PAVO Analysis and SUSI Update

Mike Ireland, Australian National University, and the loose PAVO collaboration (Vicente Maestro, Peter Tuthill, Gail Schaefer, Aaron Rizzuto, Dan Huber)

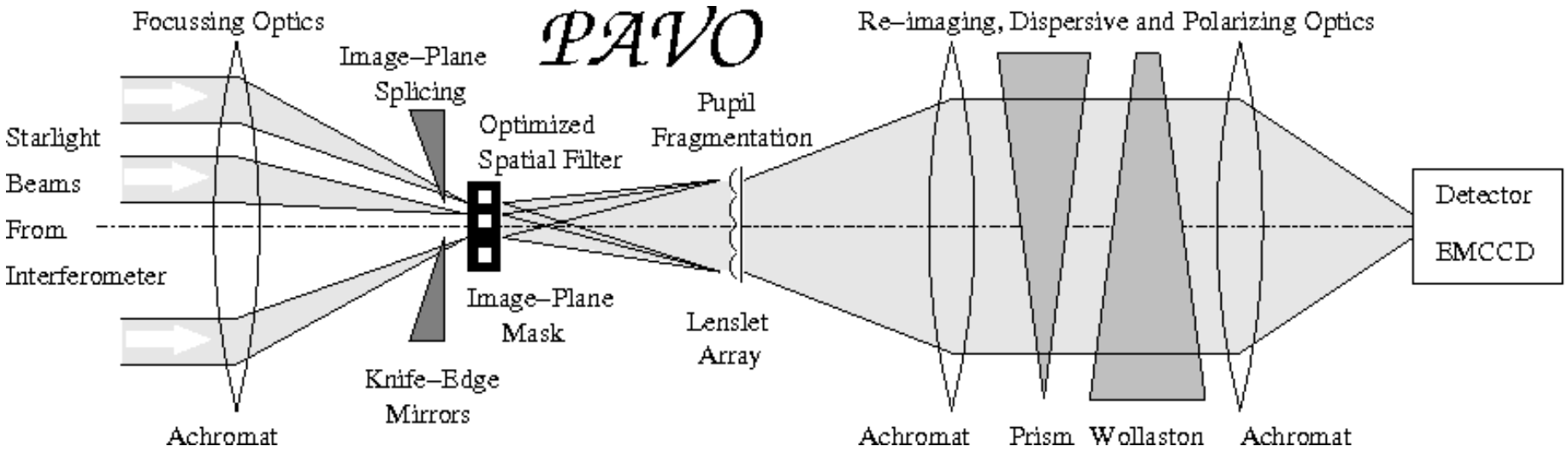
Outline

- Very quick PAVO introduction.
- Rapid rotators and PAVO.
- Unresolved issues:
  - The “Wiggles” mostly from pre-2011 data.
  - Data with choppers.
  - Low-V^2 work (IR tracking).
  - Closure-phase from faint stars.

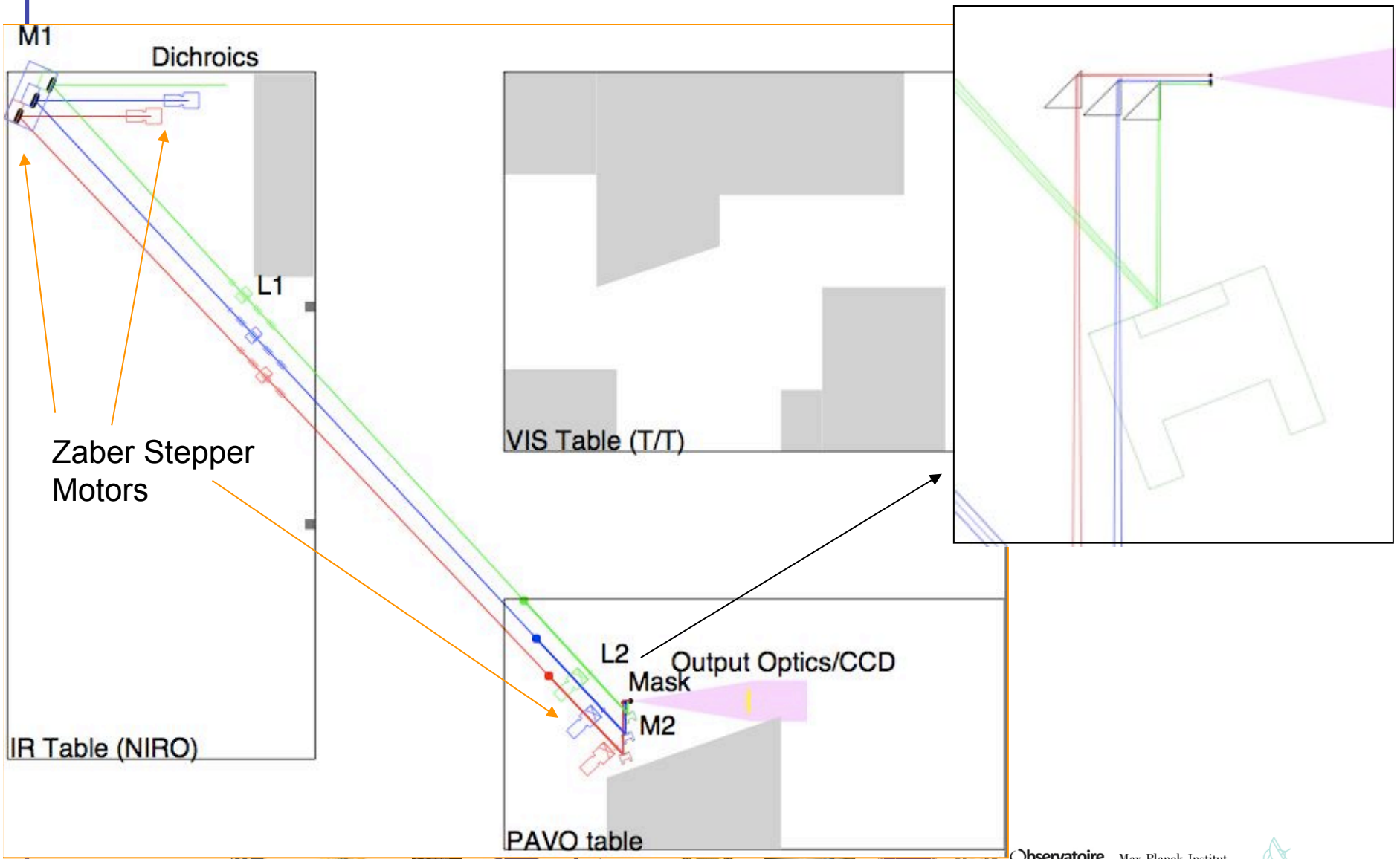
PAVO Optical Concept

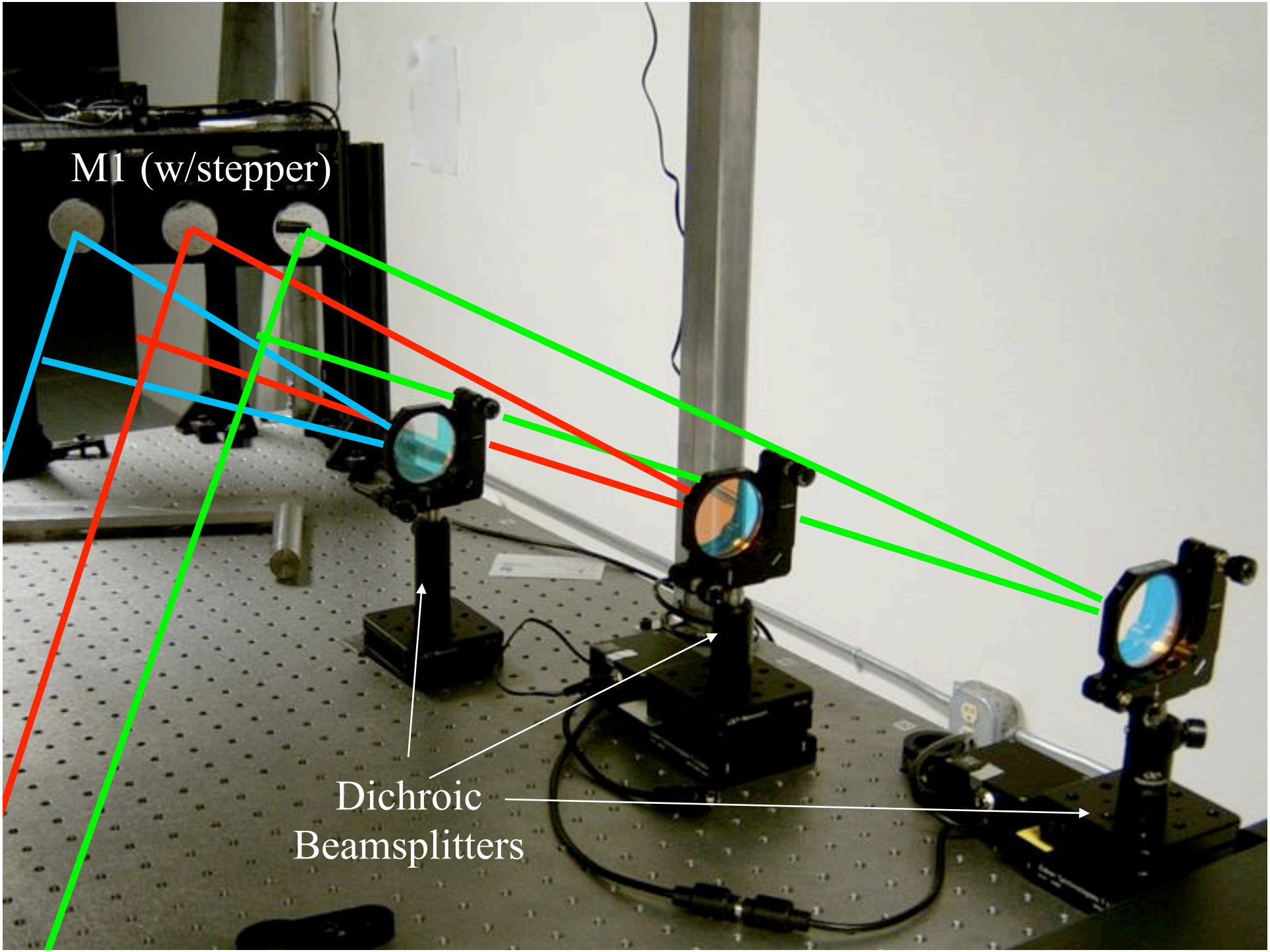
Quick Intro:

