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

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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

\[ \mathcal{P}_1(I) = \frac{1}{I_s} \exp \left( -\frac{I + I_c}{I_s} \right) I_0 \left( \frac{2\sqrt{I} \sqrt{I_c}}{I_s} \right) \]

\[ < I > = I_c + I_s \quad \sigma_I^2 = I_s^2 + 2I_sI_c \]
Verification on real data

First verification on sky of speckles rician statistics:

Fitzgerald & Graham (2005)

Soummer & Lloyd in prep
Speckle pinning

High continuous value amplification of the fluctuation

\[ \sigma_I^2 = I_s^2 + 2 I_s I_c \]

\[ P_I(I) = \frac{1}{I_s} \exp \left( -\frac{I}{I_s} \right) \]

Aime & Soummer 2004
Effect of a coronagraph

Is speckle halo term: not affected by a coronagraph

\[ \sigma^2 = (2I_s I_c + I_c) + (I_s^2 + I_s) = \sigma_c^2 + \sigma_s^2 \]

Can be removed by a coronagraph

Unaffected by a coronagraph
Static + Quasi-static + atmospheric

- new decomposition:

\[ \Psi_1 = A + A_s(x) + a_1(x) + a_2(x) \]

\[ \sigma_I^2 = N(I_{s1}^2 + N I_{s2}^2 + 2I_c(I_{s1} + N I_{s2}) + 2I_{s1}I_{s2}) + \sigma_p^2 \]
High contrast imaging

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

N is the ratio of the life times

N is LARGE
High contrast imaging

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

AO system: minimize static aberrations

Speckle pinning: coronagraph

Calibration, active correction, speckle nulling

Remaining parts removed by post processing

(Angular/Spectral/Polarimetric differential imaging etc.)
References

Aime & Soummer ApJL 2004
Soummer & Ferrari 2007 ApJL, accepted

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