Two-Photon Interferometry for Wide-Angle Precision Astrometry

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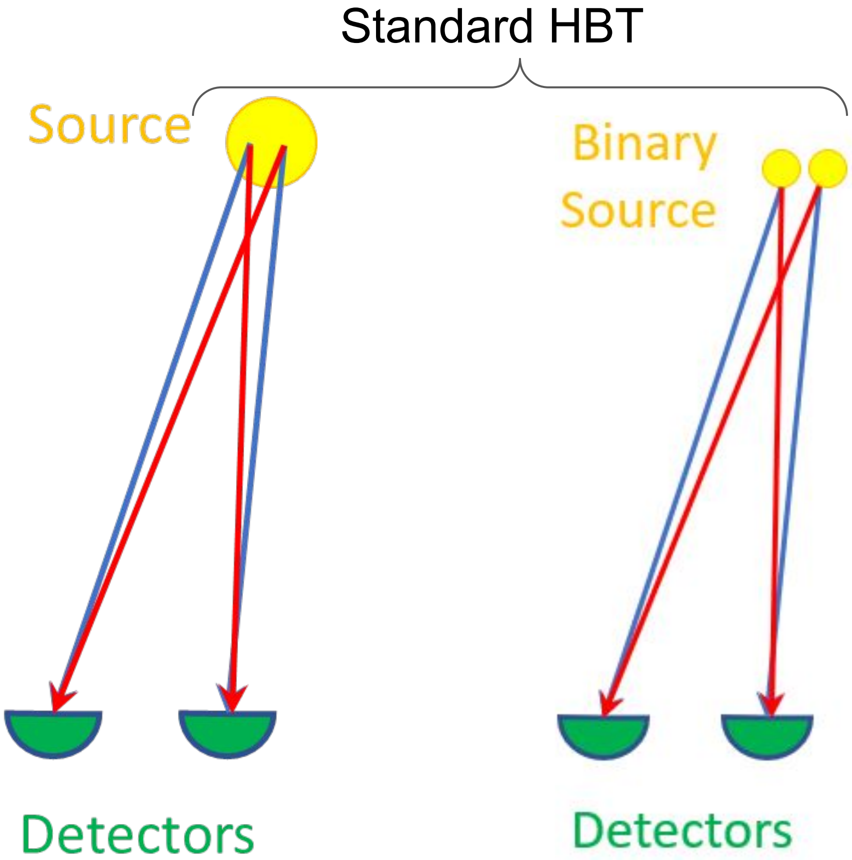
Stony Brook University & Brookhaven National Lab

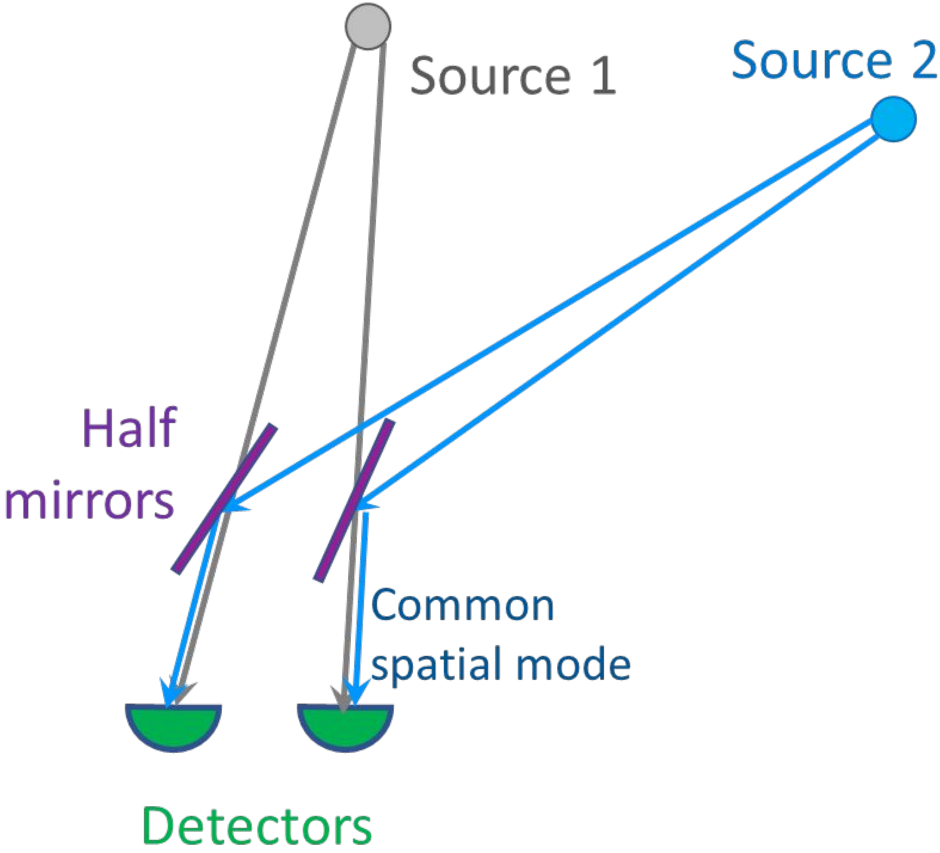
Future Prospects of Intensity Interferometry - Perimeter Institute
10/30/24

