Fast and Furious wavefront control at W.M. Keck Observatory

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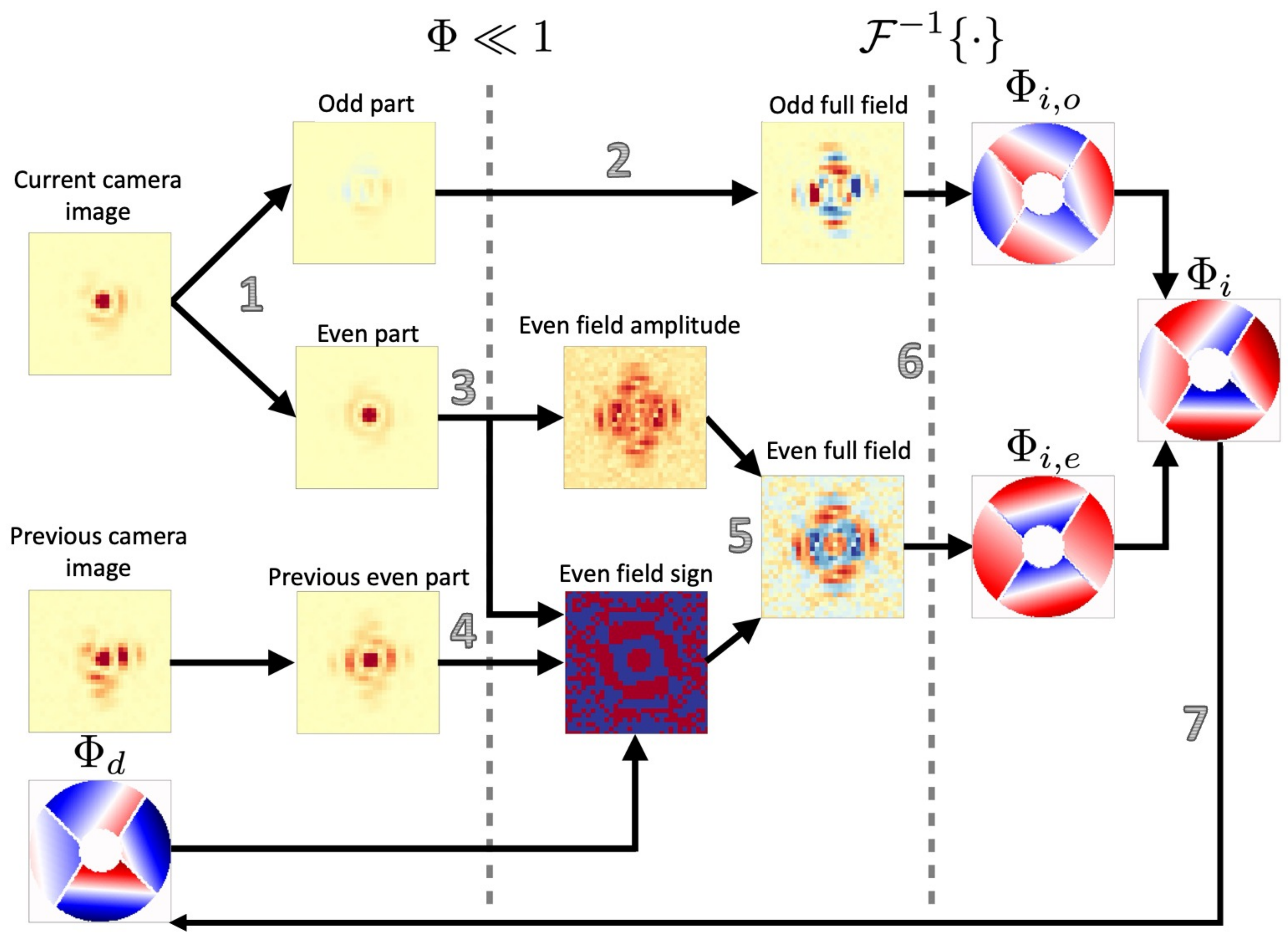
Abstract. Many of the Keck AO system's non-idealities are due to issues with non common path aberrations, including **mirror cophasing issues and optical errors downstream of the wavefront sensor**. These manifest themselves as **quasi-static aberrations** in the point-spread function (PSF). **We have demonstrated the ability to correct these errors using the Fast and Furious algorithm**. This algorithm requires **no extra hardware, no calibration frames, and converges rapidly**. It will be available for general AO observers imminently.