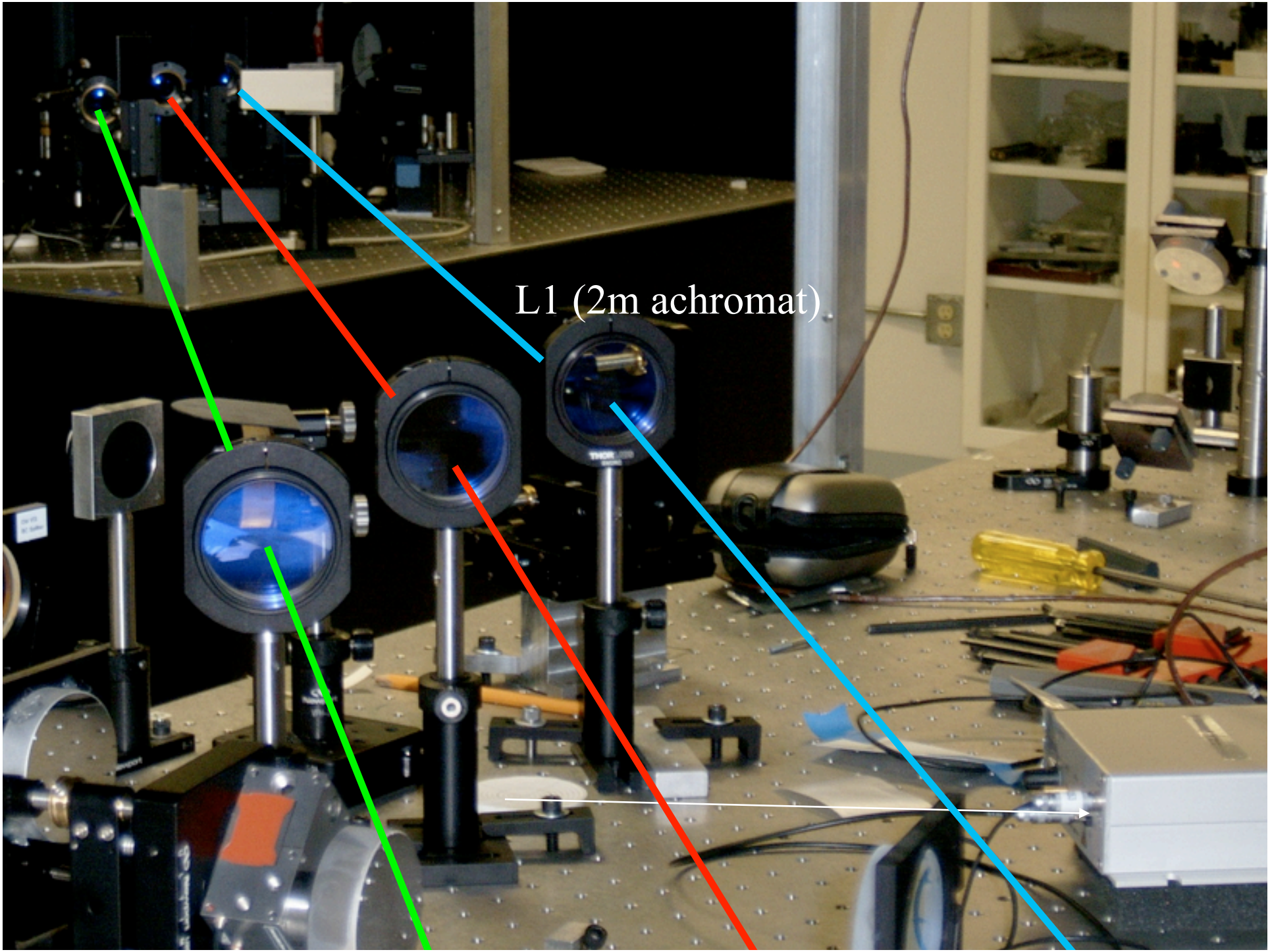
1) The PAVO beam-combiner places 2 (SUSI) or 3 (CHARA) star images beside each other.
2) The images pass through a mask, which acts as a spatial filter
3) Fringes are formed in a pupil-plane
4) An IFU turns these fringes into a data cube, with an image of the fringes at every wavelength (R~50, 620-950nm)
5) Correlated magnitude limit R~7 (most seeing conditions) or R~8.5 (best conditions). Practical bright limit R~4 for long baselines.

