Title: Progress Toward Multi-Channel Intensity Interferometry with the Southern Connecticut Stellar Interferometer

Speakers: Elliott Horch

Collection/Series: Future Prospects of Intensity Interferometry

Subject: Cosmology

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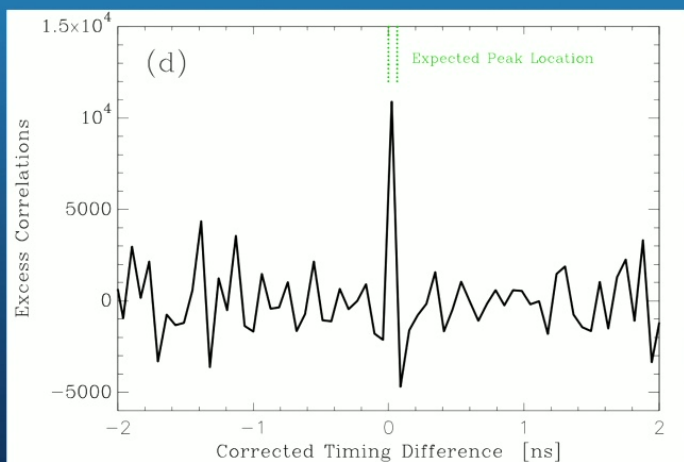
Abstract:

The renaissance in stellar intensity interferometry has resulted in two main types of telescope arrays: those using large "light bucket" telescopes and photomultiplier tubes, such as CTA, VERITAS, MAGIC, and others, and those that instead use smaller, more traditional astronomical telescopes with high-grade optics, such as the systems at the Cote d'Azur and Asiago Observatories. To detect and timestamp photons, these latter systems have used single-photon avalanche diode (SPAD) detectors. This talk will focus on the latter type of instrument, which is also being pursued at Southern Connecticut State University. The current status of our instrument, the Southern Connecticut Stellar Interferometer (SCSI), will be reviewed, and prospects for improved sensitivity will be discussed. Principal among these is the use of SPAD arrays, which are increasingly available, to record different wavelengths simultaneously. If a sufficient number of channels can be employed, this type of intensity interferometer can reach much fainter magnitudes than currently possible. The talk will also briefly discuss work toward wireless intensity interferometry with SCSI, which will make larger baselines easier to set up and use, and ideas for quantum-assisted intensity interferometry that might be employed with SCSI in the future.

Progress Toward Multi-Channel Intensity Interferometry with the Southern Connecticut Stellar Interferometer

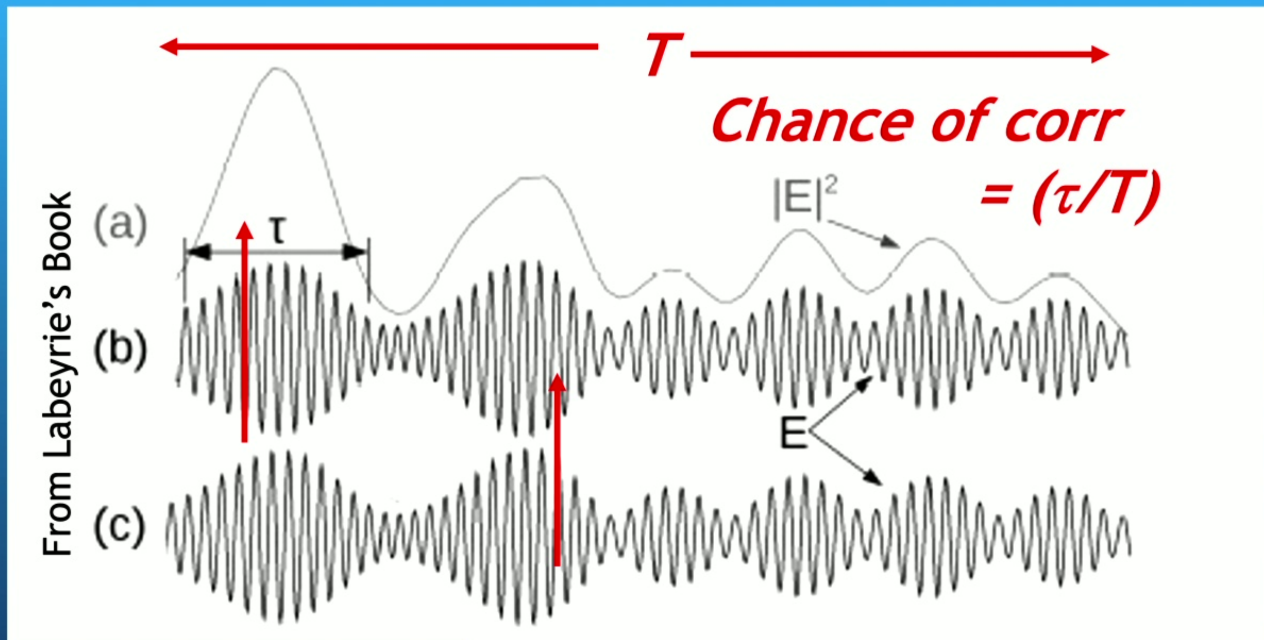
Elliott Horch,
Southern Connecticut State University

Astronomical Instrumentation Lab at SCSU.



