Plans for Unprecedented Imaging of Stellar Surfaces with the Navy Precision Optical Interferometer (NPOI)

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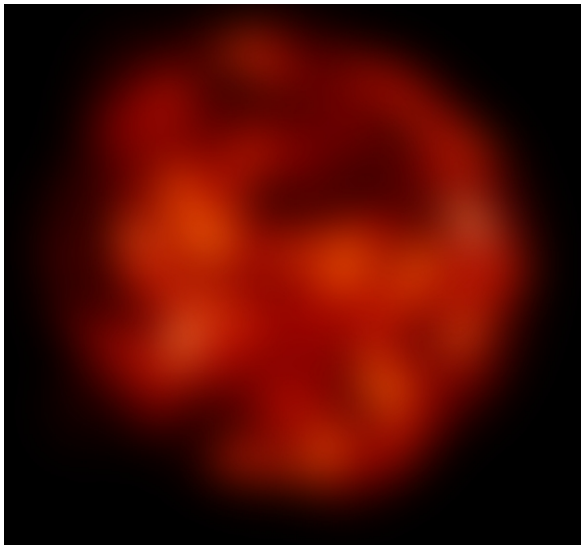
Outline

- Why image stars?
- How to image stars – the State of the Art
- Moving beyond the State of the Art
- NPOI imaging plans and status
- Conclusion

Why Image Stars?



Photometry can provide information about pulsations, but has limited SNR when it comes to non-radial pulsations. Spectral methods provide information about rotation and surface motion, but also has limited SNR as the detail sought is increased.

Surface structure

Non-radial pulsations

Spots

Rotation axis

Convection

Cluster behavior

Better models

Better understanding of the Sun?

Future of humanity

Public outreach

Journal covers

... and much more...

Science

Coolness!

