The Precision Astronomical Visible Observations (PAVO) instrument for CHARA

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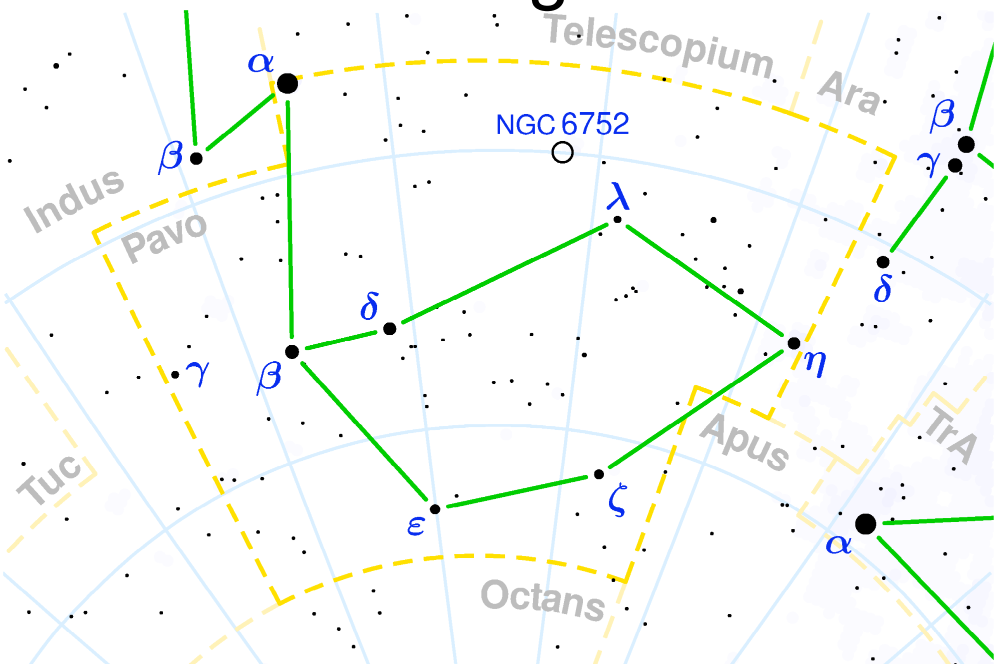
Outline

- What is PAVO?
- Why is it operationally different to VEGA?
- What is the timeframe and proposed details of the SUSI/CHARA collaboration?
- What are the science goals?



What is PAVO?

- PAVO is an integral-field-unit for measuring spatially-modulated pupil-plane fringes.
- PAVO will (pending funding) be prototyped at SUSI and then brought to CHARA during 2009.