New Instrumentation and Software Development for High-resolution imaging.

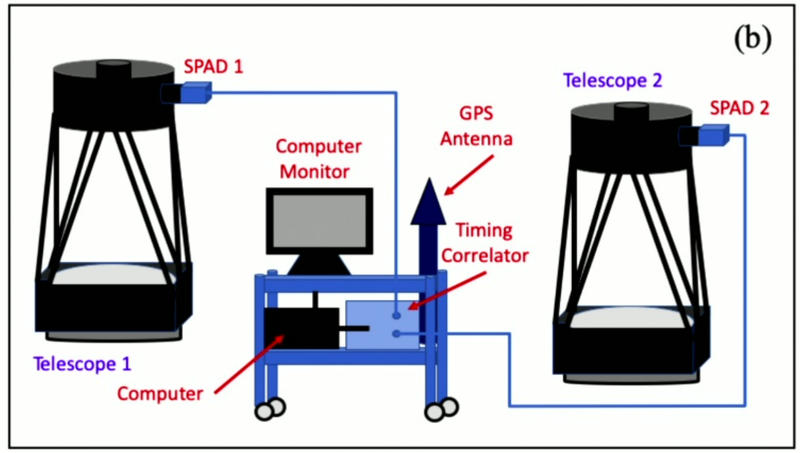
What Makes Stellar Intensity Interferometry Hard?



$$\gamma^{(2)}(\mathbf{r}, \tau) = 1 + |\gamma(\mathbf{r}, \tau)|^2$$

Talking: Perimeter-A

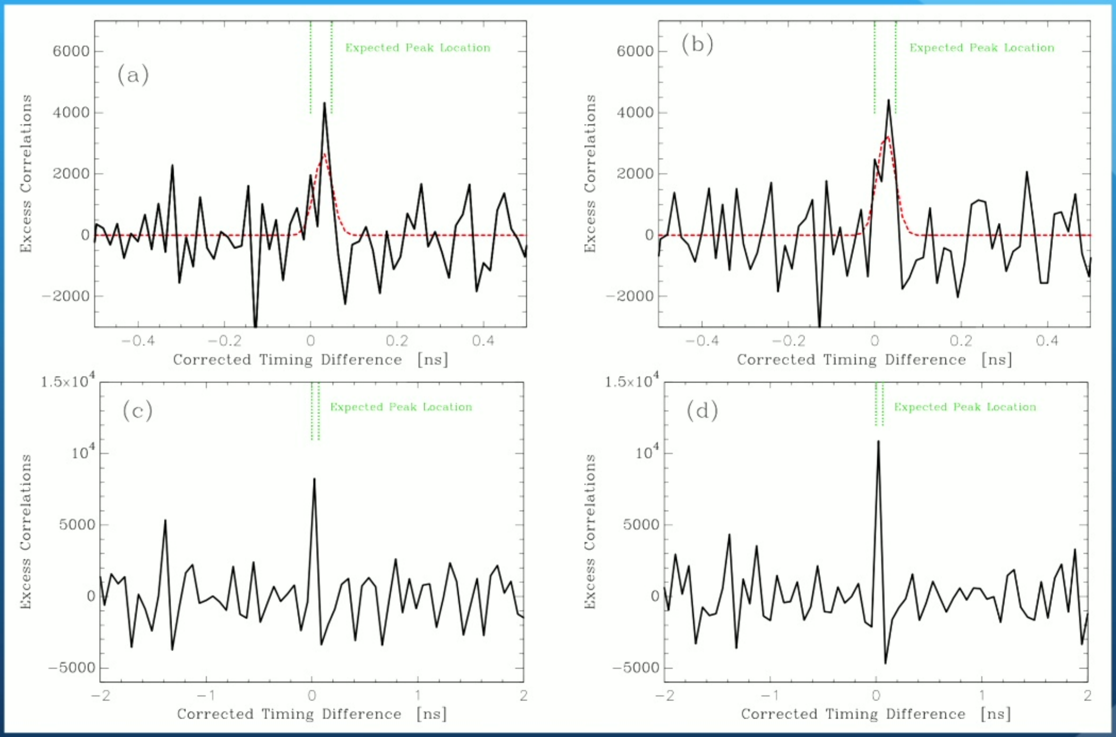
SCSI: A three-station intensity interferometer



- ***60-cm Dobsonian telescopes.***
- ***Meinberg GPS modules***
- ***MPD SPAD detectors***
- ***Picoquant timing modules***

Group Members:
Justin Rupert, M.S. 2016
Olivia Weiss, M.S. 2018
Paul Klaucke, M.S. 2021
Rich Pellegrino, M.S. 2023
Torrie Sutherland, M.S. expected 2025
Sebastian Lucero, B.S. expected 2025