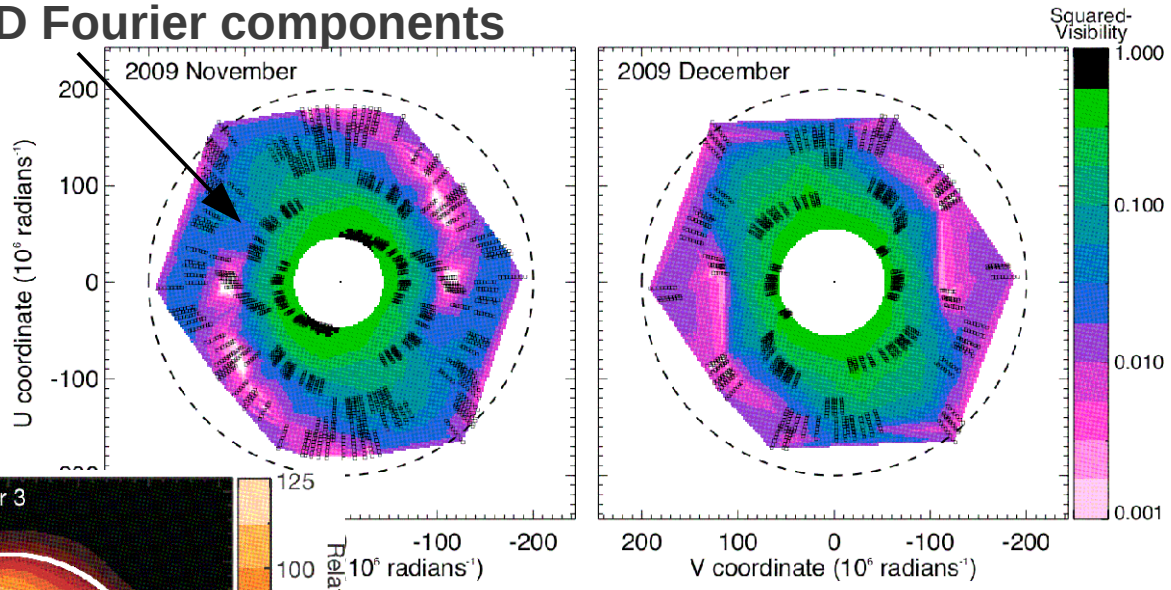
Broad Impacts

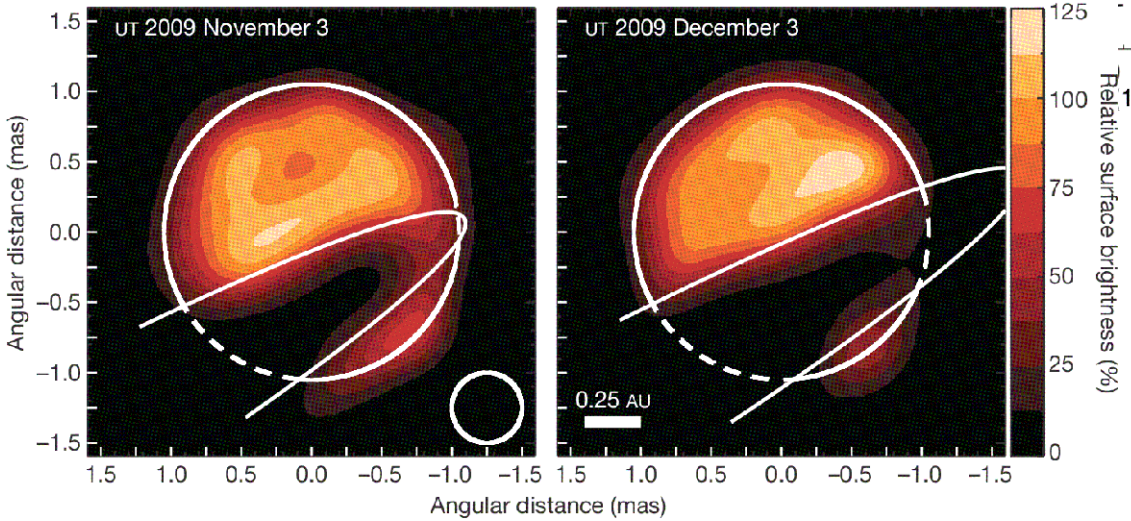
Imaging – Current State of the Art

- Measure Fourier components, one per telescope pair (baseline), and inverse FT to get the image – using some imaging software
- Example from CHARA:

(Kloppenborg, et al., 2010)

Excellent images showing cloud/disk passing in front of stellar disk.
Uses V^2 and closure phases





Sparse Fourier coverage.

Longest to shortest baseline length factor 3(?), determines resolution.

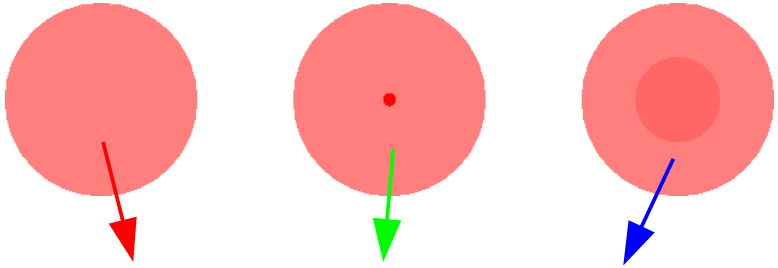
Other examples presented, mostly from CHARA/MIRC, exist.

Beyond the State of the Art: Fringe Tracking and Bootstrapping

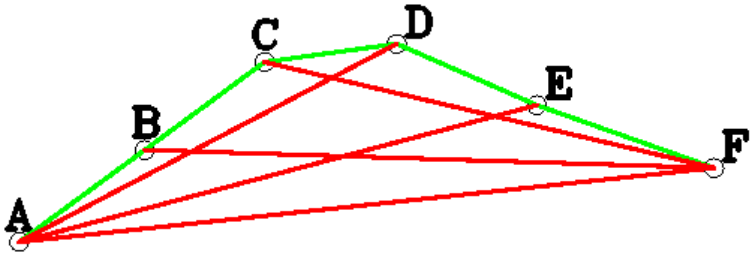
- Requires a great variety of short and long baselines to fill Fourier (visibility) plane