Figures: Paul Stankus

HBT Generalization



Two-Photon Interferometry for Wide-angle Precision Astrometry



Figures: Paul Stankus

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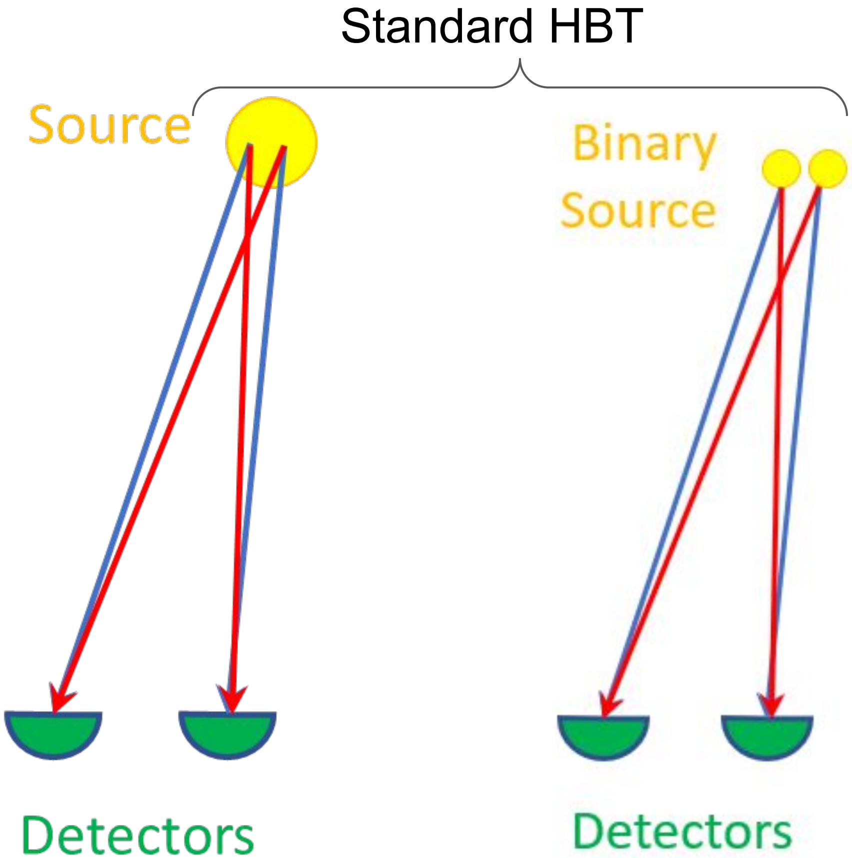