Photon Bunching Observed



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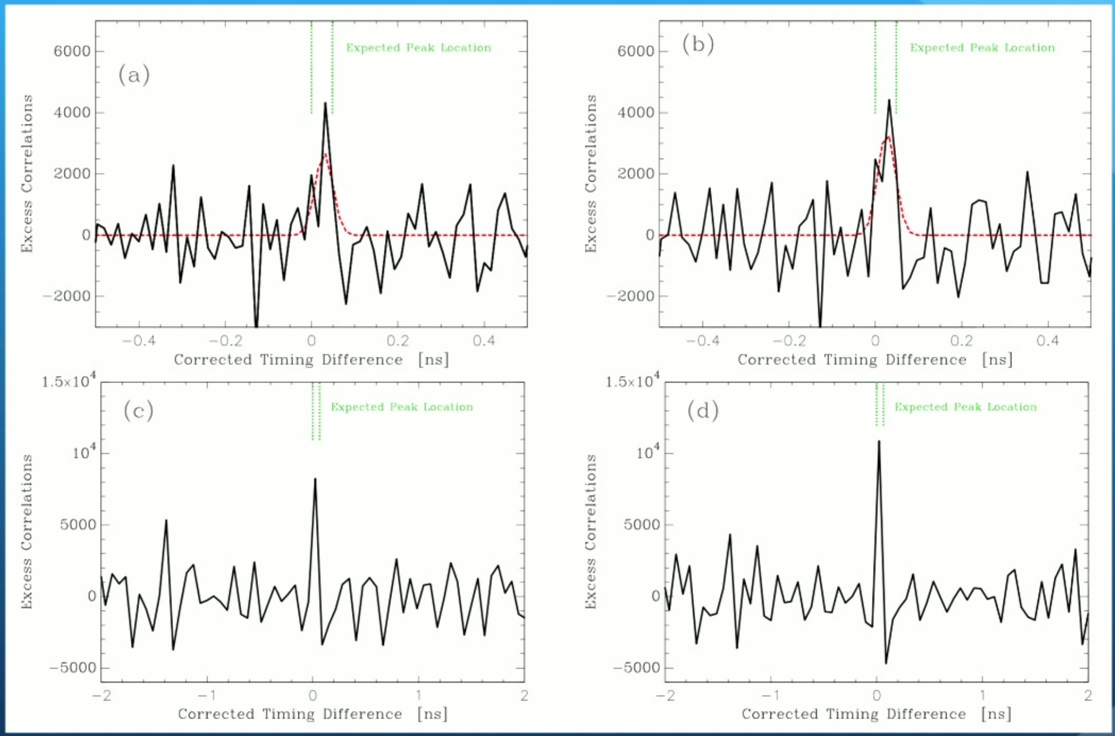
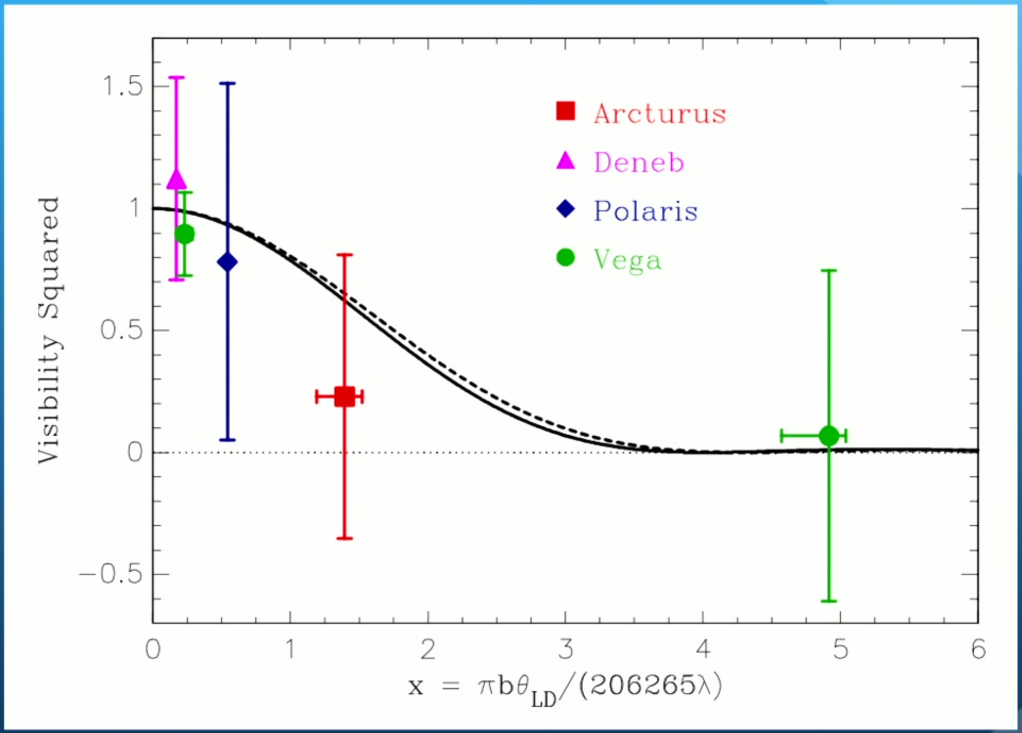
Photon Bunching Observed