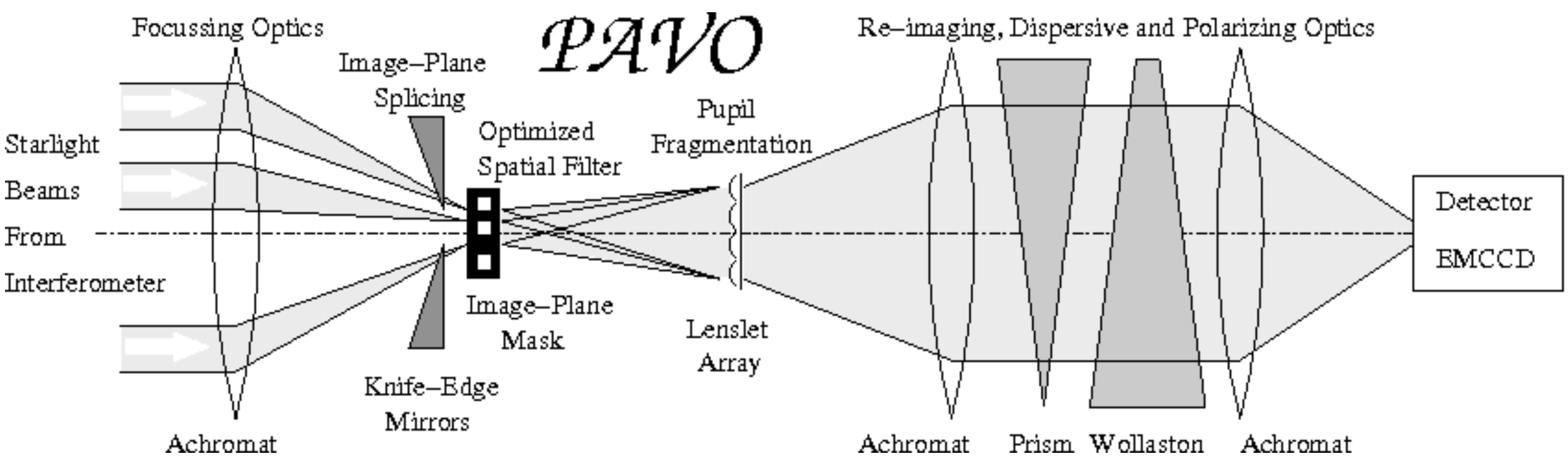
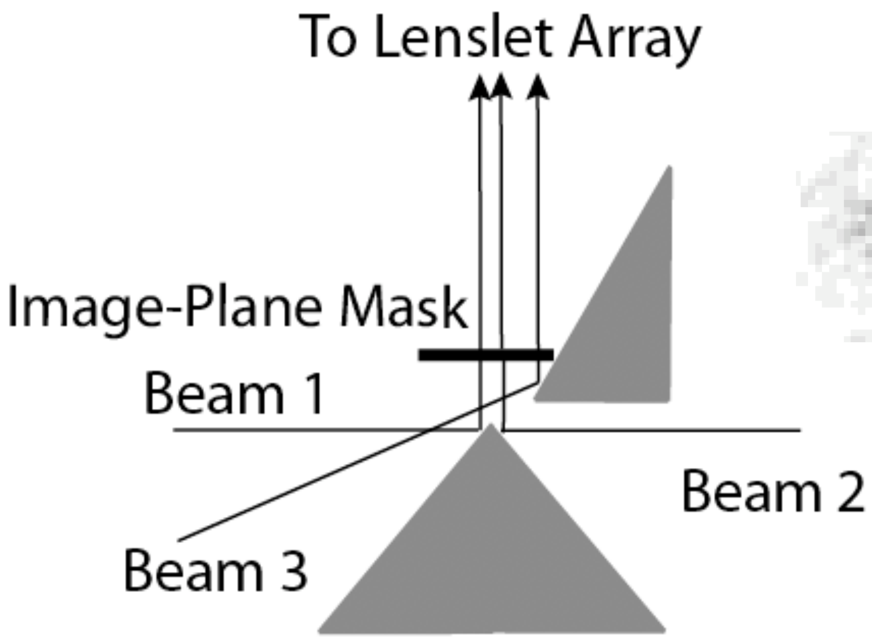
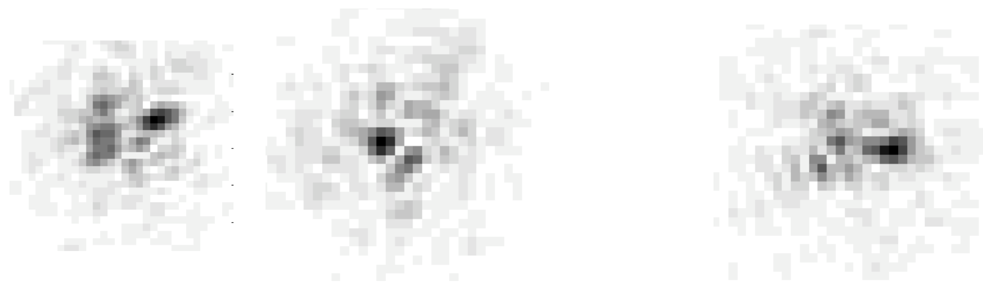


Image-Plane Splicing

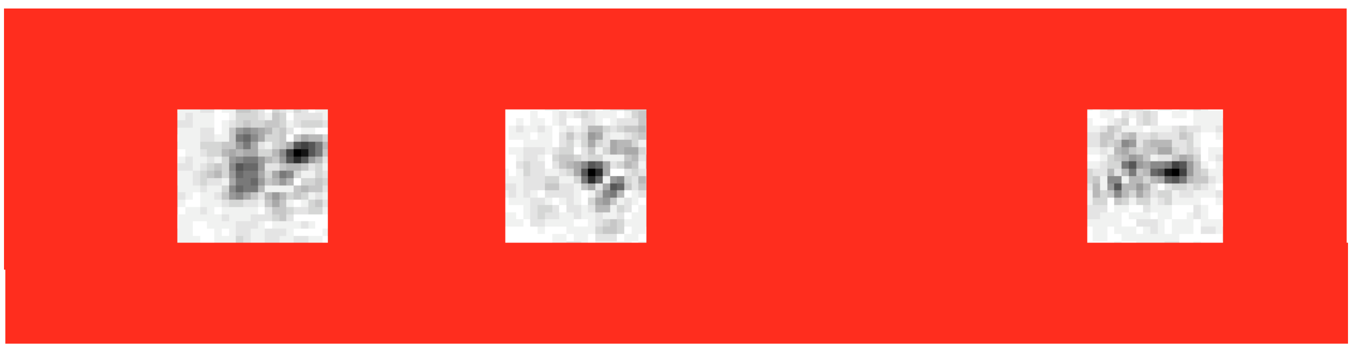
• Catalog knife-edge and prism mirrors brings f/100 beams together.