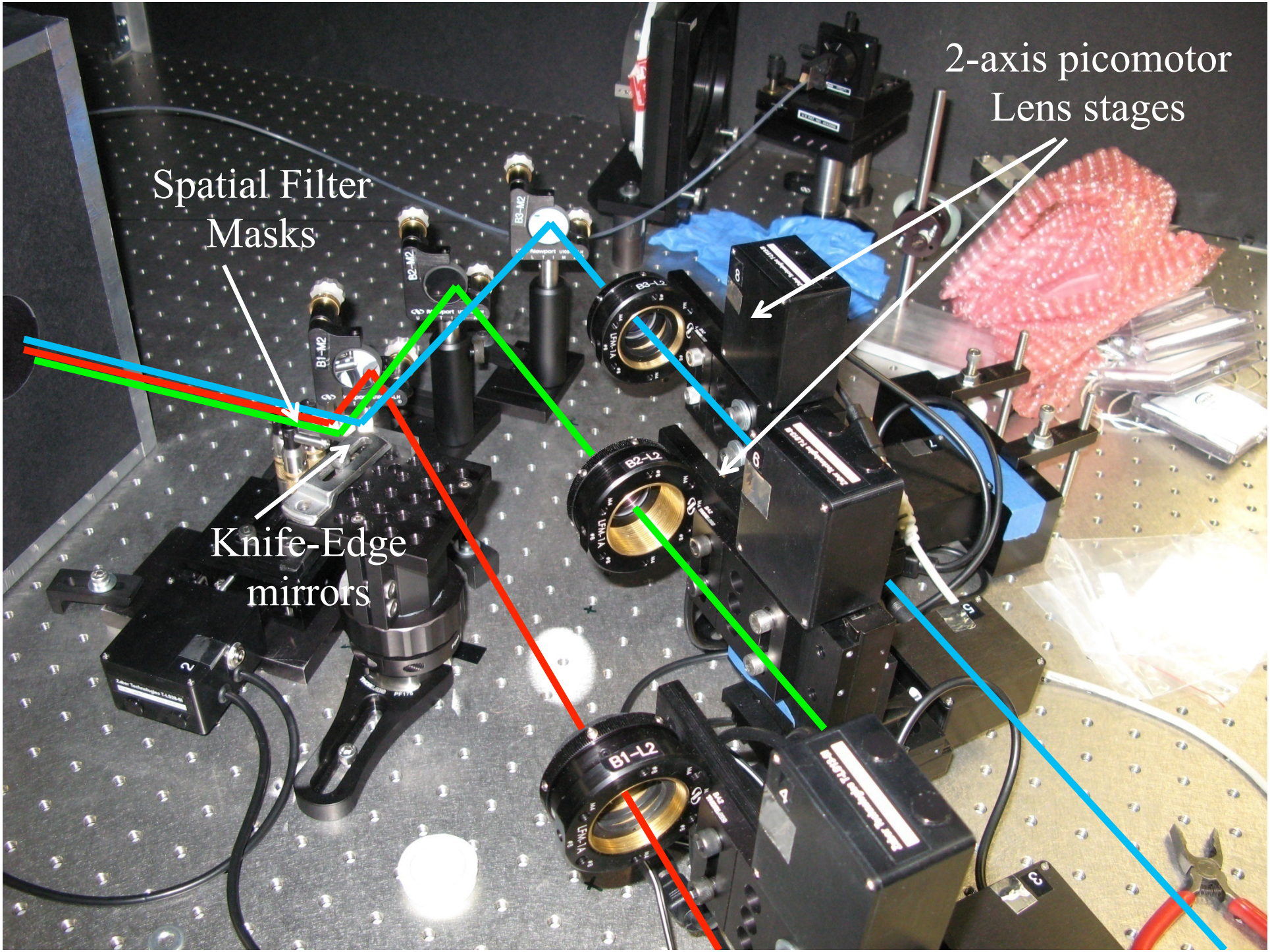


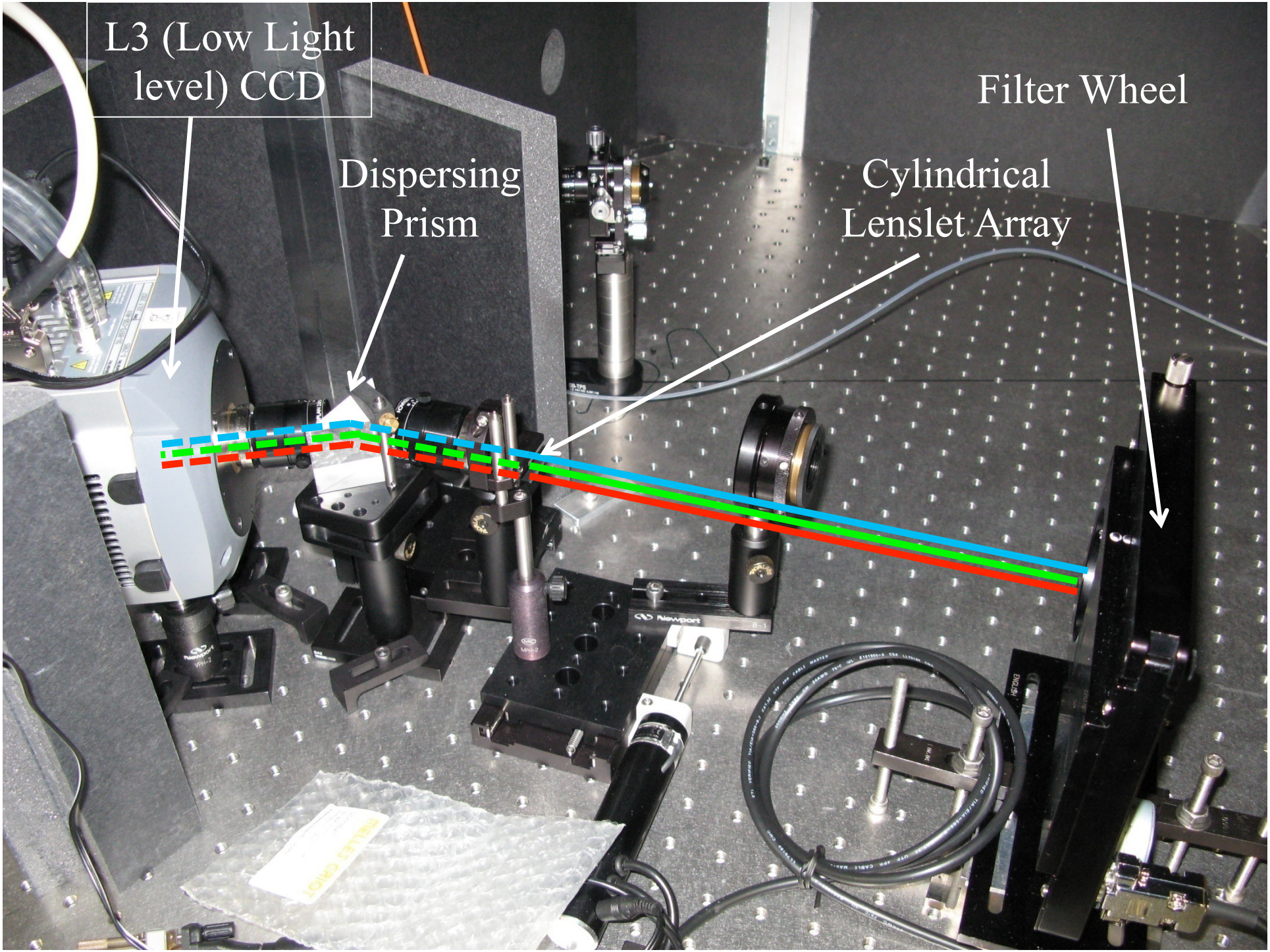
Optics at CHARA




M1 (w/stepper)
Dichroic
Beamsplitters


L1 (2m achromat)


2-axis picomotor
Lens stages
Spatial Filter
Masks
Knife-Edge
mirrors
B1-L2
B2-L2


L3 (Low Light level) CCD
Dispersing Prism
Cylindrical Lenslet Array
Filter Wheel

Technical Team Status

- I had an "astrophotonics" joint AAO/Macquarie Uni position Feb 2011 to Jan 2014. Kind of difficult to spend much time on CHARA since 2012.
- The USyd team over this period lacked someone really willing to e.g. write a new pipeline or significantly change the existing one, so there are a few remaining issues.
- In my new fellowship at ANU, there is more flexibility for me, but the key for me will be to focus on young stars (needs AO) and continue collaborations (plus new ones!).

Recent Science Highlights

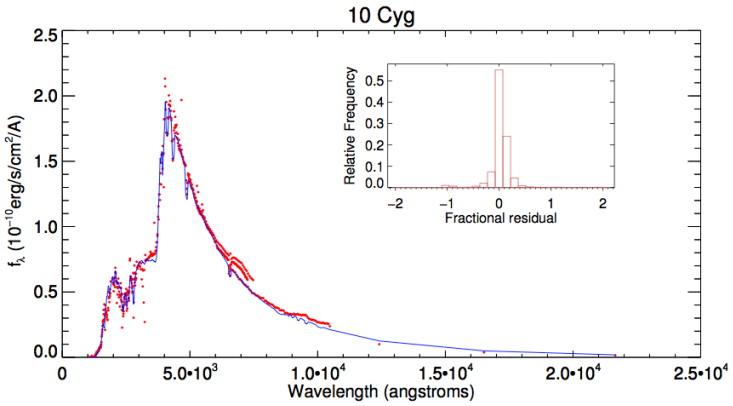
Huber et al 2012, ApJ, *Fundamental Properties of Stars Using Asteroseismology from Kepler and CoRoT and Interferometry from the CHARA Array* (44 cites)

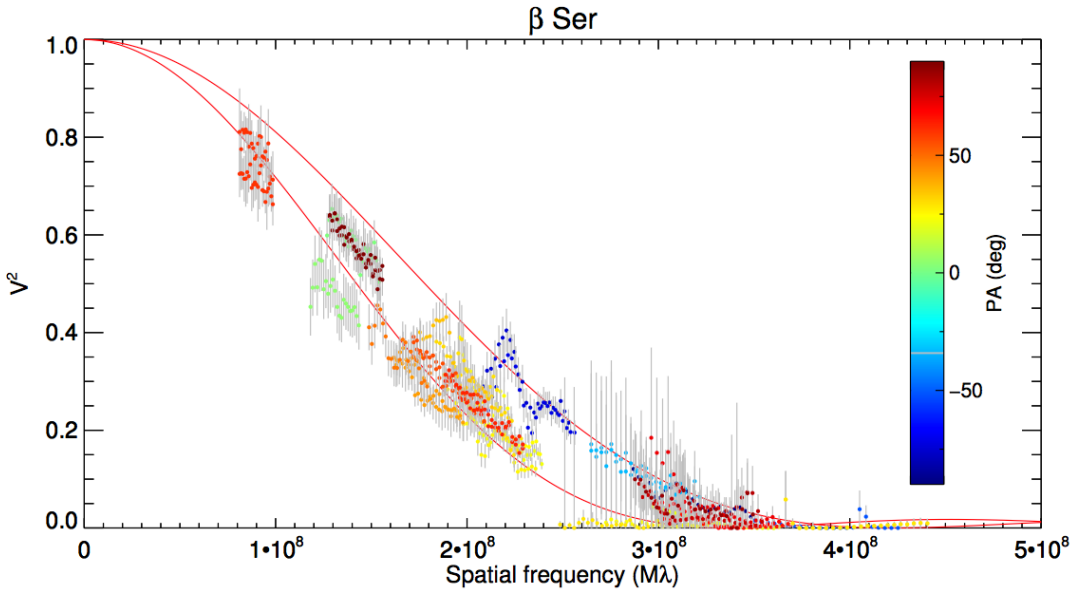
White et al 2013, MNRAS, *Interferometric radii of bright Kepler stars with the CHARA Array: θ Cygni and 16 Cygni A and B*

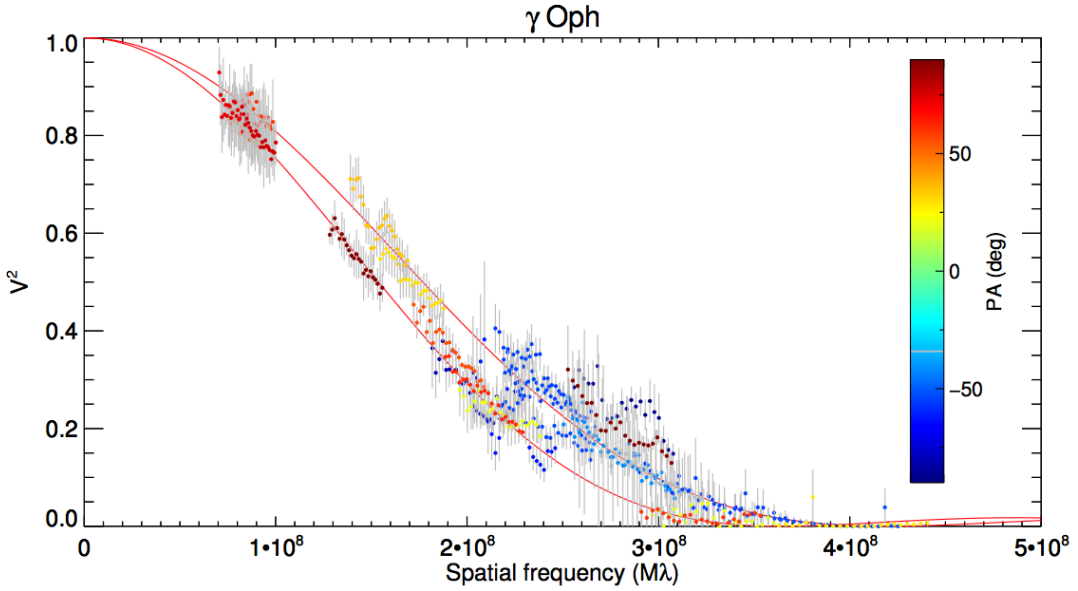
Maestro et al 2013, ApJ, *Optical interferometry of early-type stars with PAVO@CHARA - I. Fundamental stellar properties*

Science results soon to be this year – Maestro et al.

Vicente has spent most his time recently developing the "FRESCO" code, which uses 2D stellar models ESTER + ATLAS surfaces.