Algorithm overview

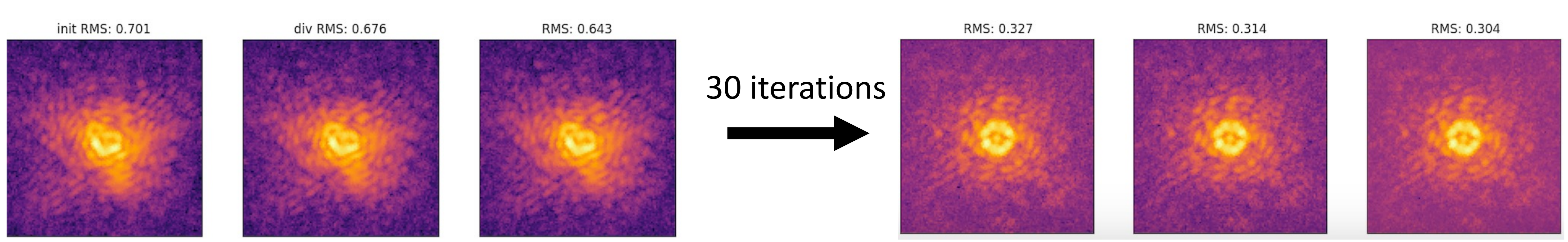
1. The PSF is divided into even (symmetric) and odd (antisymmetric) parts.
2. The odd part can directly solve for the odd electric field.
3. The even part can find the amplitude of the even electric field but not its sign.
4. Using the previous PSF and correction, get the sign of the even component
5. The sign and amplitude components provide the full even electric field.
6. By Fourier transforming the odd and even electric field solutions, the complete wavefront error is reconstructed.
7. A correction is made ($\Phi_i \rightarrow \Phi_d$), and the process repeats.



The limitations to this algorithm are you need a symmetric pupil (OK for most telescopes), translation invariance of the PSF (eg, won't work with coronagraphs), and reasonably good starting Strehl (>10%)

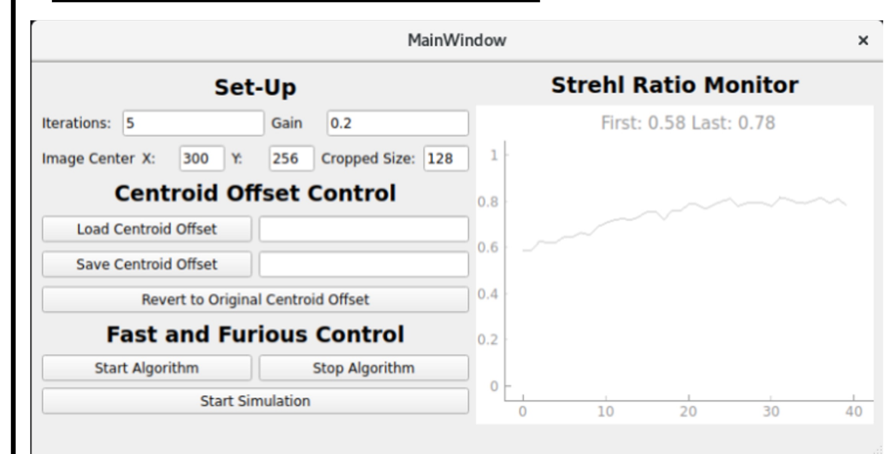
Bonus: coronagraphic mode

We have developed a version of the algorithm suitable for coronagraphs. **This presents a robust solution to a long-standing issue of how to optimize the PSF on a coronagraph, where it is most important**. This version also does not make requirements on symmetry, translation invariance, or low wavefront error.



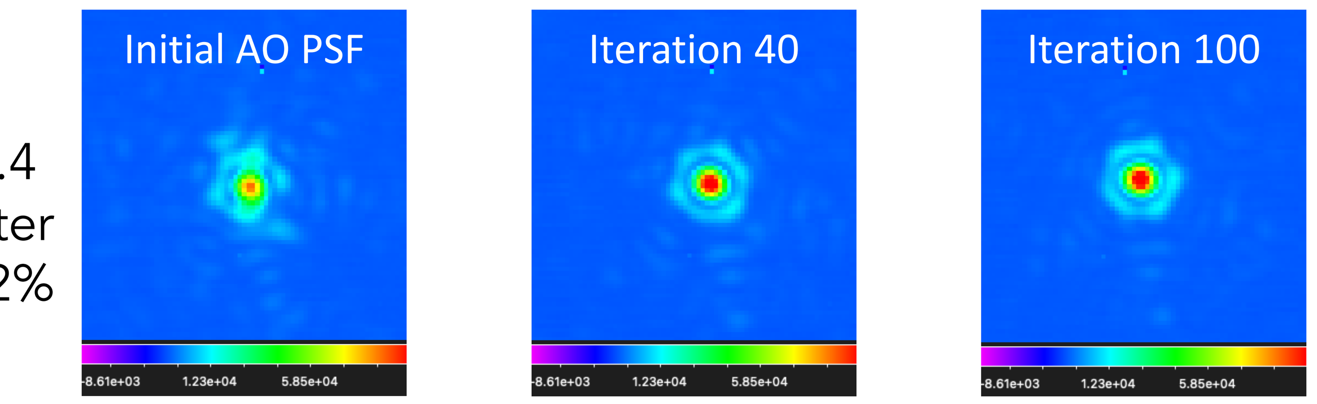
The above images show **bench tests using the vortex coronagraph at Subaru**.