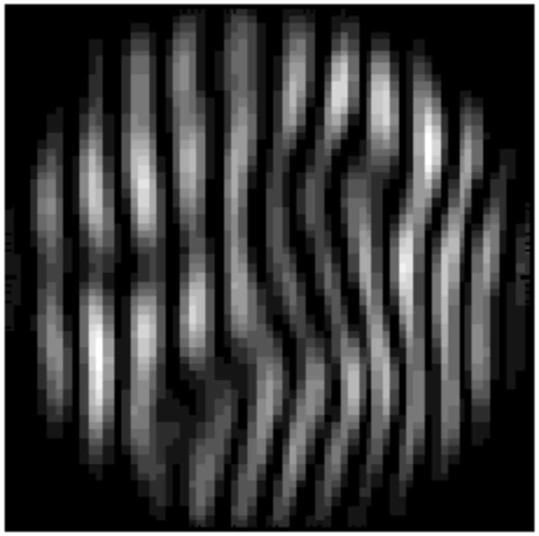
Spatial-filtering

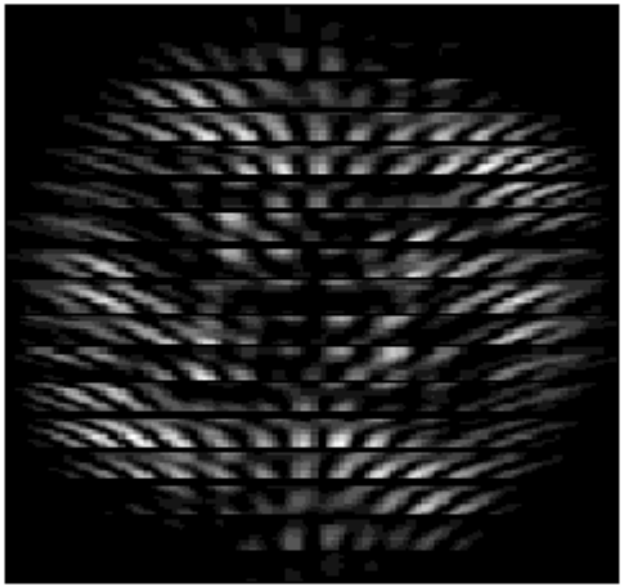
- The image-plane spatial filter is a pinhole spatial-filter, that allows >50% of the starlight through in average seeing.



Pupil-plane Fringes

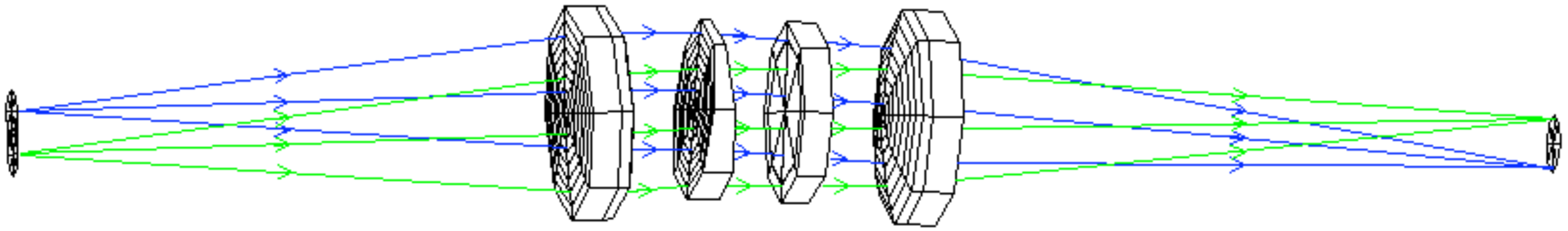
- Spatially-modulated fringes are formed in the pupil-plane.
- Seeing and aberrations will prevent fringes from being straight.
- The effect of the spatial-filter is to cause non-uniform intensity.