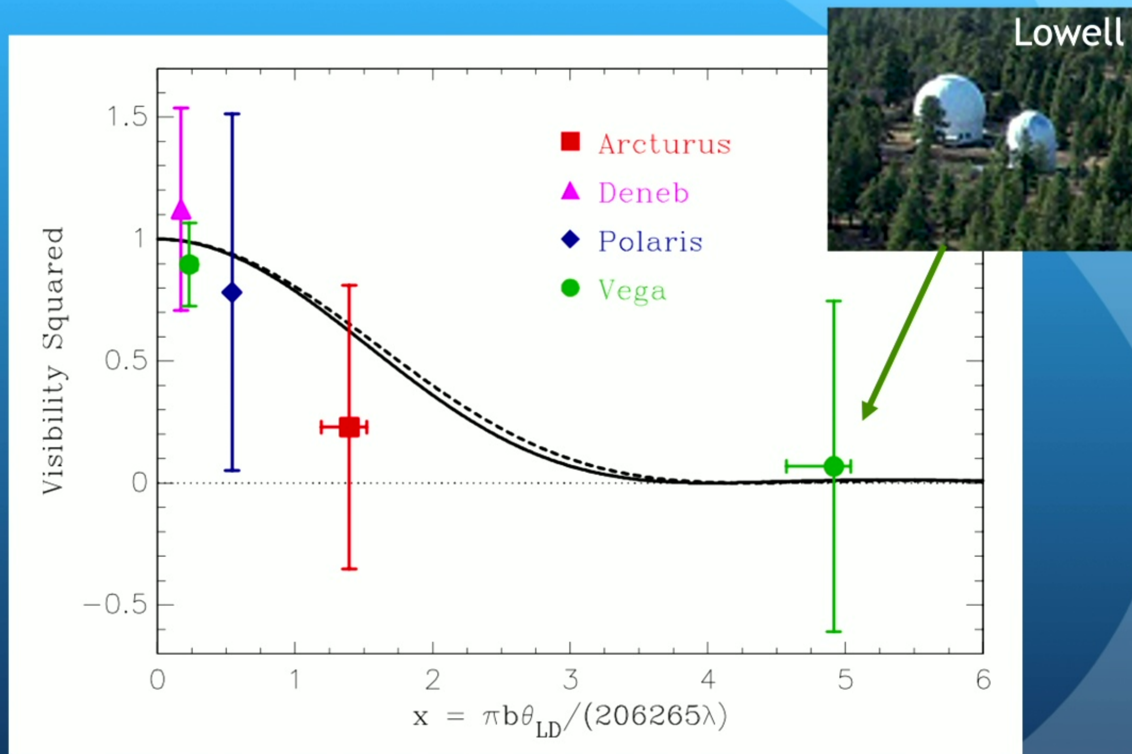


A pedestal of ~3x10⁶ counts per 64 ps is subtracted!

Toward Stellar Diameters



Toward Stellar Diameters



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Current Challenges

- Reliable Positioning of Telescopes
- Collimation and Focus of Telescopes
- Detector Active Area
- Telescope Tracking
- Operating 3 telescopes at the same time is hard!

Holy grail: Wireless operation - each telescope has its own clock and these are synchronized through GPS.

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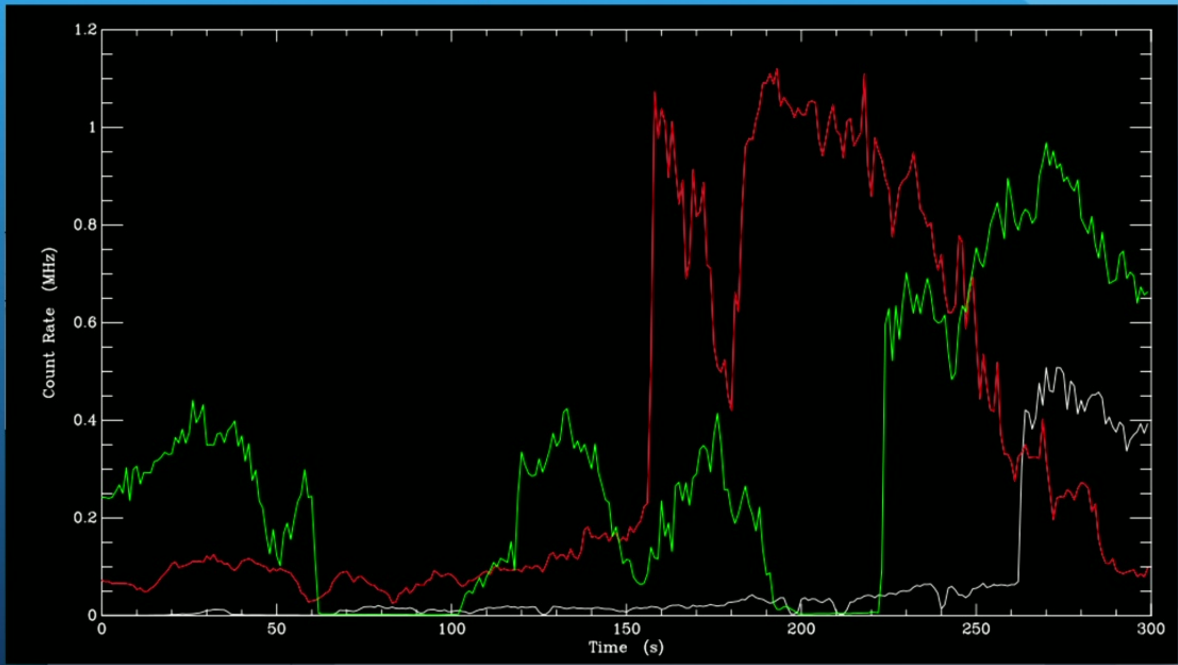
Two examples