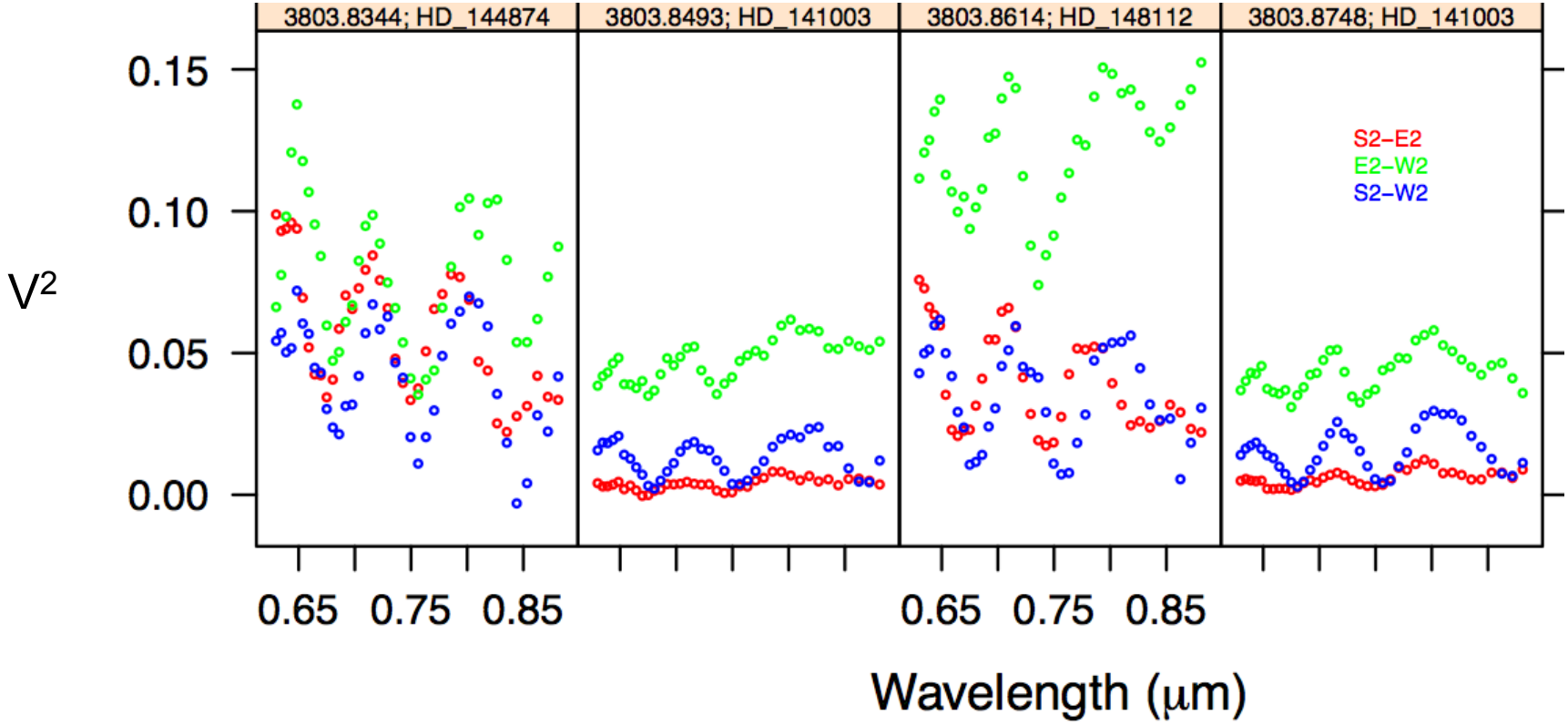






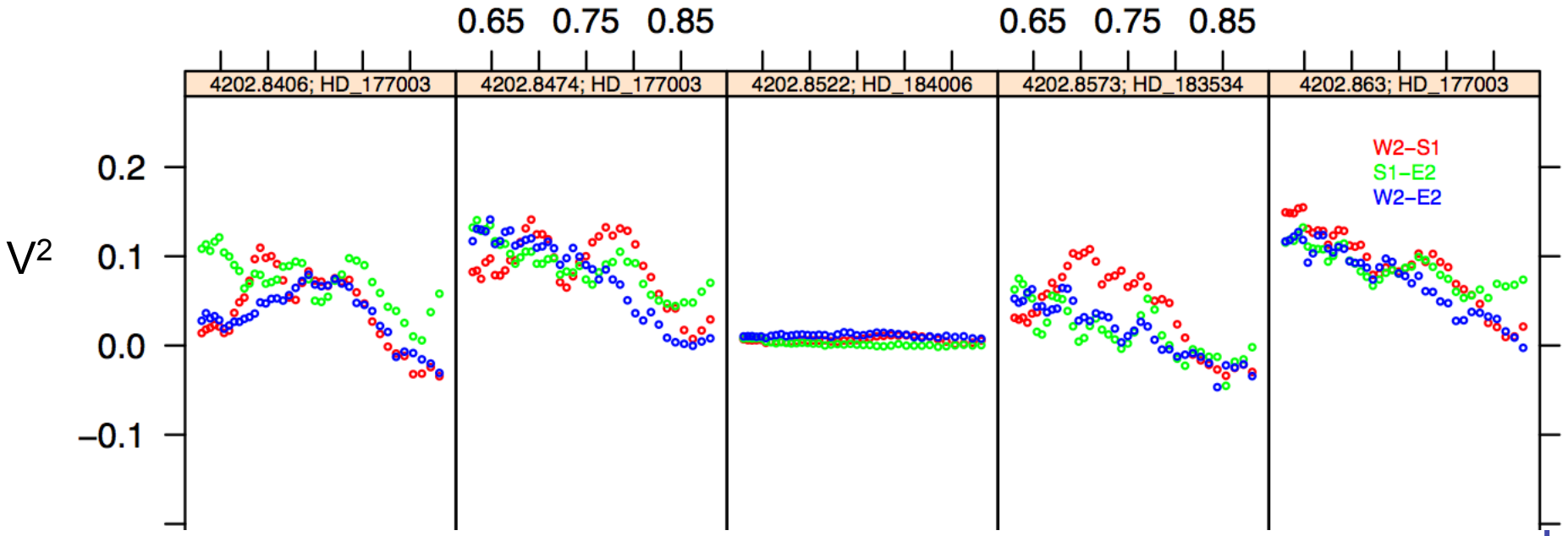
The "Wiggles" 2010

(Only happened when telescopes from different arms were used. Also note low V^2 values)



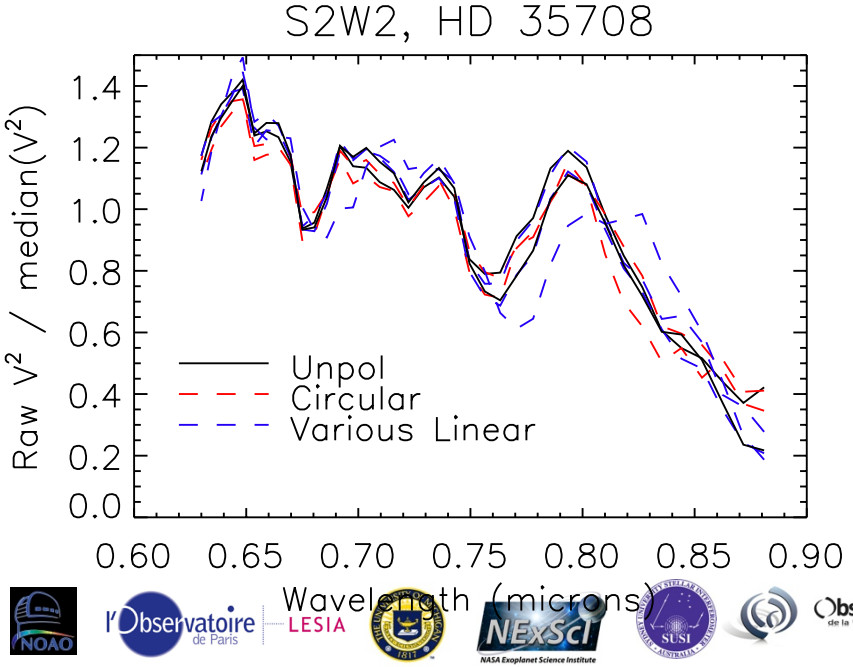
The "Wiggles" 2011

(still mystery low V^2 values)



Polarization Tests for "Wiggles"

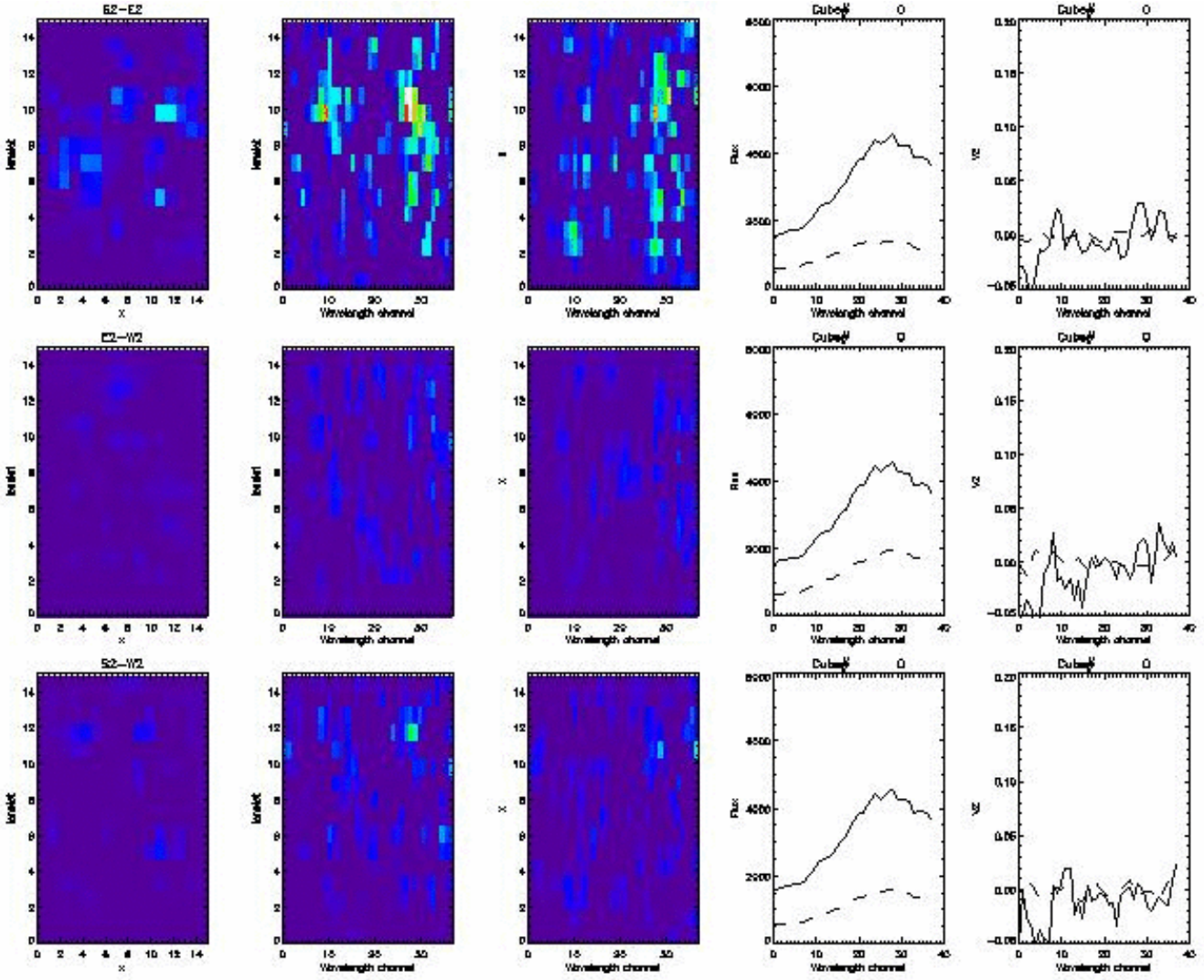
- Although much improved (by symmetrical coatings?) in 2011 onwards vs before 2010, the partially calibratable "wiggles" in PAVO data remain.
- Early 2011 tests (accidentally) only measured circular polarization. Now all have been measured.
- Only a small polarization-dependent effect is seen.



