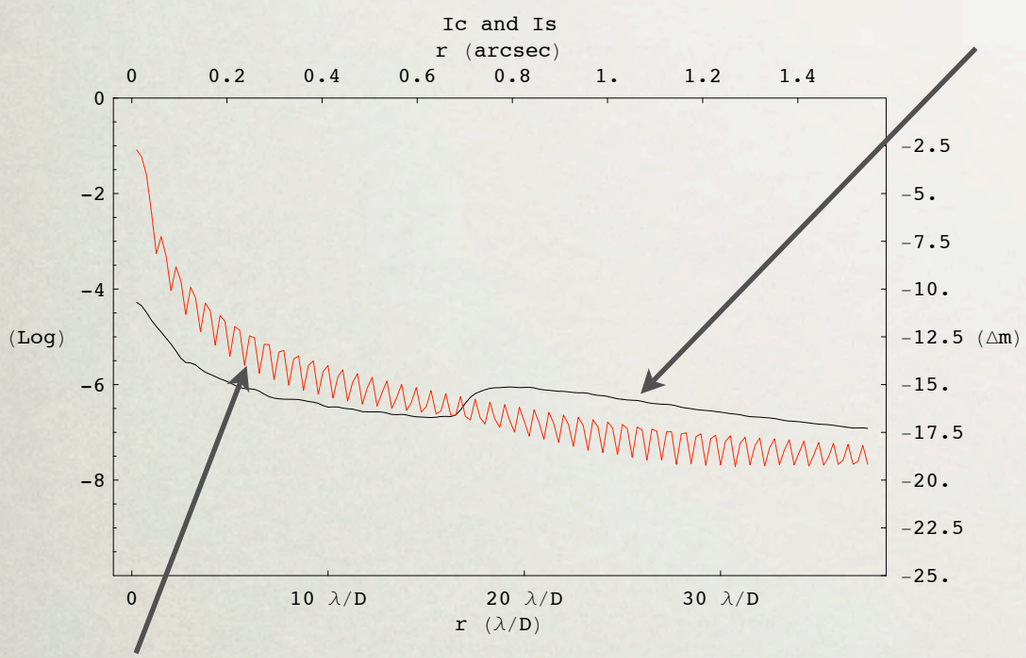
low value of the continuous level



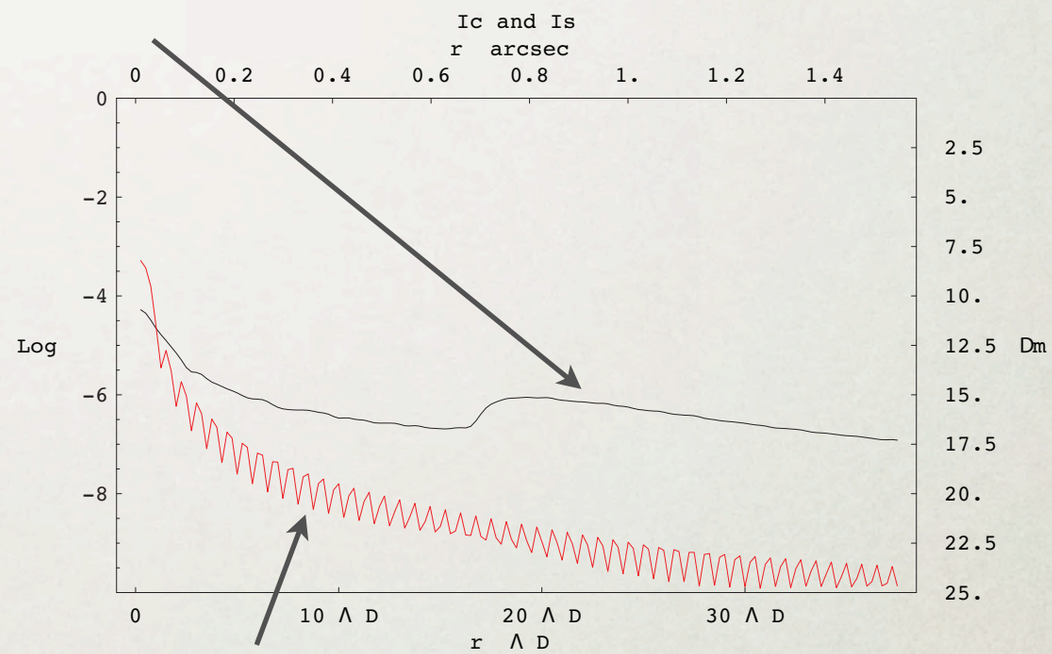
Aime & Soummer 2004

Effect of a coronagraph

Is speckle halo term: not affected by a coronagraph



Ic without coronagraph



Ic with coronagraph

$$\sigma^2 = (2I_sI_c + I_c) + (I_s^2 + I_s) = \sigma_c^2 + \sigma_s^2$$

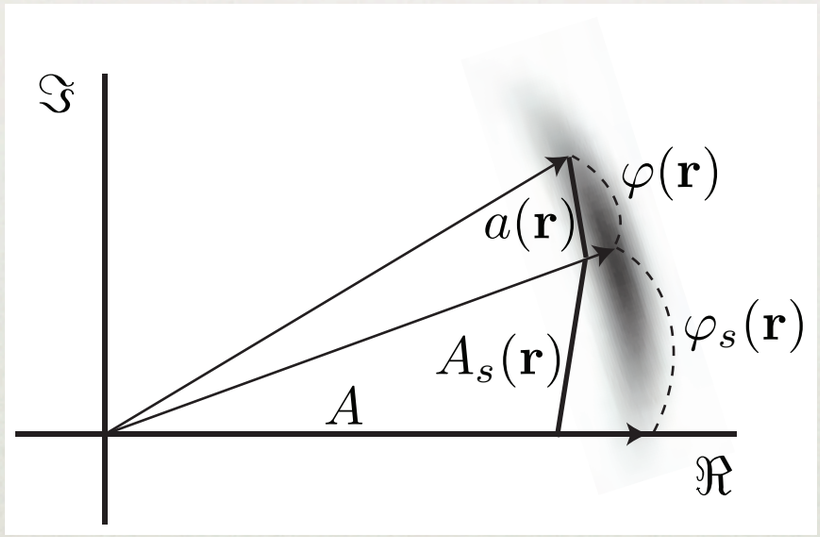
Can be removed by a coronagraph

Unaffected by a coronagraph

Static + Quasi-static + atmospheric

- new decomposition:

$$\Psi_1 = A + A_s(x) + a_1(x) + a_2(x)$$



$$\sigma_I^2 = N(I_{s1}^2 + NI_{s2}^2 + 2I_c(I_{s1} + NI_{s2}) + 2I_{s1}I_{s2}) + \sigma_p^2$$

Soummer etal 2007

High contrast imaging

PSF with static aberrations

Pinning by direct or coronagraphic PSF

atmospheric halo

$$\sigma_I^2 = N(I_{s1}^2 + NI_{s2}^2 + 2I_c(I_{s1} + NI_{s2}) + 2I_{s1}I_{s2}) + \sigma_p^2$$

Quasi~static halo

atmospheric pinning

quasi~static pinning

cross pinning quasi~static atmospheric

N is the ratio of the life times

N is LARGE

High contrast imaging

Speckle pinning: coronagraph

AO system

$$\sigma_I^2 = N(I_{s1}^2 + NI_{s2}^2 + 2I_c(I_{s1} + NI_{s2}) + 2I_{s1}I_{s2}) + \sigma_p^2$$

minimize static aberrations

Calibration, active correction, speckle nulling

Remaining parts removed by post processing

(Angular/Spectral/Polarimetric differential imaging etc.)

References

Aime & Soummer ApJL 2004

Soummer, Ferrari, Aime, Jolissaint ApJ 2007, accepted

Soummer & Ferrari 2007 ApJL, accepted

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