$$\delta\theta \sim \frac{\lambda}{B}$$

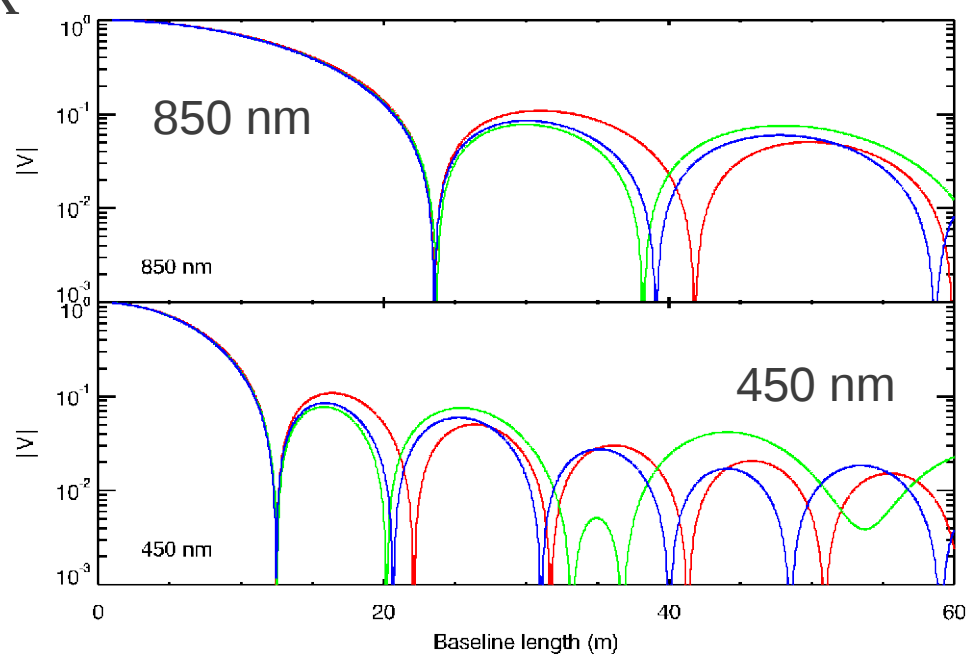
- Requires tracking fringes on the long baselines to get complex V (see next slide for why we need V)