Wiggles are Pupil-Position Dependent

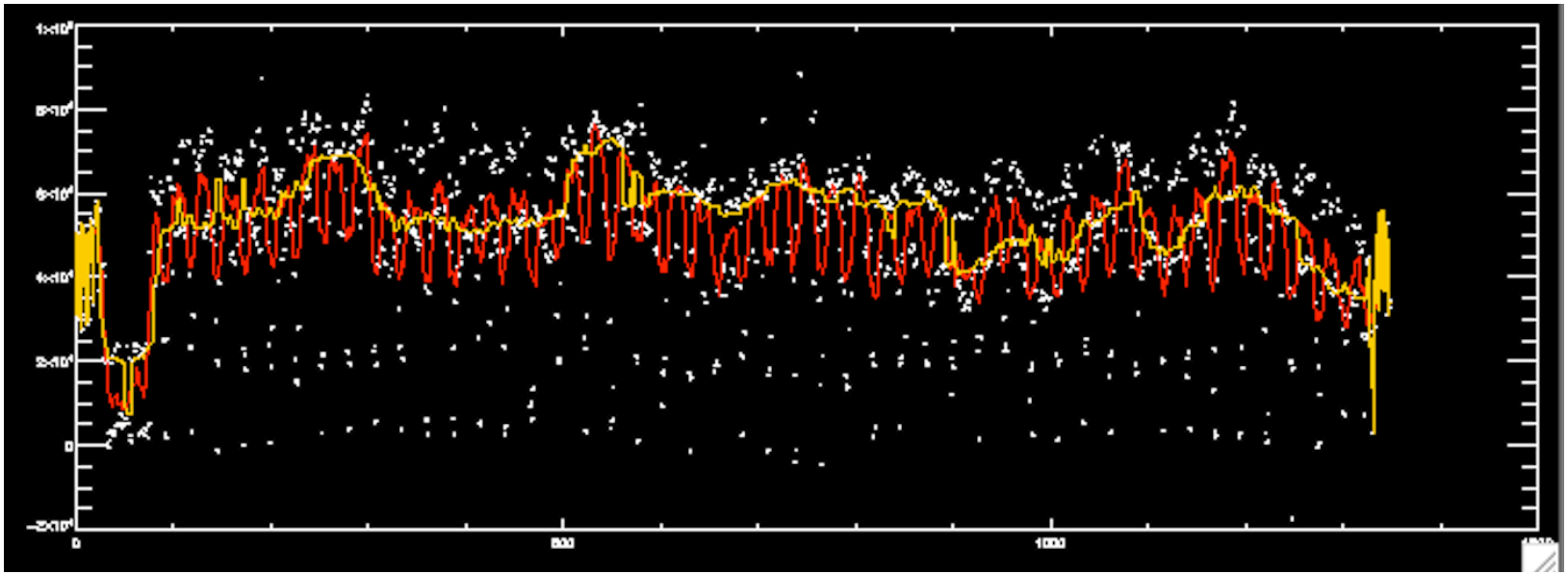
… so can be **calibrated out**. But this needs a major pipeline re-write.

Their cause (and the low spatially-filtered V^2) are still a mystery.



Chopper Data

- One issue with calibration has been that "ratio" frames are only taken at the end of an observing sequence.
- For 3-telescope data, this means that a 10% change in flux in one beam produces a 7% change in V^2. This is worse if aberrations are present.
- The chopper pipeline is incomplete (Vicente struggles with detector bias issues) and somewhat separate to the main pipeline.
- As some Hyades data were taken with choppers, I'm willing to take over this aspect during May (a hand-over post-PhD submission time for Vicente).

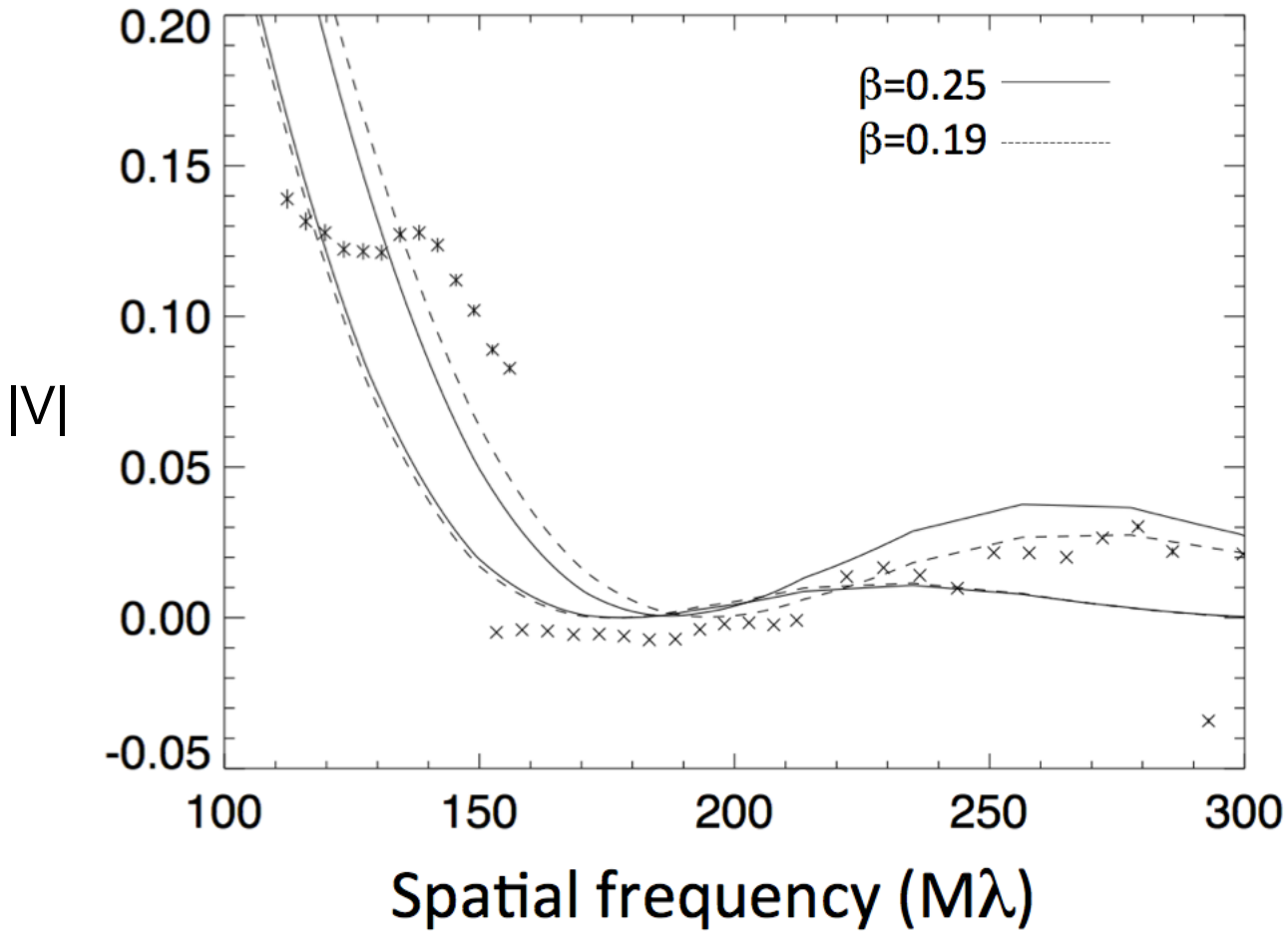


IR Tracking Data

Data have certainly been reduced with simultaneous IR tracking (right, α Leo).

The idea is that PAVO integrates without the need to fringe-track, enabling a much fainter correlated magnitude limit.

Calibration is not yet reliable, the analysis time-consuming and manpower is needed to add this to the pipeline. Reduced IR data with fine time resolution needed.

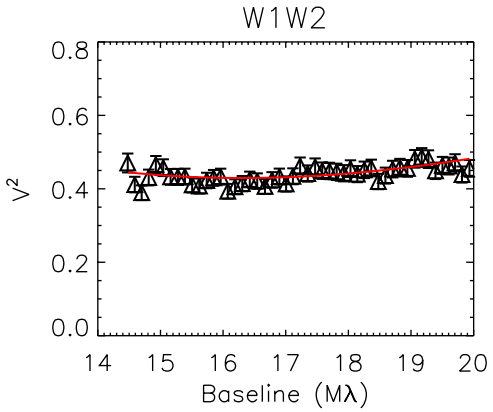


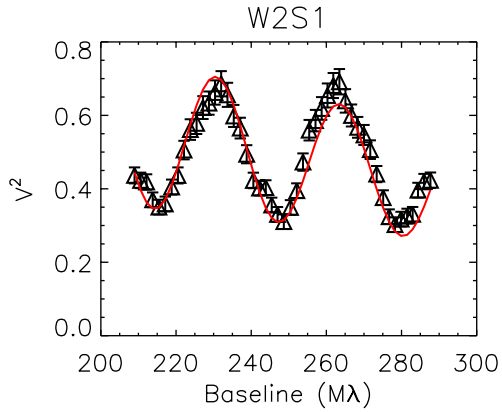
Closure-phase example: HD 30869 (vB 124)

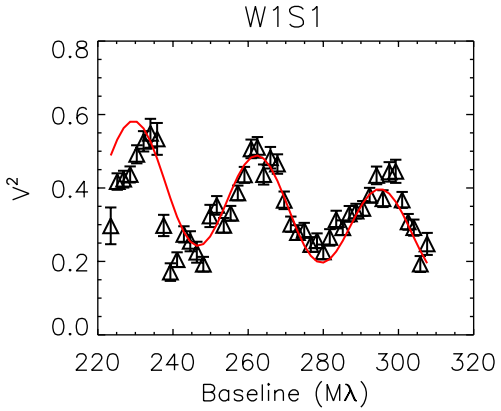
R = 6, observed on 2008 Sep 24.ρ= 6.24±0.03 mas

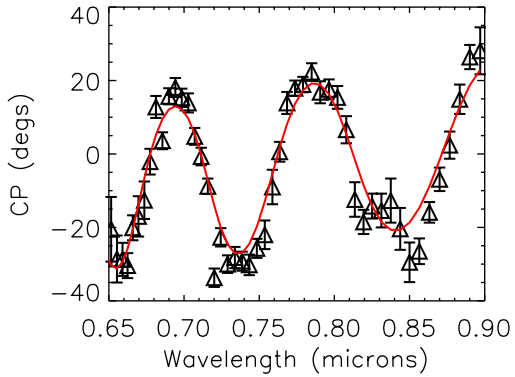
Systematics for fainter stars not well characterized, and diagnostics currently inadequate in post-processing.