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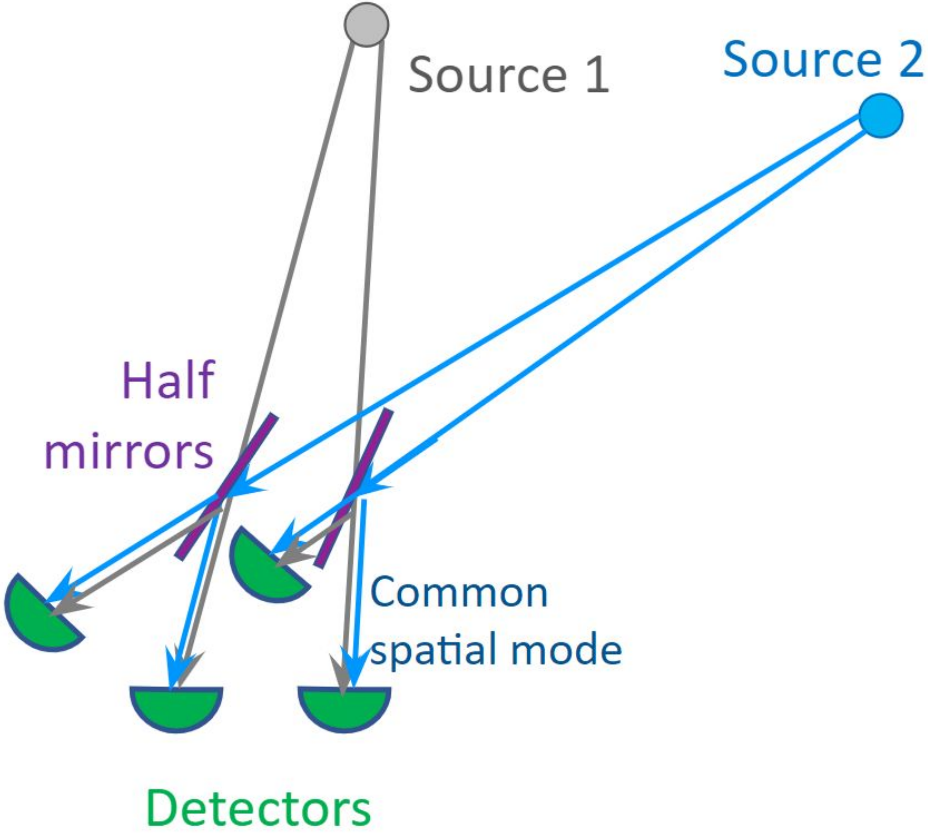
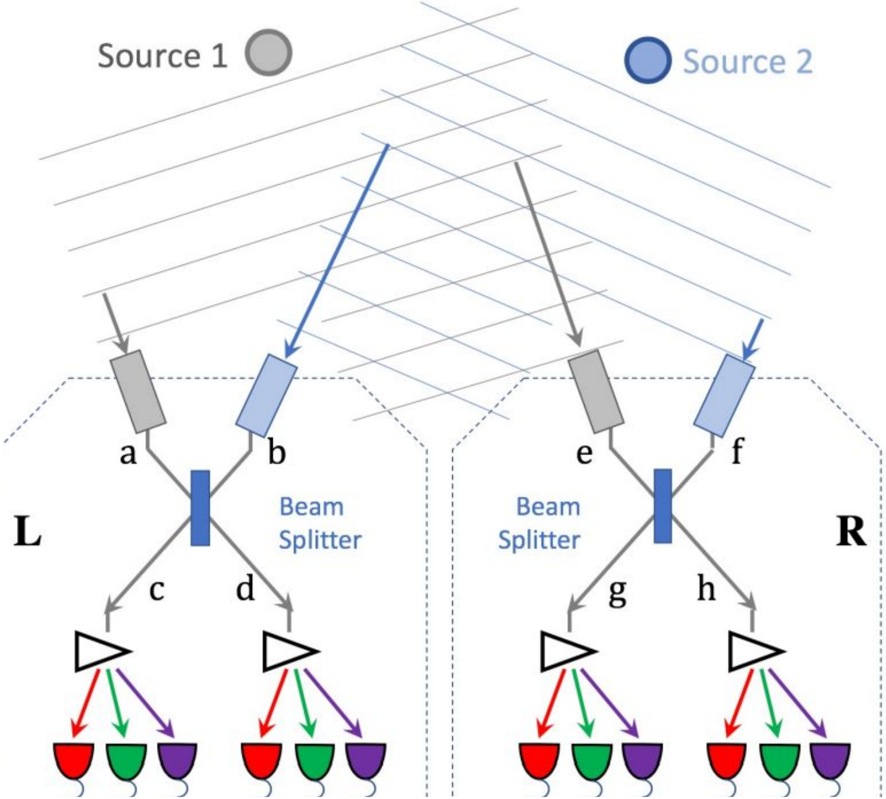


The SNSV Scheme

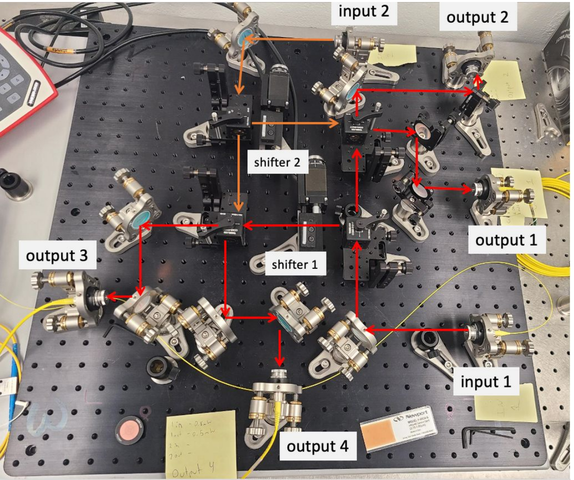
- Original paper: Stankus et al. (2022) *Open Journal of Astrophysics* doi:10.21105/astro.2010.09100
- Two stations with no optical connection
  - Longer baselines, higher precision
- Astrometric measurement (dynamic)
  - Parallax distance measurement
  - Exoplanet-induced stellar reflex motion
  - Stellar spin axis (photocenter movement)
  - μHz gravitational wave detection