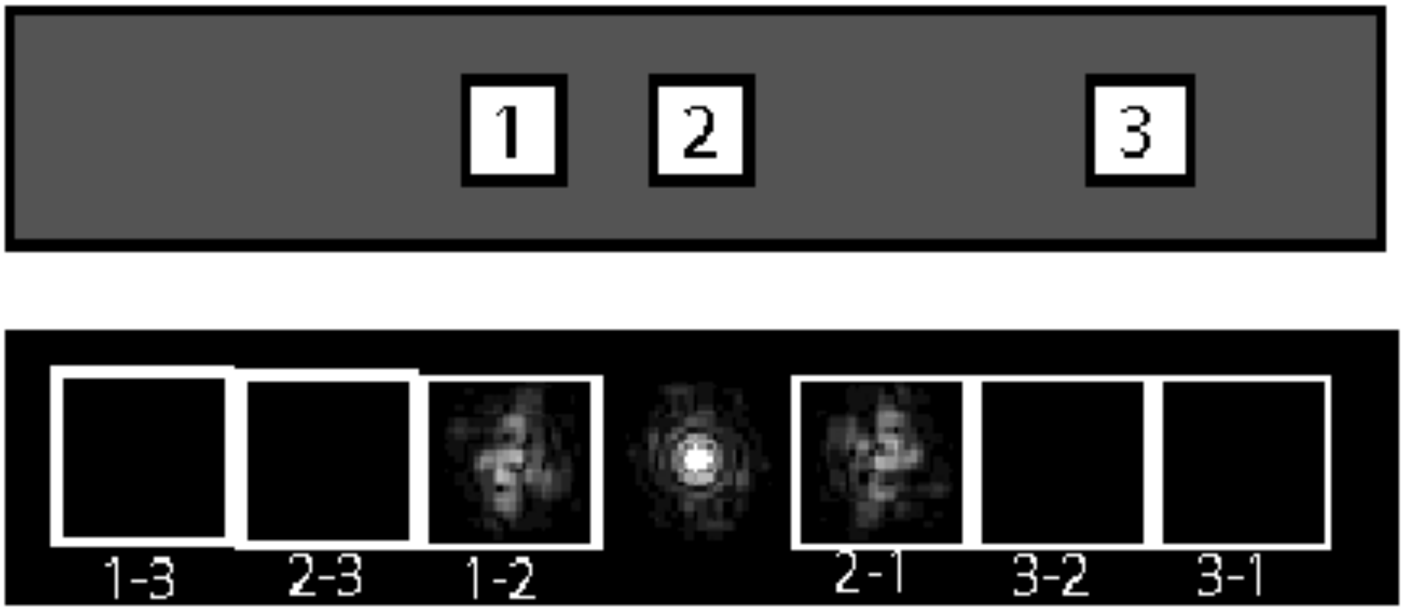
Integral-Field Unit

- Cylindrical lenslet array (catalog item), prism, re-imaging achromats.
- Dispersion curve of BK7 ensures near-constant coherence lengths over the 620-900 nm bandwidth. 14 wavelength channels in baseline design.



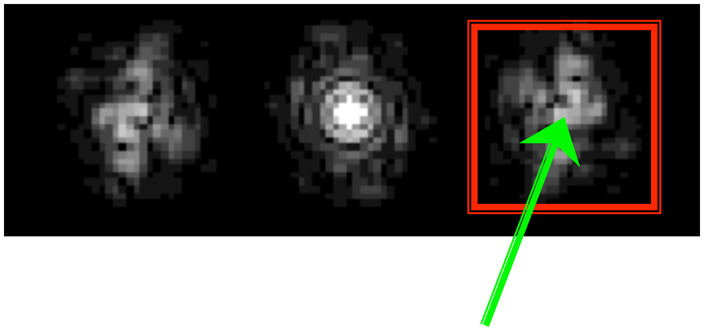
Data-analysis Magic

- The lenslet separation is such that ALL of the pupil-plane fringe power is sensed. This is as good as single-mode fibers (but without photometric channels: needs MIRC-like chopping).