Three-Telescope observations in Jun 2022.



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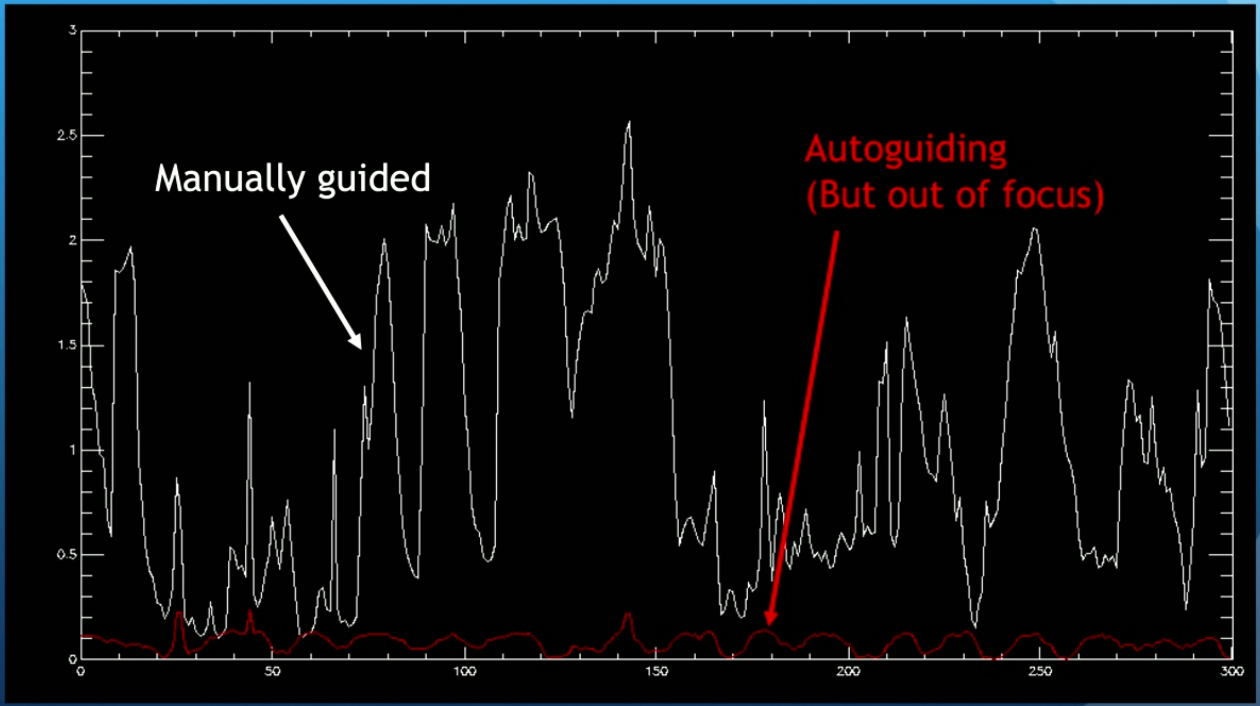
Two examples

Three-Telescope observations in Jun 2022.

Two examples

Two Telescope operation (Aug 2024, Sebastian and me).