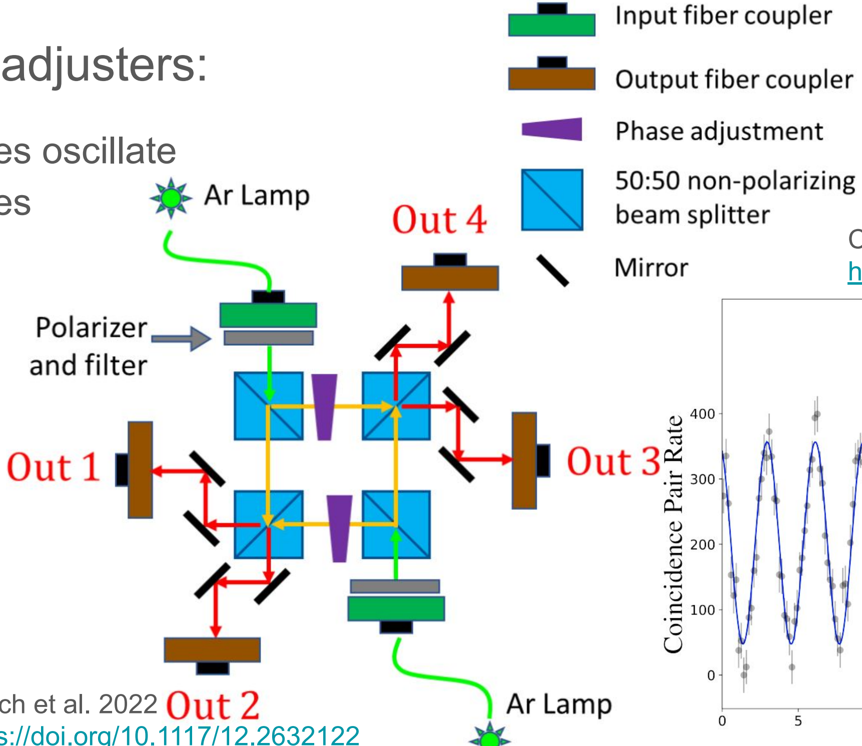


Stankus et al. 2022
https://doi.org/10.21105/astro.2010.09100

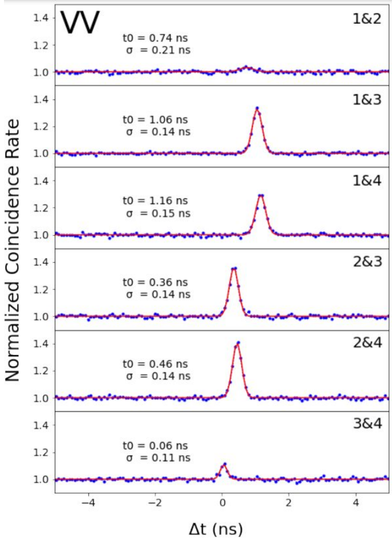
SNSV Scheme: Tabletop demonstration

- Tested principle in a tabletop demonstration
- When moving phase adjusters:
  - Cross-station pair rates oscillate
  - Same-station pair rates remain constant