On-sky results

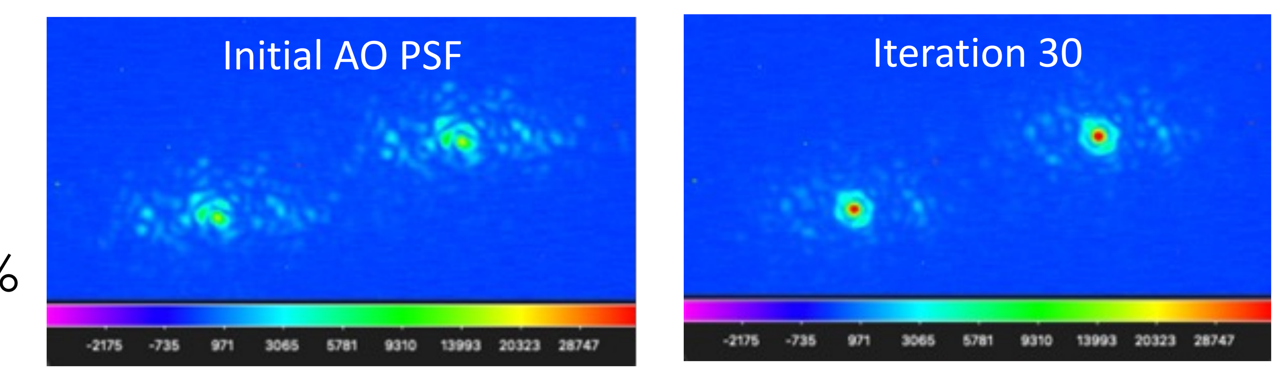


Results on-sky have **typical Strehl improvements of ~10%** and **no cases of divergence or Strehl decrease**. Higher Strehl increases are possible if the system is imperfectly tuned. **Convergence takes less than ten minutes, limited by camera readout speed.** A GUI runs the algorithm with minimal complexity.

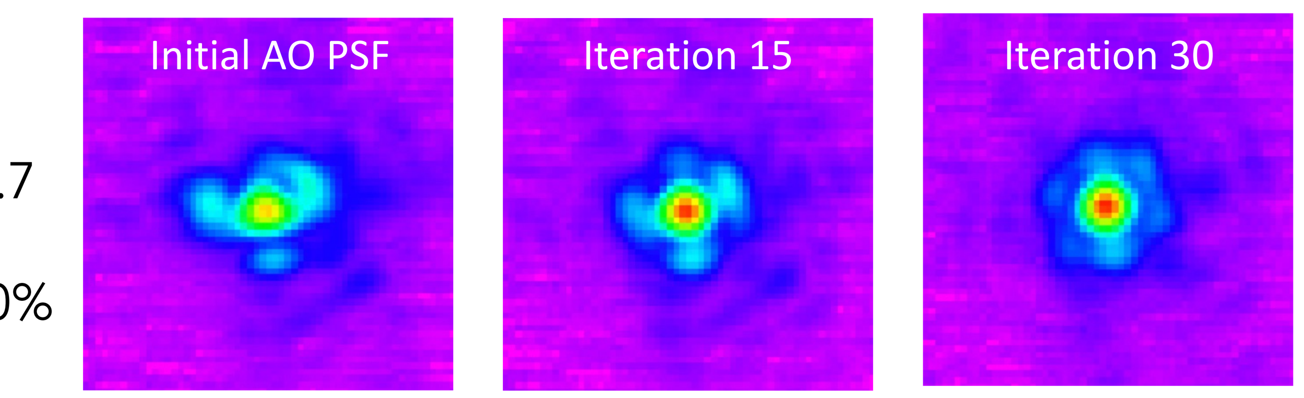
NGS Mode
40 UMa
Magnitude 6.4
Br-gamma filter
Strehl 34->52%