Post-Detection Aberration Removal

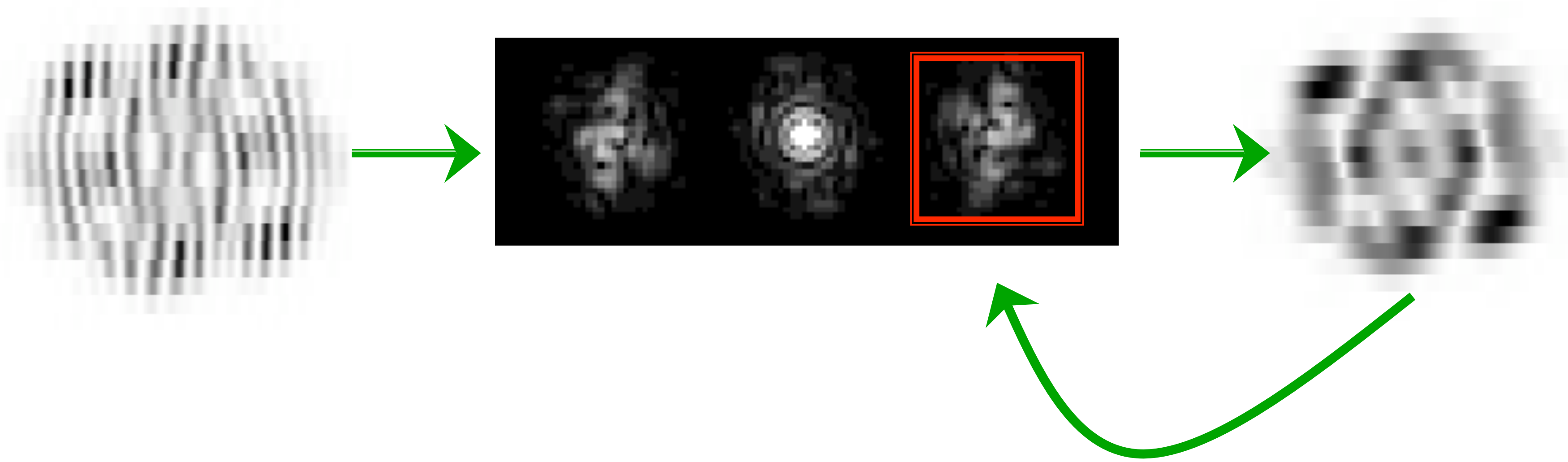
- Although spatial-filtering only works completely if fringe power is integrated over the full Fourier-plane square, S/N is maximized if a weighting function is used (both for detecting fringe-power and the group-delay algorithm).
- So… we want to 'peak-up' the fringe Fourier-transform



Weight to the center point.

Post-Detection Aberration Removal

- Aberrations, including static aberrations (e.g. measured on a bright star) and un-corrected tip/tilts by:
  1. Window and Inverse-transform (2D equivalent of the phase of Bracewell's analytic signal).
  2. Phase-shift the complex pupil-visibility.
  3. Forward-transform.



Group-Delay Tracking

- Group-delay estimate has been simulated in detail.
- Fringe-tracking limit occurs at ~70 photons per 10 ms exposure over a 0.6-0.9 micron bandwidth.
- At 1% Photon-detection probability (3% throughput to the spatial-filter), this is R=~10.
- For an A0 star, this is equivalent to 23 H-band photons (less if H-band is spatially-filtered).
- So: arguably there is a regime for blue stars where CHAMP can not fringe-track, but PAVO can group-delay track.

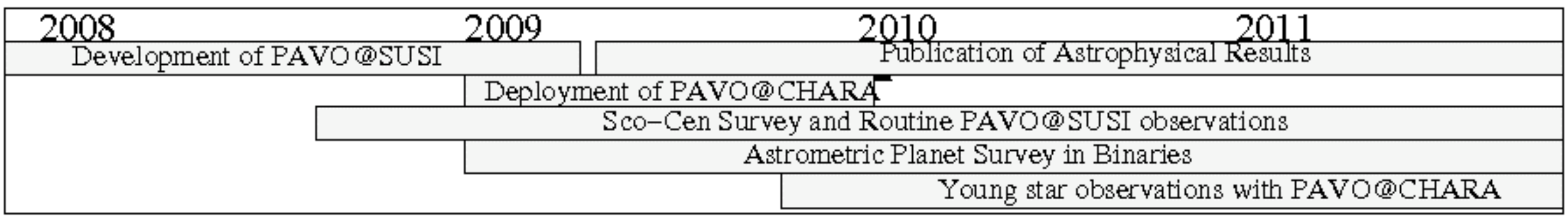
Why PAVO *and* VEGA?