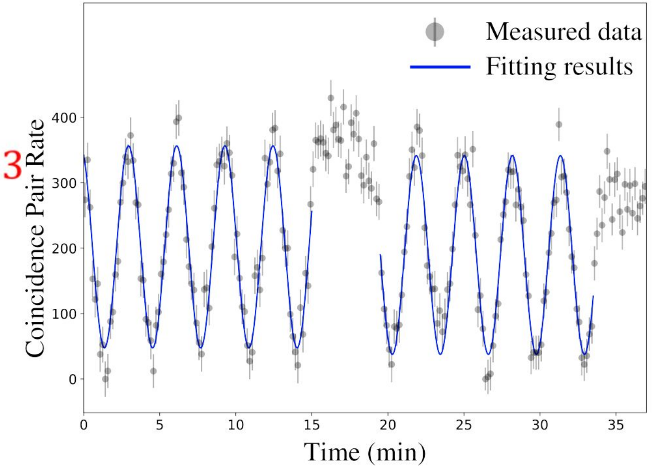




Keach et al. 2022
https://doi.org/10.1117/12.2632122

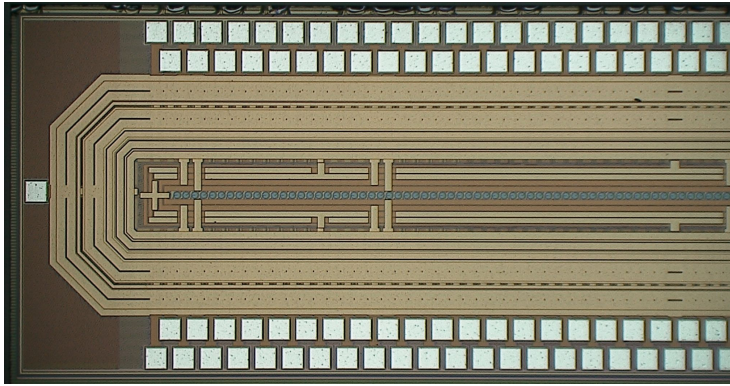


Crawford et al. 2023
https://doi.org/10.1364/OE.486342



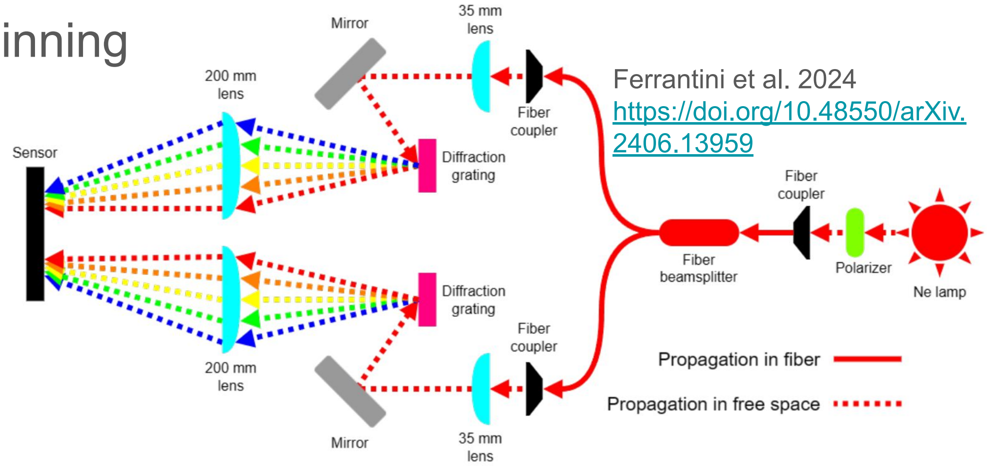
LinoSPAD2 Fast Spectrometer

Milanese et al. 2023
https://doi.org/10.1364/OE.505748



- LinoSPAD2: 1x512 linear array of Single-Photon Avalanche Diodes (SPAD)
  - Made by EPFL in Switzerland
  - ~50ps RMS timing resolution (single photon)
  - Low dark count rate
  - Room temperature operation
- Dual spectrometer key to spectral binning
  - 0.1nm/pix spectral scale
- $(\Delta t)(\Delta E) \sim 10 * (\hbar/2)$
  - Benchmark, not direct comparison

Ferrantini et al. 2024
https://doi.org/10.48550/arXiv.2406.13959



LinoSPAD2 Fast Spec.: Multifrequency HBT

- Simultaneous detection of HBT for 5 Neon lines
- Disambiguate from crosstalk via delay fiber
- Working towards broadband HBT measurement