If a science user is willing to help out with testing and publication, I can make this work. NB for highly resolved objects (V<0.1) it is unlikely closure-phase will be useful.









SUSI (PAVO, ~~MUSCA~~)

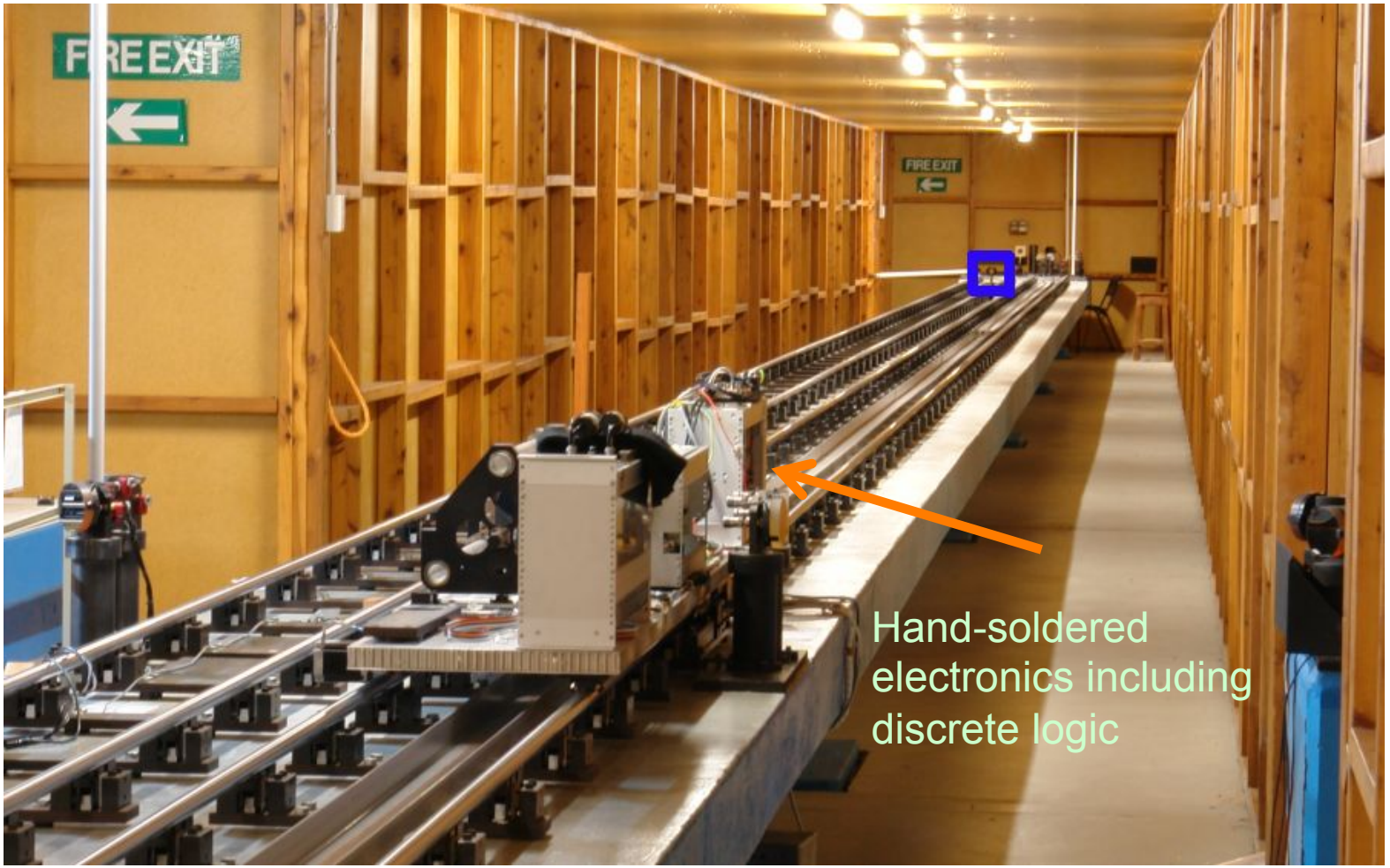
- The precision astrometry experiment at SUSI called MUSCA appeared to be on-track for precision but not for sensitivity. After Yitping Kok graduated, we chose not to support it.
- PAVO@SUSI can operate with a point-source magnitude limit of V=5.5, and 5 to 160m baselines. Operations are fully remote, and I'm willing to support anyone willing to use it while it is still functional. Aaron Rizzuto has one more major paper planned from the instrument this year (Sco-Cen survey published 2013).
- Data were last obtained on Nova Cen 2013, but due to weather, not on long baselines.
- Several publications, including:

Rizzuto, A. C., 2013, MNRAS,

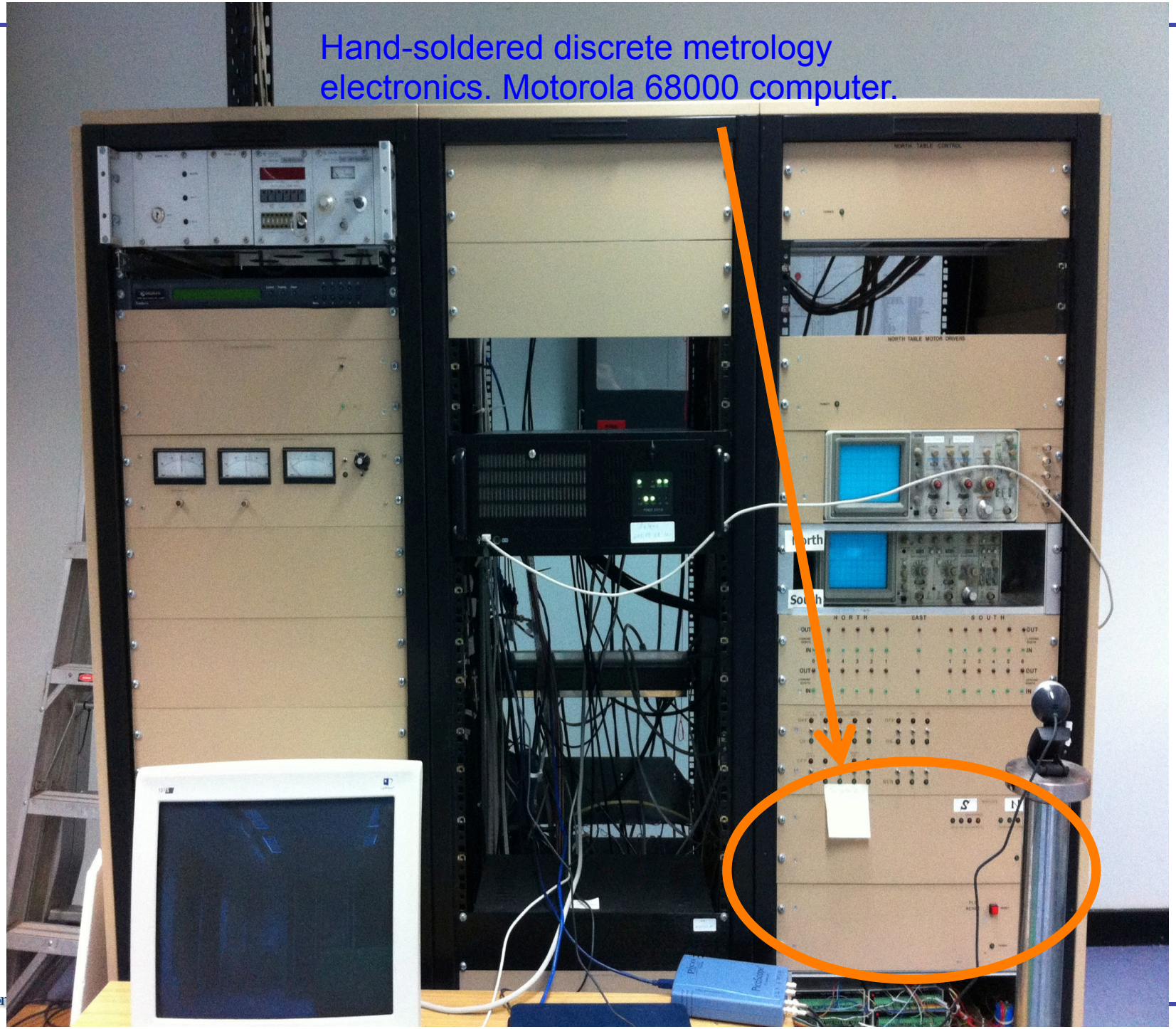
Long-baseline interferometric multiplicity survey of the Sco-Cen OB association