- Because V is small we must track on short baselines and bootstrap



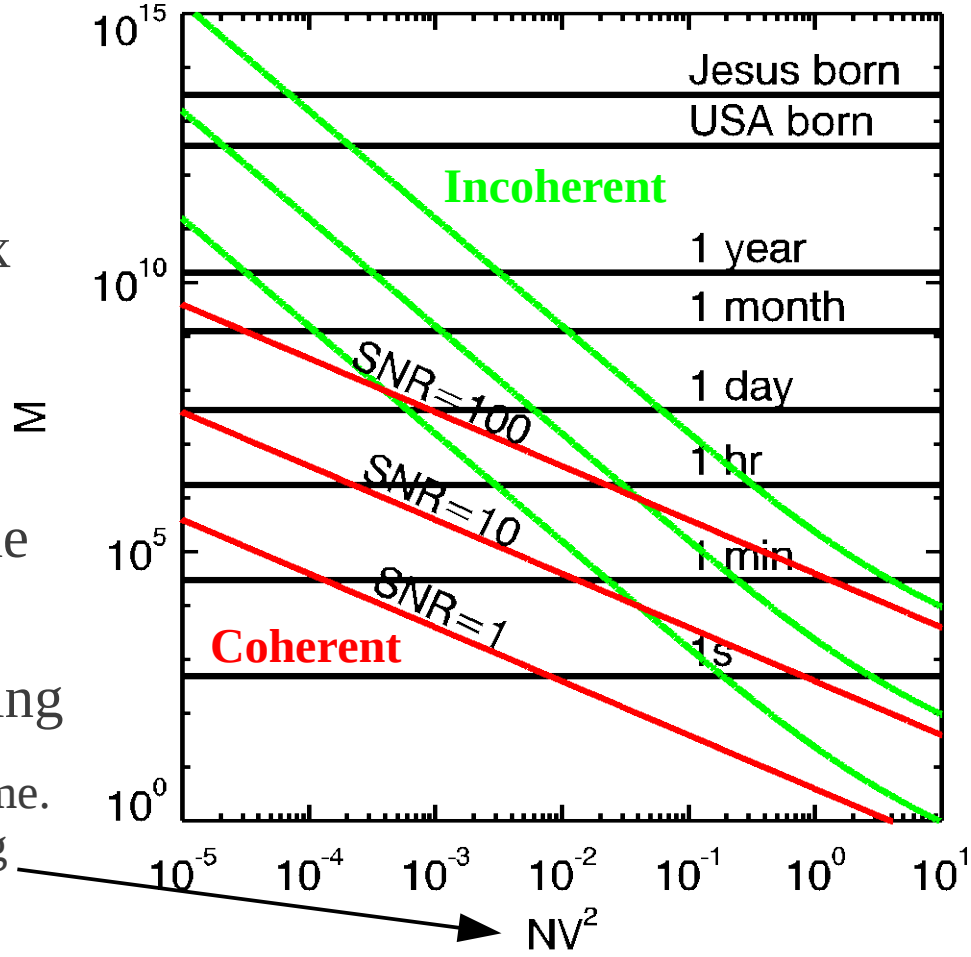
Short baselines barely resolve the star. The more short, the more resolution elements.



Beyond the State of the Art: Coherent Integration and Complex Visibilities

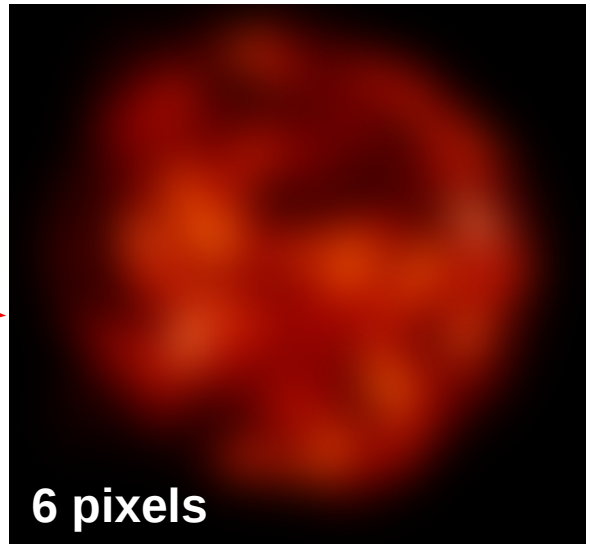
- Very small fringe contrast of long baselines requires new processing technique to get sufficient SNR. We call it coherent integration.
  - Traditional V^2 analysis fails for small fringe amplitude.
  - Coherent integration adds complex V with phase reference which can come from high-SNR baselines or other wavelength channels.
  - Can reduce required observing time by orders of magnitude
  - Essential for high-resolution imaging

NV^2 is SNR per atmospheric coherence time. Can be very small when imaging with long baselines