Ferrantini et al. 2024
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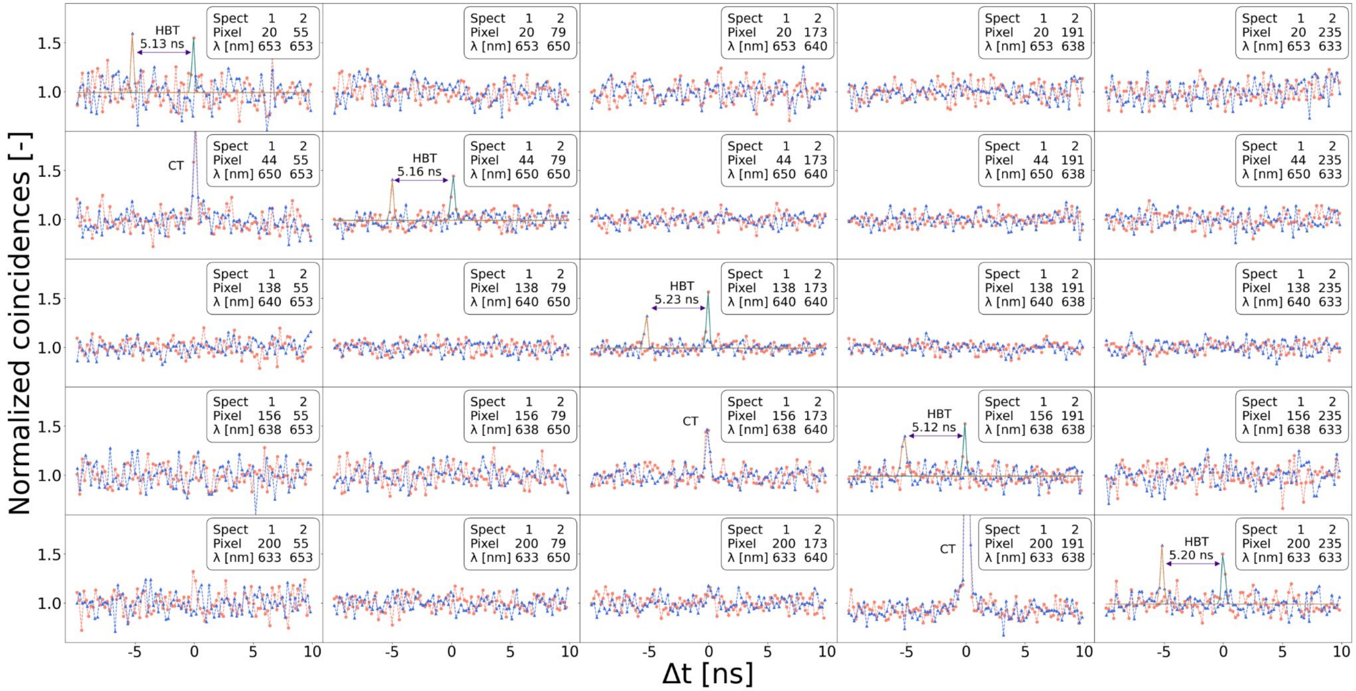