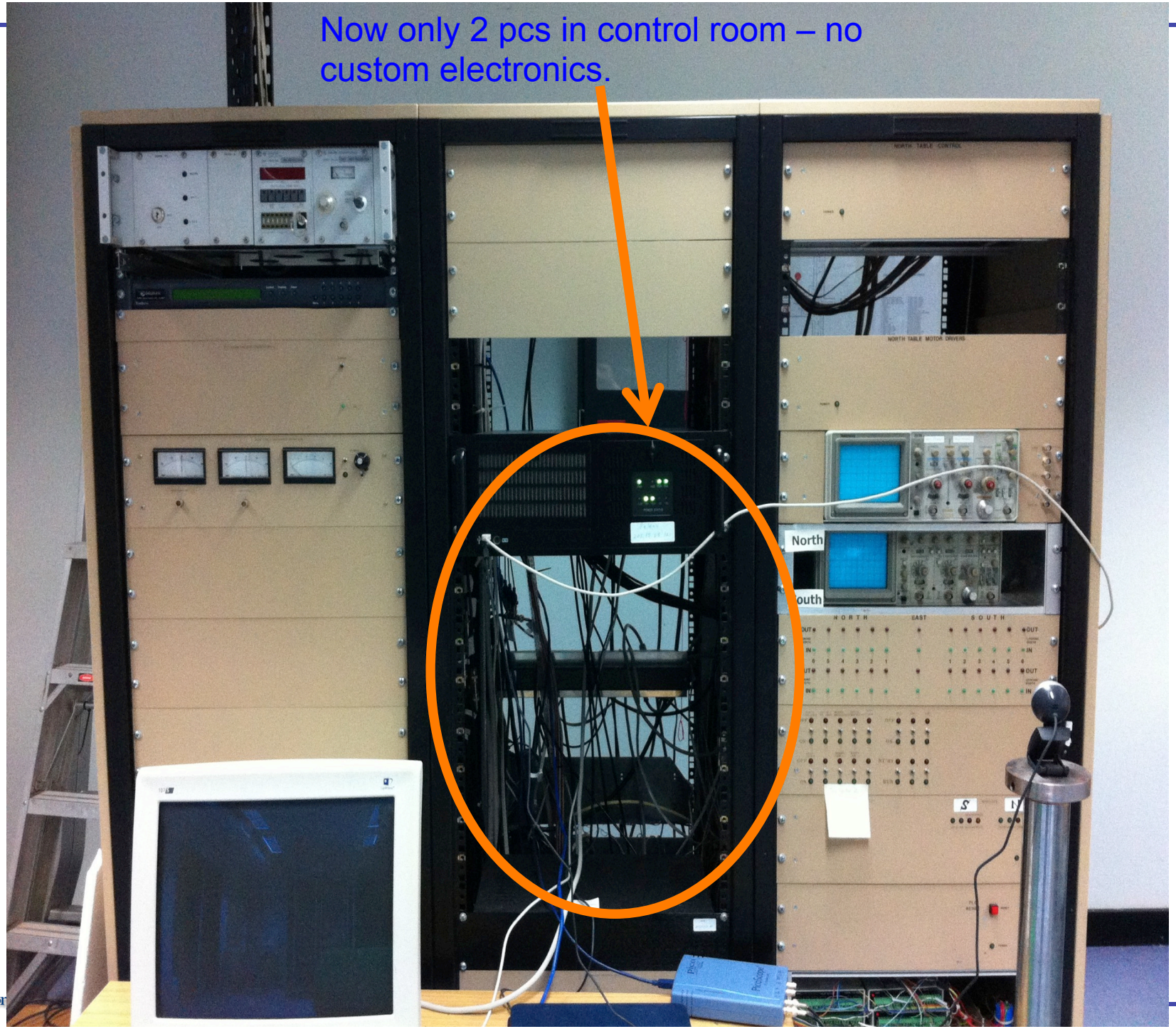
[Survey of 58 hot stars]

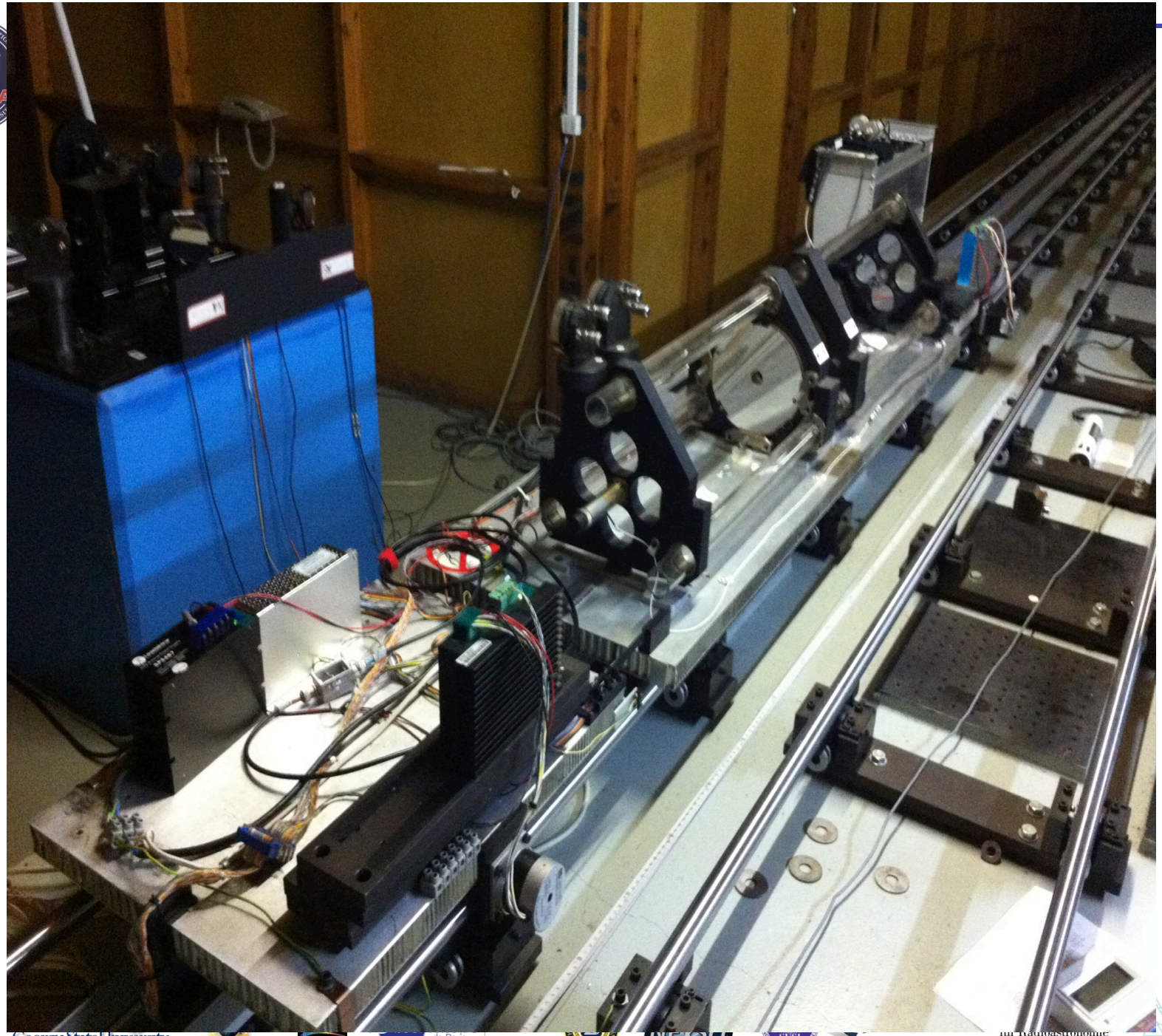
Optical Pathlength Compensator Upgrade



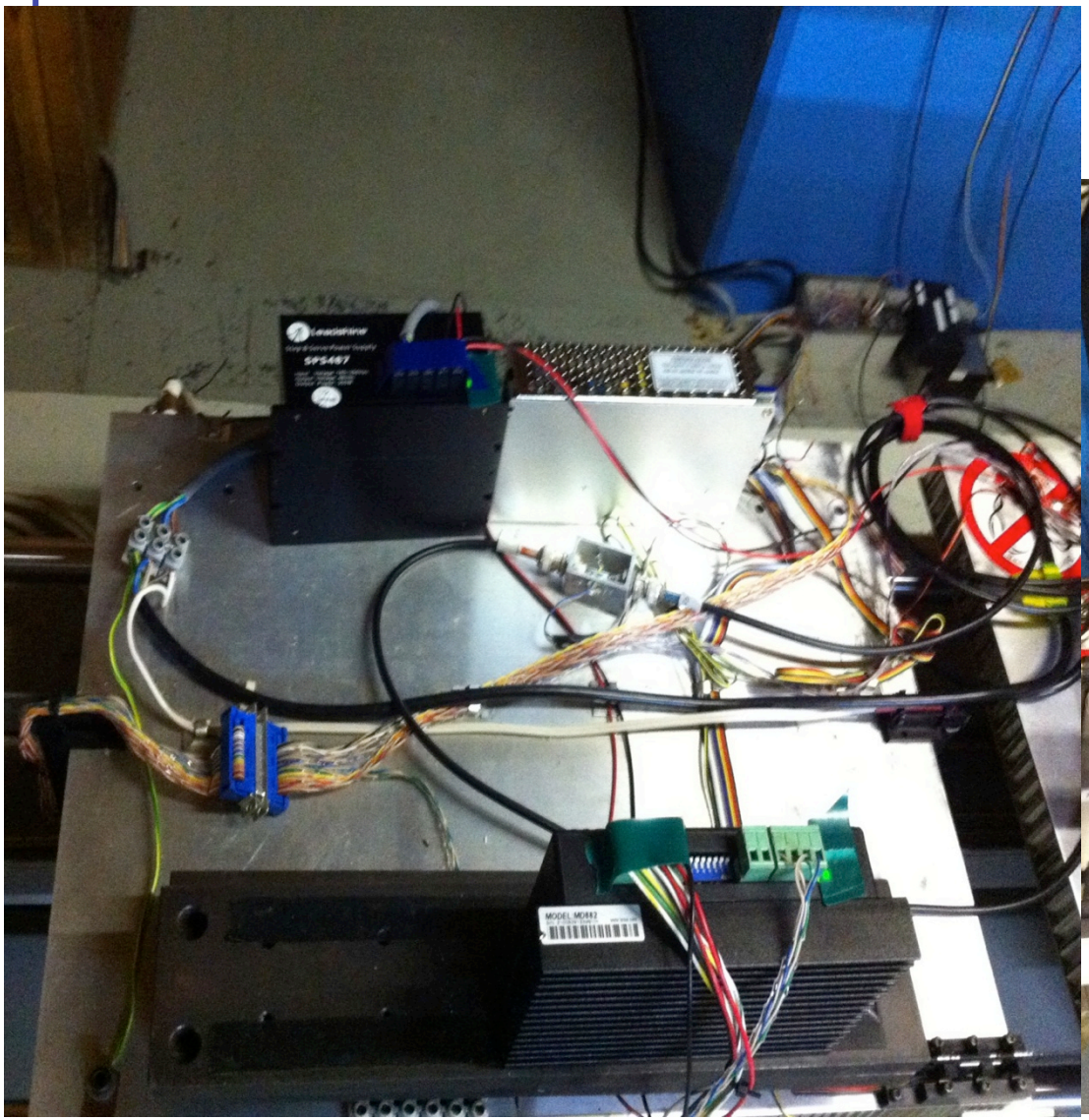
Speed wobbles esp at 2-3mm/s limited baseline. Electronics/ software limitation, preventing real 160m baseline work