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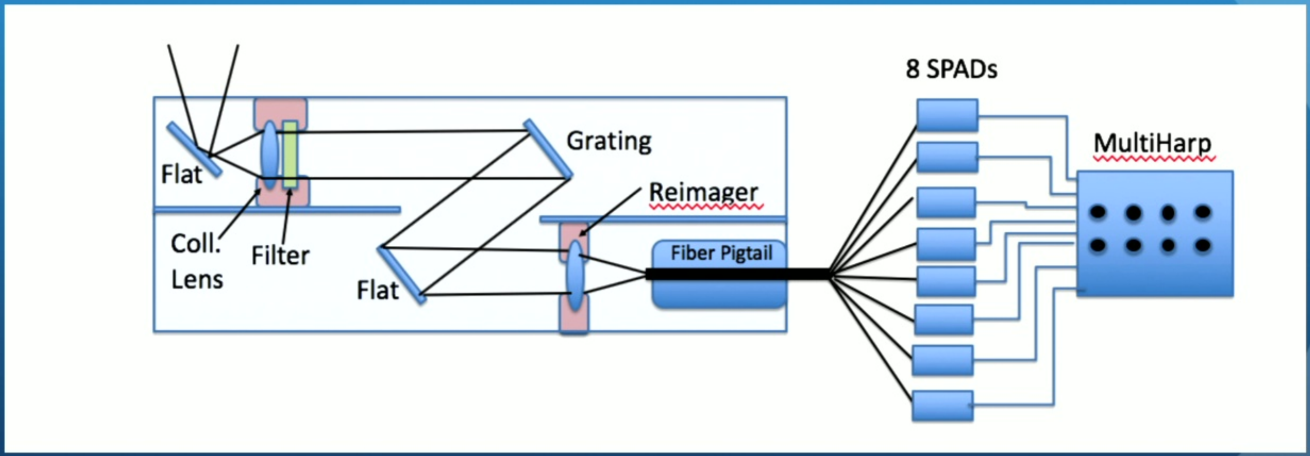
Increasing Efficiency

- Idea: Observe multiple wavelengths simultaneously. Originally, thought to fiber-feed with single-mode fiber.



SPAD Arrays

512-pixel Linear Array

axiom OPTICS

8-pixel linear array

- Deadtime and small size can be mitigated if you have many SPADs all looking at the same source.
- Can use more light.

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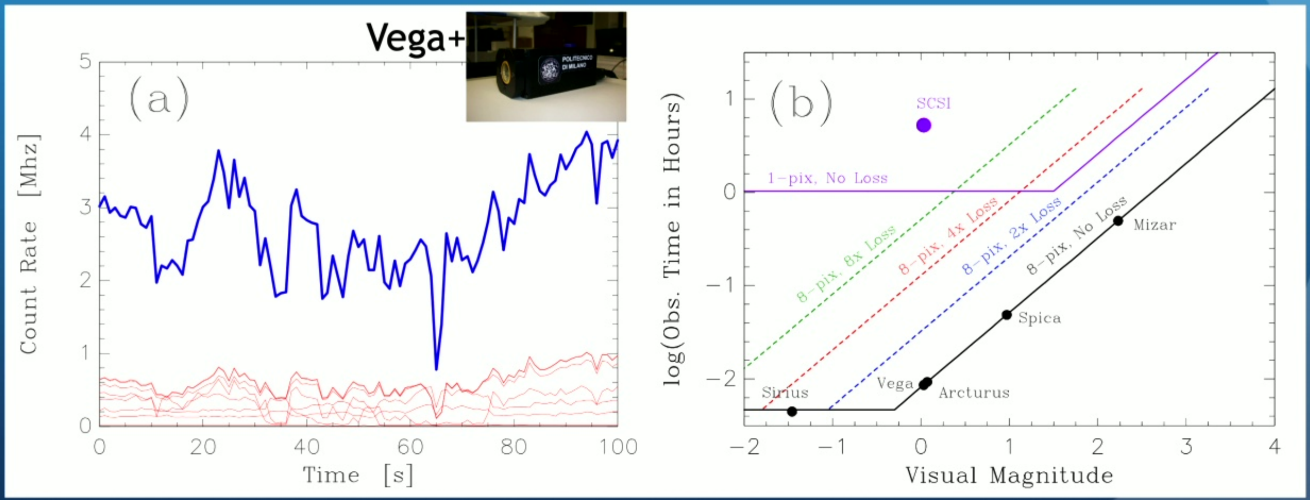
Preliminary Multi-Channel Work

- Using our 8-pixel SPAD array, we have taken preliminary data reading out all 8 channels with a PicoQuant HydraHarp 8-channel timing correlator.