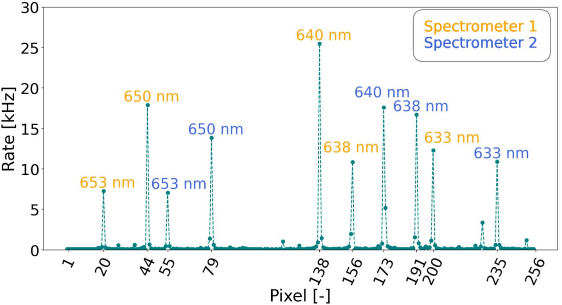

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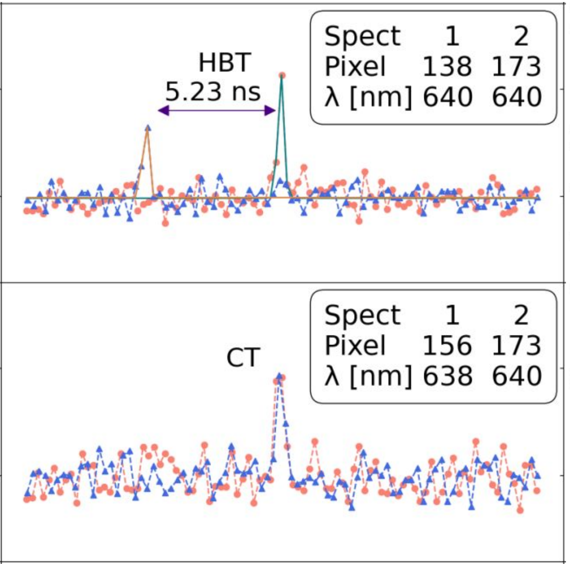
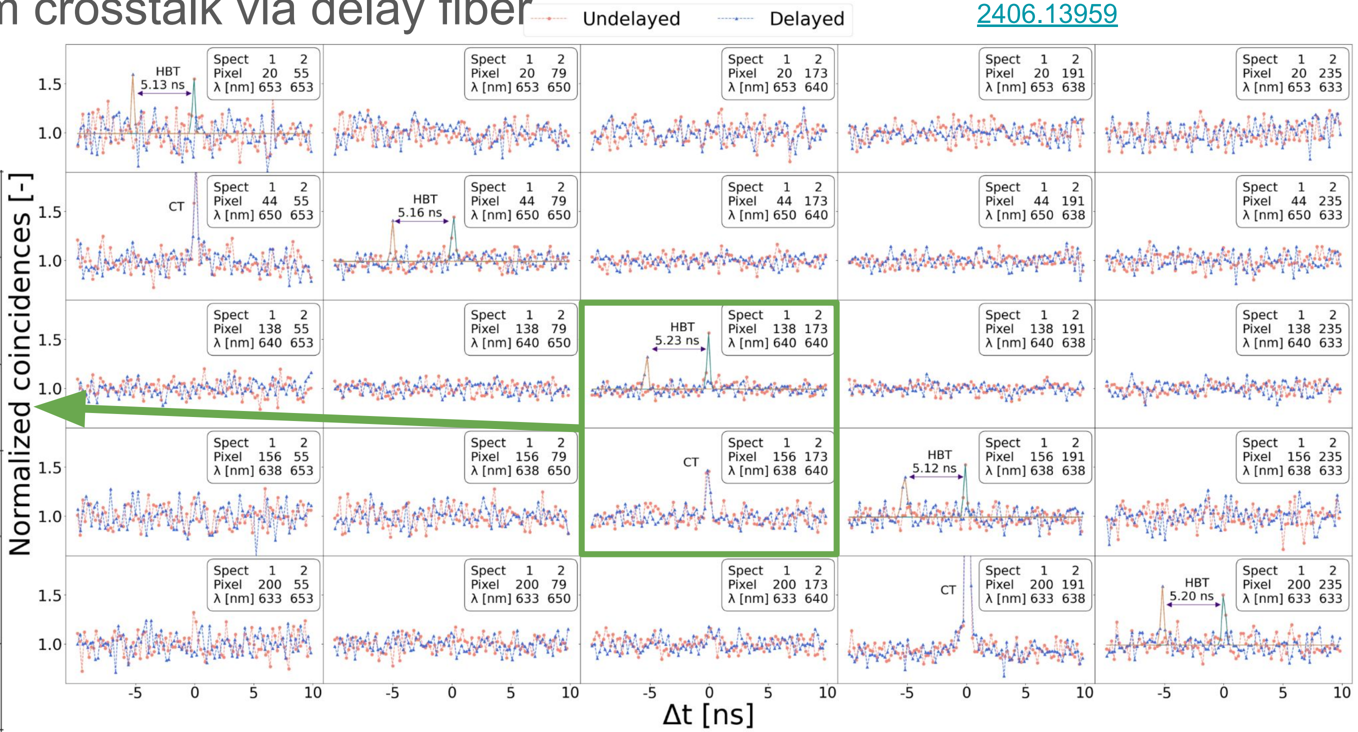
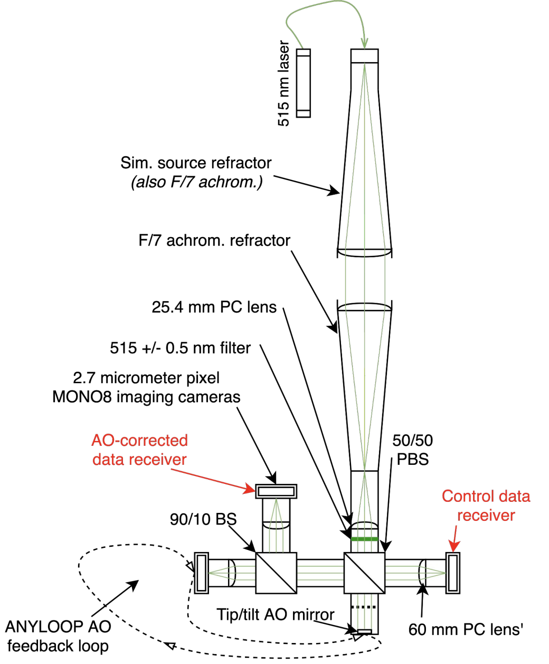
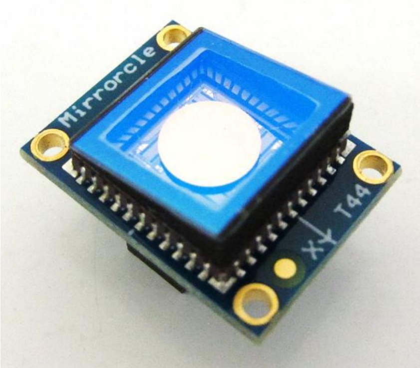