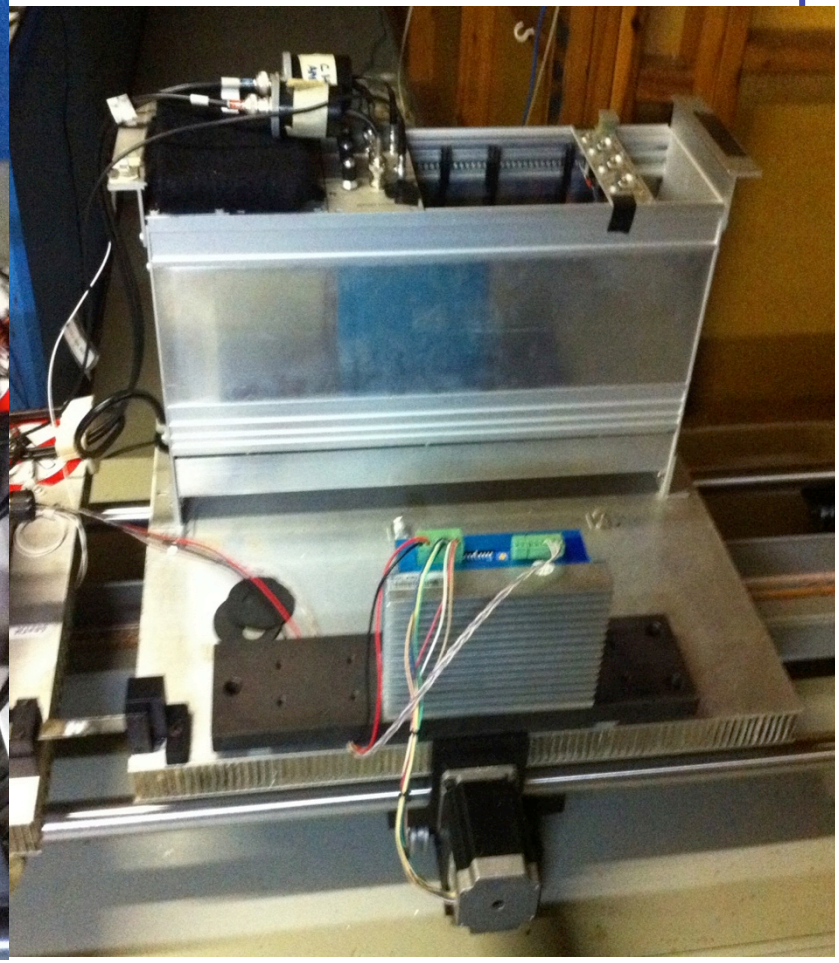

Hand-soldered discrete metrology electronics. Motorola 68000 computer.


Now only 2 pcs in control room – no custom electronics.
North
NORTH
EAST
SOUTH



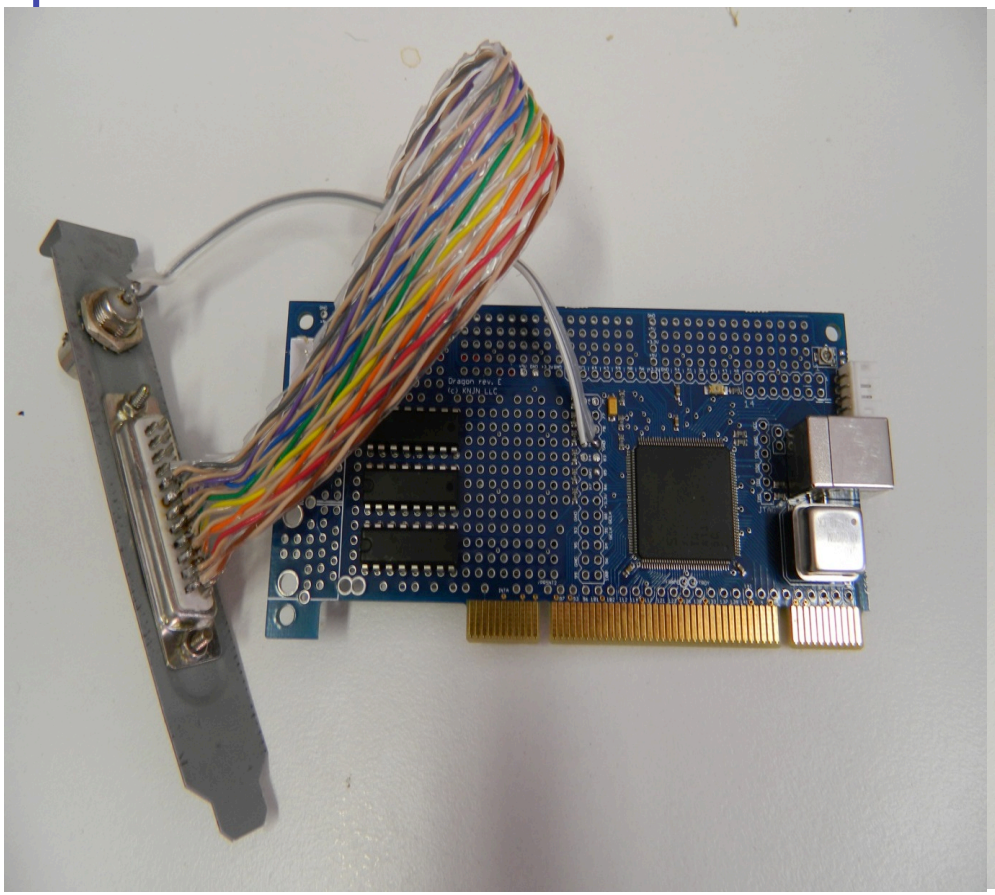
Commercial microsteppers, analog piezo signals

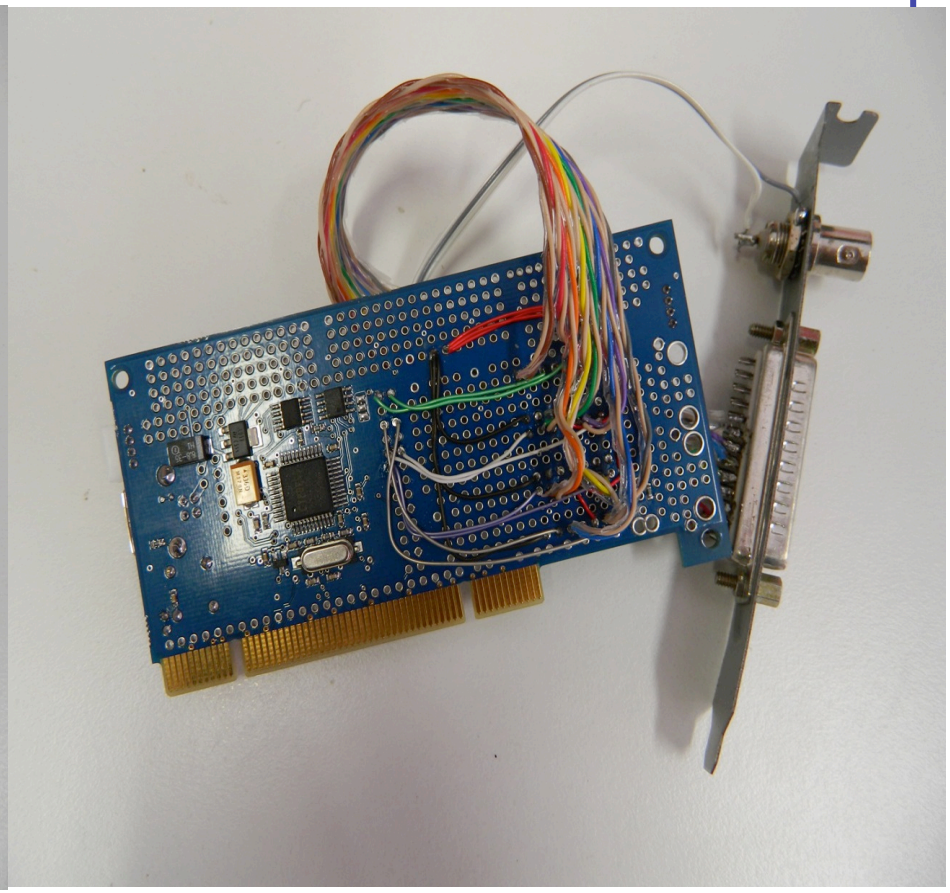




Metrology, motor control Functions on Cheap FPGA PCI card

- PCI I/O verilog code came with Dragon PCI
- Metrology is another 35 lines of verilog – double the old resolution and 20 times the IO speed





Thanks for listening!

The "Wiggles"

- Dec 2011: "There are still (small) wiggles on the S2W2 baseline, and they do not go away with my new polariser tests. I don't have the plot as I lost it from the screen before a screen capture, but V^2 versus wavelength variation was less than 5% for all polarisation states other than Vertical... where there was a 10% shift."
- All as if there is a second beam copy interfering… but from where?