- PAVO will be at least 2 mag (~6 times) more sensitive than Vega.
- This means that 250 times more solar-type stars, and 40 times more hot stars, can be observed (at the same S/N in the same integration time).
- But: spectral resolution is important for a wide variety of science cases, so PAVO does *not* ever replace VEGA.

Instrumental Parameter	Difference	Sensitivity
Quantum Efficiency	2x	2x
Bandwidth	2x	1.4x
Spatial filter/slit throughput	5x	2.2x

PAVO Timeline

- 2-beam system and software developed during 2008. Deployment to CHARA during 2009
- Announcement of ARC funding ~November…

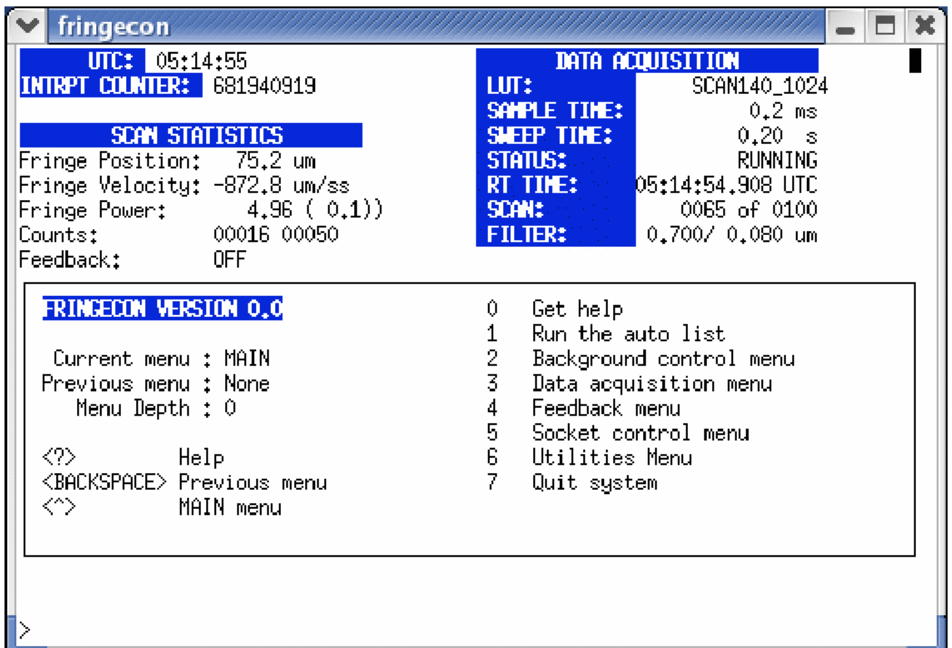


How will PAVO fit?

- PAVO *will* replace (i.e. is an upgrade to) the existing CHARA visible combiner.
- Precise optical layout not done: at least 1.5m (folded) optical path before the lenslet array, 0.3m between lenslet array and detector. i.e. relatively compact and easy to fit-in.

Software Integration…?

- SUSI already uses the same 3-layer software setup as CHARA (RT-Linux drivers, servers and GUIs).
- In collaboration with Theo, we will aim to bring the SUSI and CHARA software suites even more in-line, to aid in seamless integration of PAVO.



Science Goals

- There are *plenty* of stellar science area that one could list at an R=~10 limit (e.g. pulsating stars, outflows, binary orbits for precise masses and distances to key clusters…). The (small) group from USyd will barely be able to touch on these…
- The science theme for the proposal was "Multiplicity in Star and Planet Formation". Two key CHARA observations are:
  1. Imaging the inner-most regions of YSO disks.
  2. A multiplicity survey of Northern young OB associations (Cygnus, Orion…)

Summary

- PAVO is a R and I band beam-combiner for CHARA optimized for sensitivity.
- PAVO disperses spatially-modulated pupil-plane fringes at ~R=40, and splits in polarization.
- PAVO has a multi-mode spatial-filtering scheme that can in principle calibrate as well as using single-mode fibers.
- Pending funding, PAVO will be commissioned at CHARA during 2009 and will enable a 2-way software development flow between the SUSI and CHARA groups.