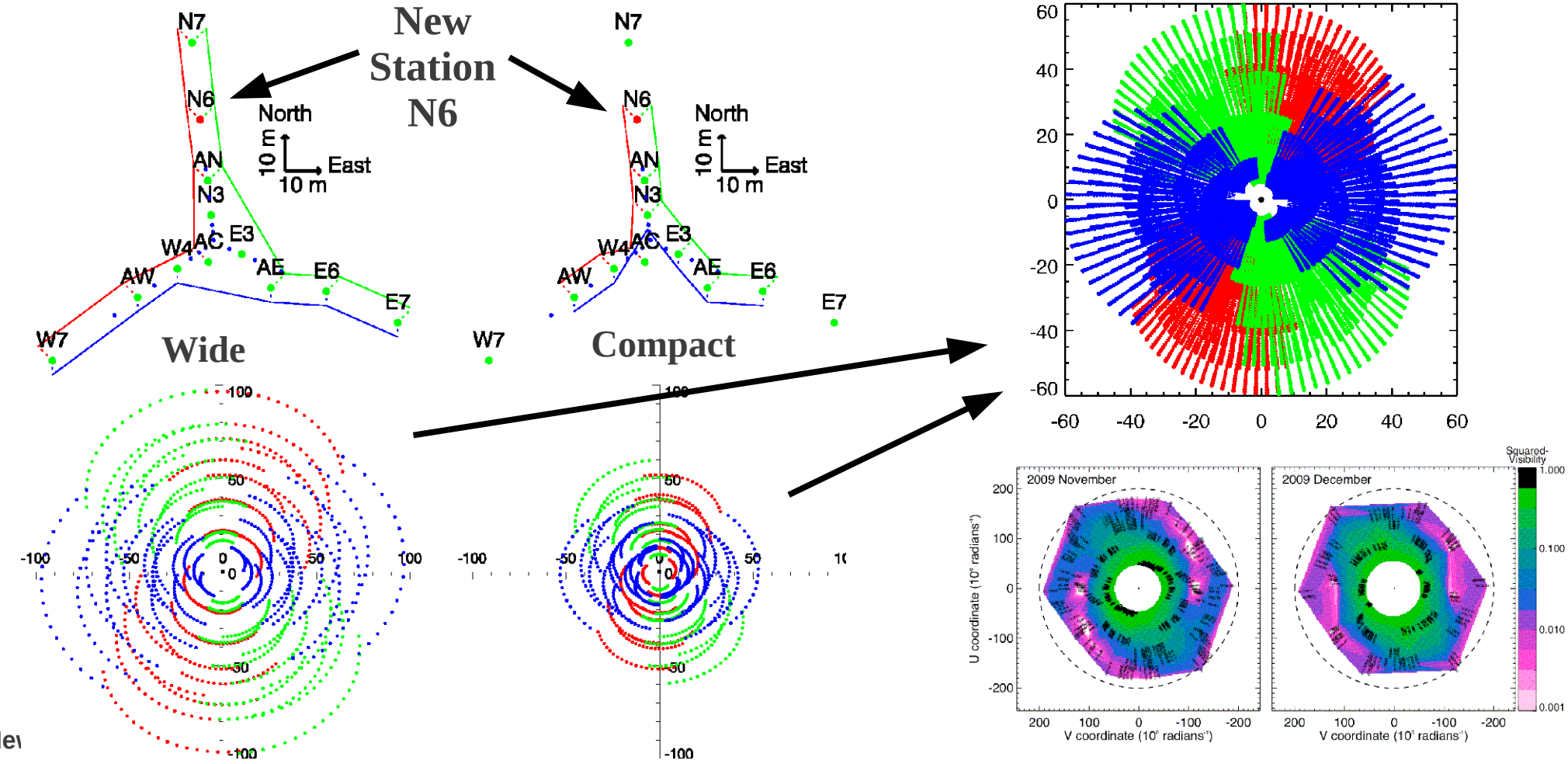
Imaging Plans for the NPOI

- NPOI is the only interferometer that can do 6-station baselines.
- 6 stations → 6 (or more) pixels across images.
- New Classic and VISION can be used
- Coherent integration: better SNR, shorter integration time.
- AIPS imaging
- Funded by NSF September 2013 (P.I. Jorgensen)



NPOI Imaging Array Layout

Green stations are installed or in the process of being installed. Only one additional station, N6, required. Fill Fourier plane in 6 hours on each of 3 consecutive nights, multiple targets. No moving telescopes required, one move (E7-E3) to switch between wide and compact array (no move if there were 7 imaging telescopes).