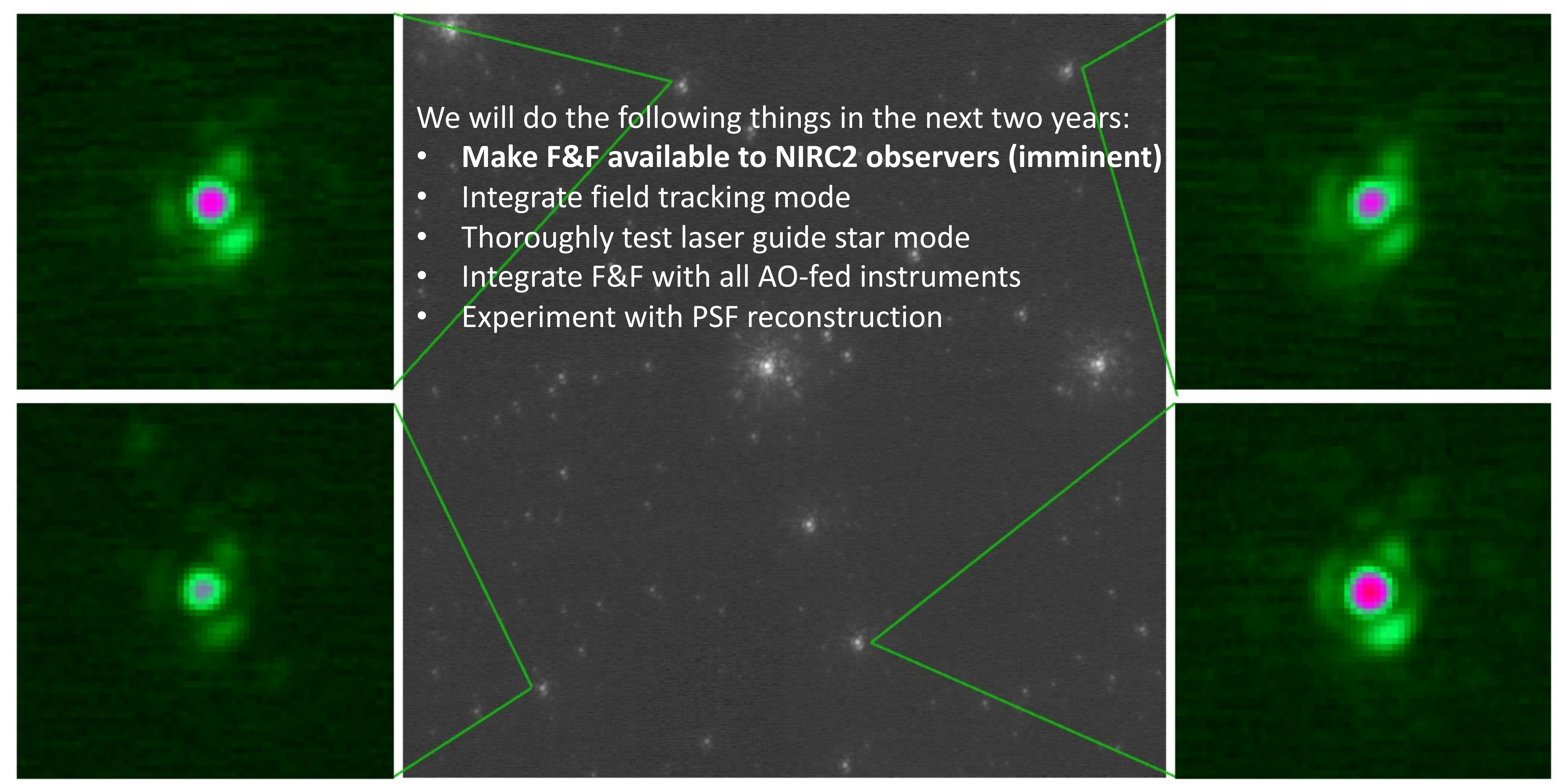
NGS/Binary
HD 176465
Magnitude 4
Kp filter
Strehl 14->36%



LGS Mode
HD99302
Magnitude 6.7
Kcont filter
Strehl 25->50%



Future work



We will do the following things in the next two years:

- **Make F&F available to NIRC2 observers (imminent)**
- Integrate field tracking mode
- Thoroughly test laser guide star mode
- Integrate F&F with all AO-fed instruments
- Experiment with PSF reconstruction

References

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