Optics Package for our 8-channel SPAD array

Matt Dever, B.S. 2020

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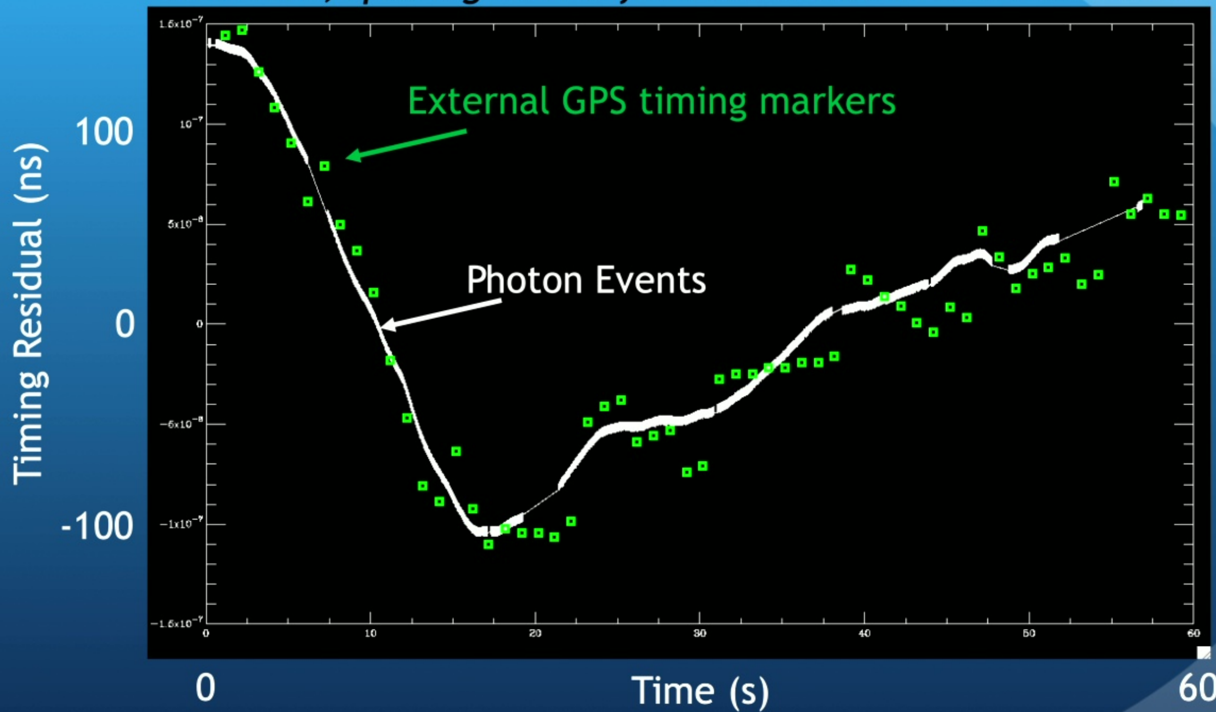
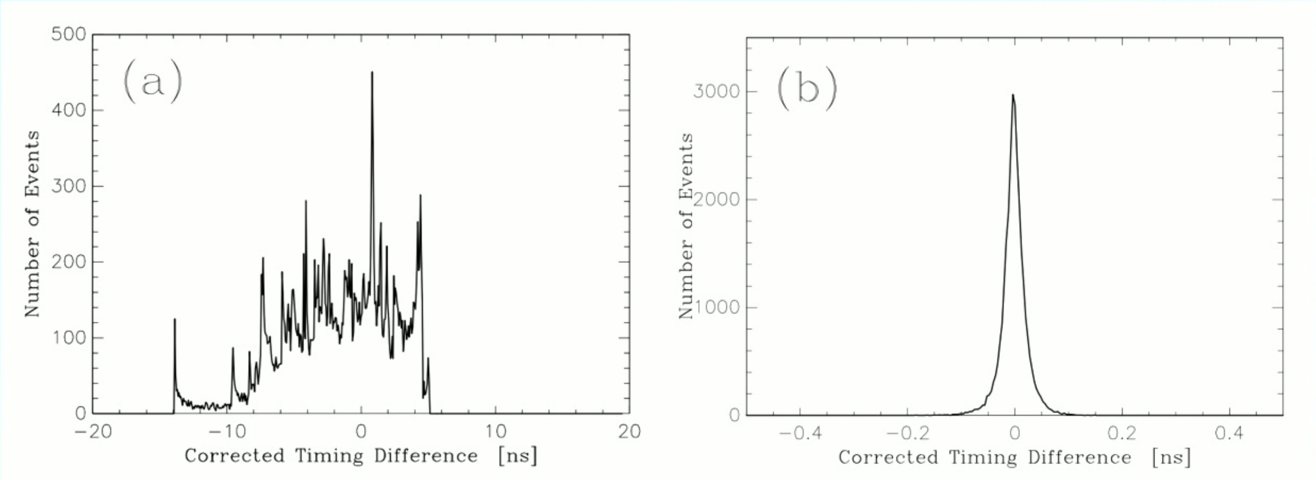
Multi-Channel SII may make wireless SII possible.

One SPAD; split signal and feed same events into two timers.



Better Efficiency Opens the Door to Wireless Interferometry

From: Horch et al 2018.



Histogram of timing differences for events read through two wireless stations.

Histogram of timing differences for events read through a single wired set-up.