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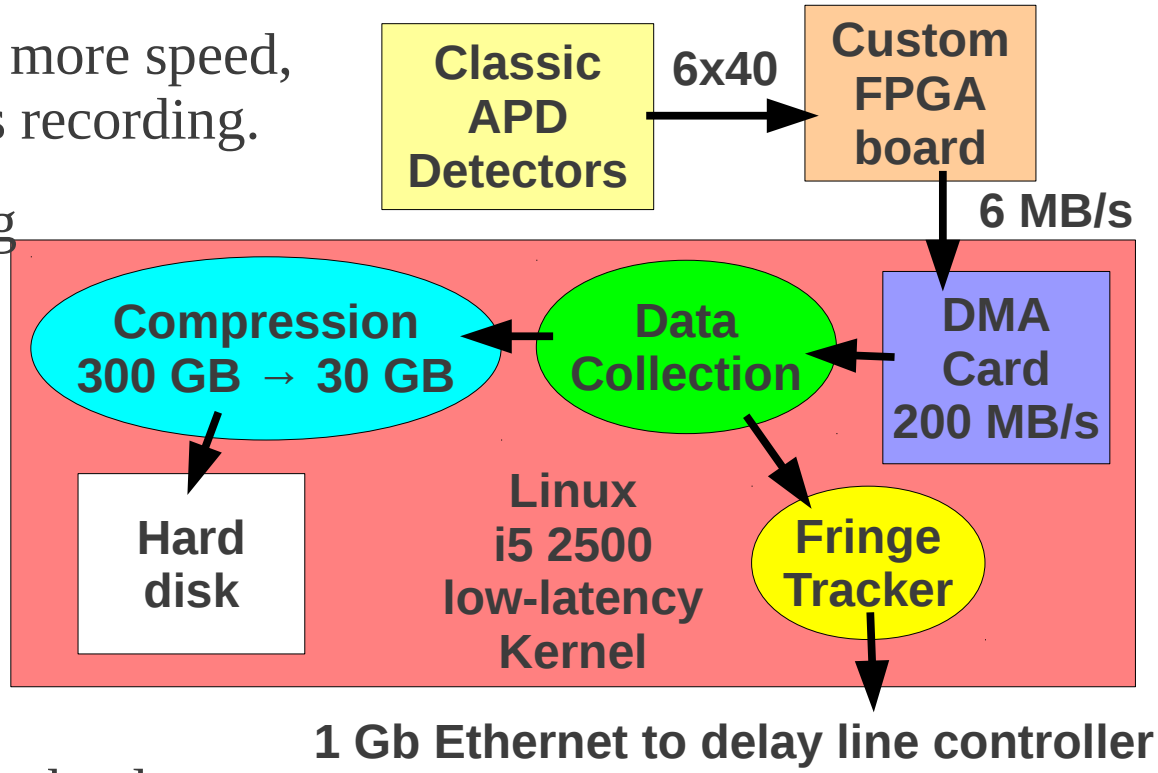
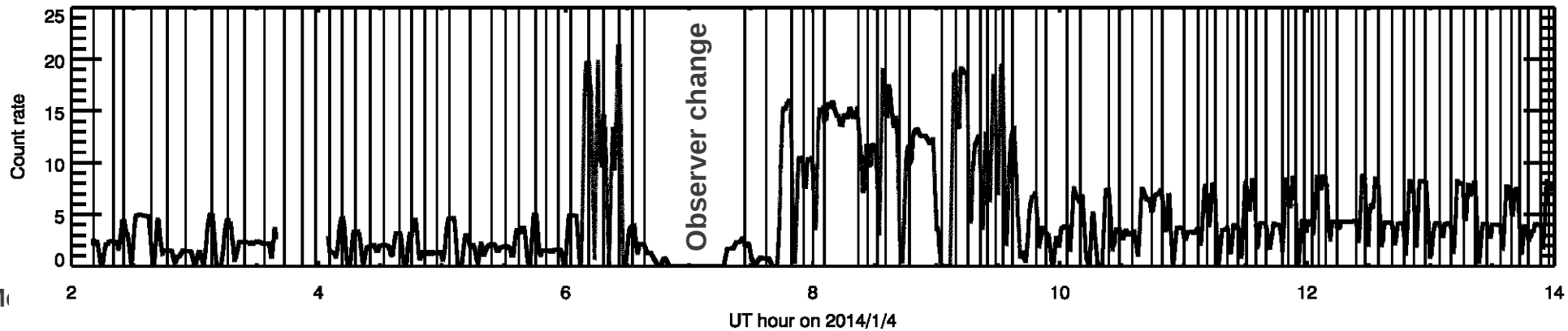
New Classic Data Acquisition and Fringe-Tracking

