Exoplanet Imaging and Characterization: Coherent Differential Imaging and Signal Detection Statistics

Recap of part 1

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Discovery of Proxima Cen b: catalyst to produce blue prints of future planet imager

- Blue prints to future instruments for ELTs, perhaps current large telescopes?
    - Proxima Cenb is 5e-8 at 30-40 mas
        - State-of-the-art is 2e-7 at 0”.4 (SPHERE on Sirius)
- WFIRST post-processing:
    - do better than PCA with single reference (library)
- HabEx/LUVOIR: how to get to 1e-11

Review of state of the art in WFC

- Focal plane wavefront sensing:
  - speckle nulling, EFC, stroke minimization
  - ms exposures (R. Frazin's regression)
- Kalman filtering, predictive control (AJ Riggs)

State of the art in coronagraphy

- New coronagraph designs accommodating complex apertures (SCDA)
  - APLC
  - PIAA-CMC
  - RAVC
- Current trend is toward hybridization
- Issue of contrast metrics: throughput vs starlight suppression, SNR, etc.

Sensor fusion

- Only scratched the surface of this key subject
- Huge potential for predictive control, solve for NCPAs, etc..
- Severe practical limitations:
  - synchronization
  - computing power
  - photon noise

Signal detection theory, contrast definitions

- Good progress has been made during part I
- Use of ROC curves (TPF vs FPF) should be widespread, with innovative graphical representations

- Framework is SAG19: clear goal => report and recommendation, publication (Jensen-Clem et al.)

Differential detection techniques & post-processing

- PCA with all the possible DI techniques is the gold standard

- Machine learning approaches go beyond PCA:
  - discriminative (training datasets) vs generative (models)
  - use of coherence and sensor fusion (telemetry a posteriori)
  - experiment with existing data sets
  - data challenges (KAGGLE)

New detector technologies (MKIDS, IR-APD)

- We do not have the detector technology to image and characterizer Earth-like planets
- At least 2 promising routes:
  - MKIDS: DARKNESS, MEC, …
  - IR-APD: Keck/Subaru IR-PWFS, Robo-AO
  - A few others: EMCCD, electron injectors

Combination of direct imaging and high dispersion spectroscopy

- Potential for large gains
- Sidesteps speckle noise
- Trade-off between R and starlight suppression
- Concept for linking high contrast imager to high-res spectrographs through single-mode fibers
  - Use coherence, and the overlap integral to our advantage
  - Limit to multiplexing?