Better Efficiency Opens the Door to Wireless Interferometry

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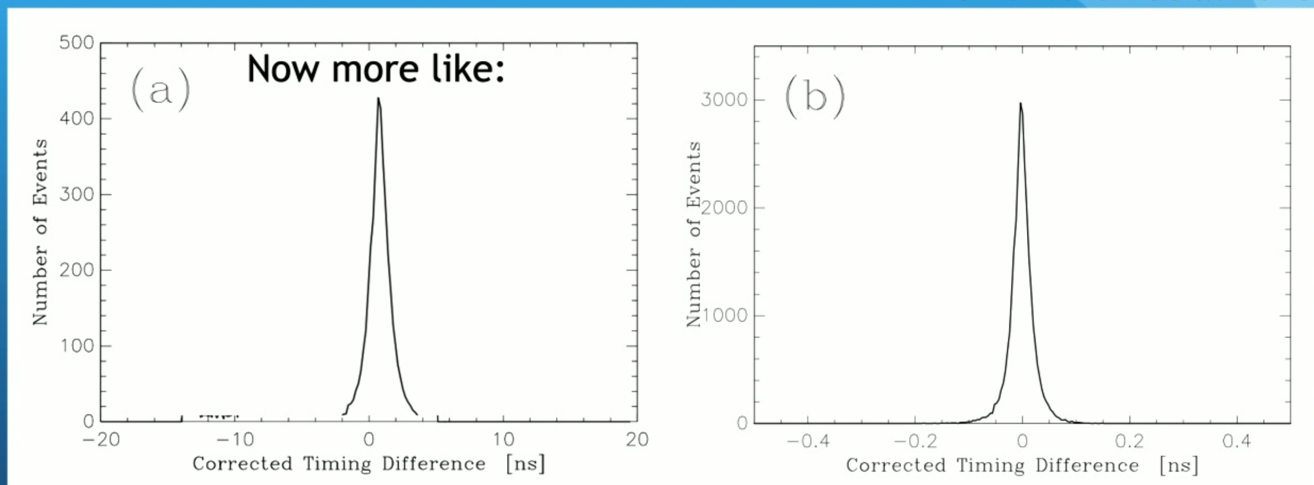

Histogram of timing differences for events read through two wireless stations.

Histogram of timing differences for events read through a single wired set-up.

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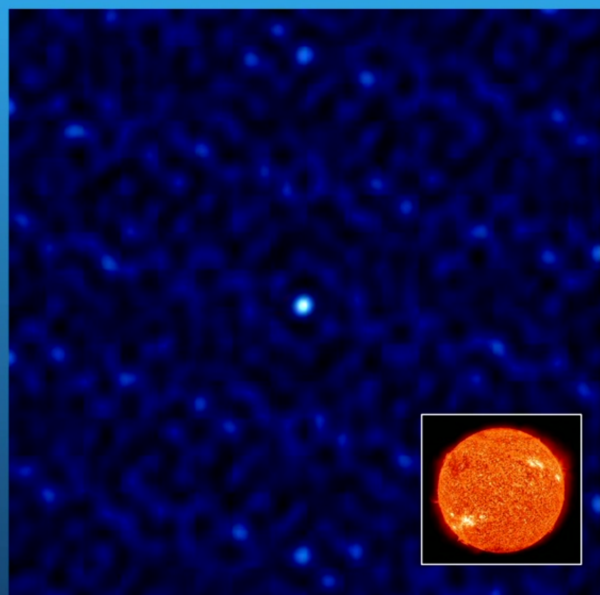
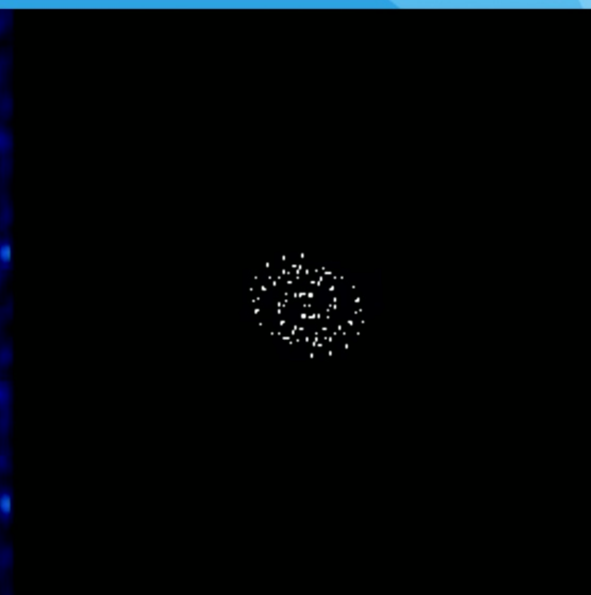
Three-Station Wireless Interferometer at SCSU

GPS Computer Cards: ~10ns Synchronization … Or better! (~3ns in Latest test)

“Dirty Beam” Simulation



FWHM ~ 0.1 mas



uv-plane coverage
6-hour observation

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Summary

- SCSU has a working, highly re-configurable stellar intensity interferometer.
- *Possible Future Directions/Projects:*
  - *Work toward measurement of stellar diameters from our campus.*
  - *Take equipment to larger observatories.*
  - *Improving reliability and throughput (Autoguiders, 8 channels per station)*
  - *Wireless data on-sky.*
  - *We are interested in quantum-assisted ideas for stellar intensity interferometers.*

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10/30/24 Perimeter Institute