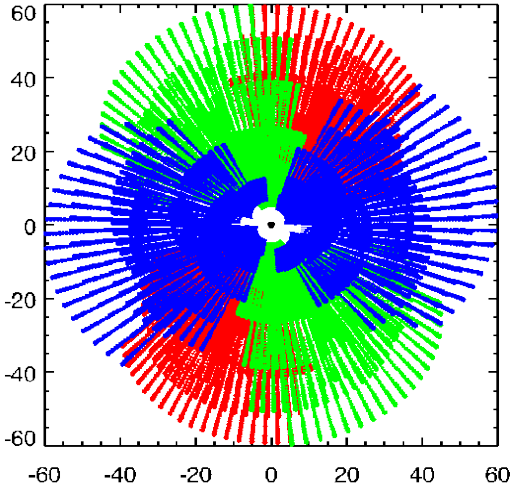
- FPGA-based data acq system: more speed, more wavelengths, continuous recording.
- Smart 6-station fringe-tracking
- Better fringe-search, tracking, longer integrations.
- January 4-5, 2014 run testing continuous data acquisition. Fringe-tracking is next.
- 40000 s of data vs. 5000 s. 96 channels vs. 32. 10+x times the data.

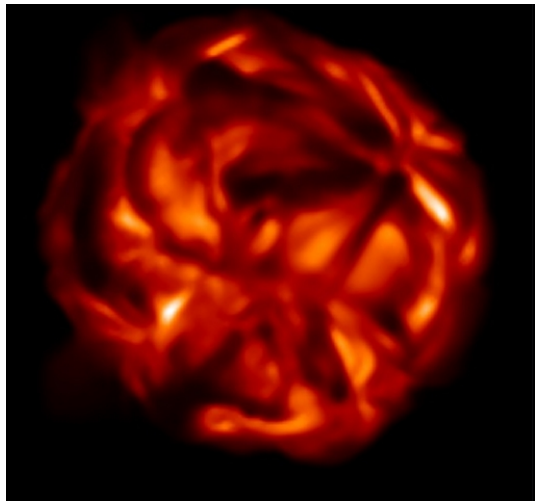


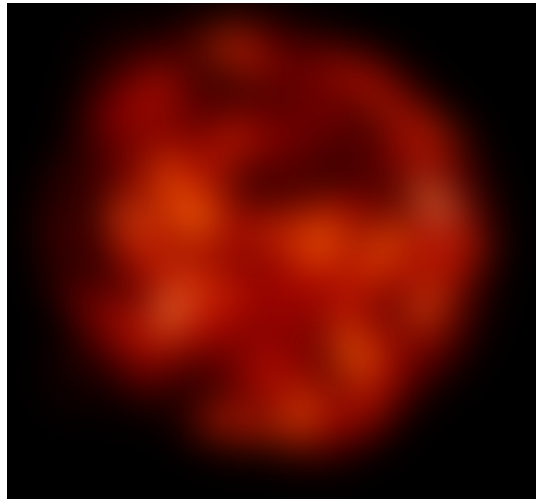


Conclusion

- Completing NPOI to fulfill imaging array promise is under way
- NSF project funds one additional station to create three 6-station chains
- Data acquisition system upgrade in progress
- 6-station fringe-tracking and bootstrapping coming next
- Imaging with coherent integration and AIPS
- Expecting unprecedented images







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