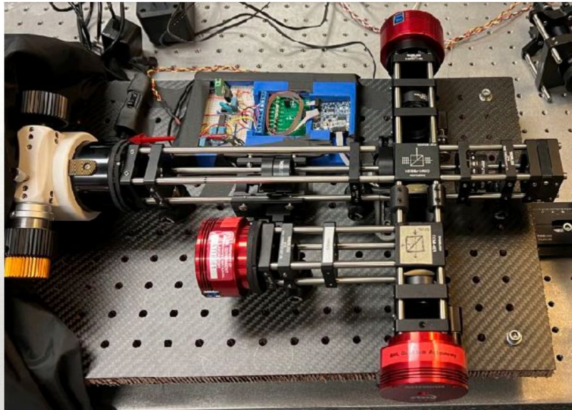


Collecting Single-mode Starlight

- Require light in same spatial mode => single-mode fiber
- First-order adaptive optics correct for atmospheric PSF position movement
- Mirrorcle fast steering mirror
    - Controlled with Anyloop, an open-source control loop software (https://github.com/cdqp/anyloop)



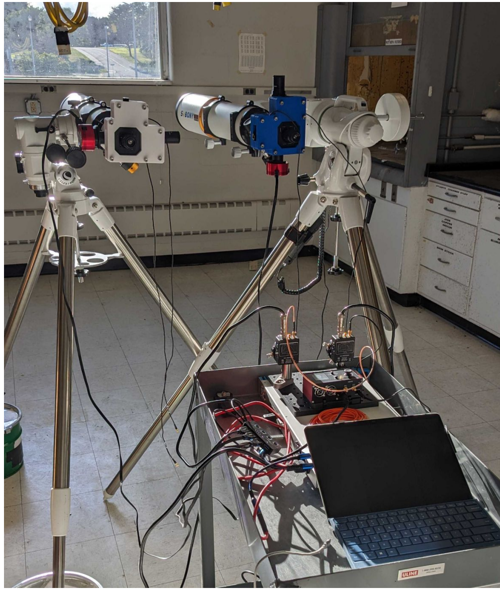


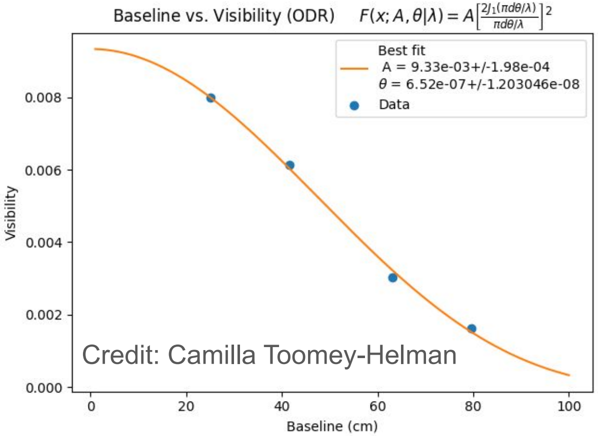


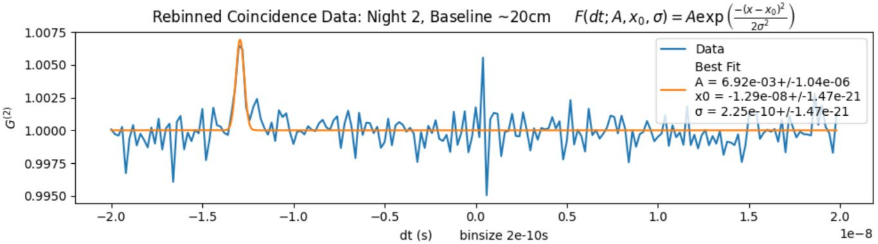
https://mirrorcletech.com/pdf/DSF/Mirrorcle_MEMS_Mirrors_-_Datasheet_A5L2.2-6400.pdf

Ground Tests with Artificial LED "Star"

- "Artificial star": D=50μm fiber emitting filtered & polarized light from a red LED
  - Alluxa ultranarrow filter 656.4nm, FWHM 0.1nm
- Collect light onto two 50μm fibers into ThorLabs SPADs
- Successful HBT measurement of fiber size
- Two 50μm fibers in one ferrule: "binary artificial star"
  - Rotate fiber bundle to measure fiber separation







$D_{Measured}$ = 51.5±1.0 μm

$D_{Manufacturer}$ = 50±1 μm

(https://www.thorlabs.com/thorproduct.cfm?partnumber=M42L01)

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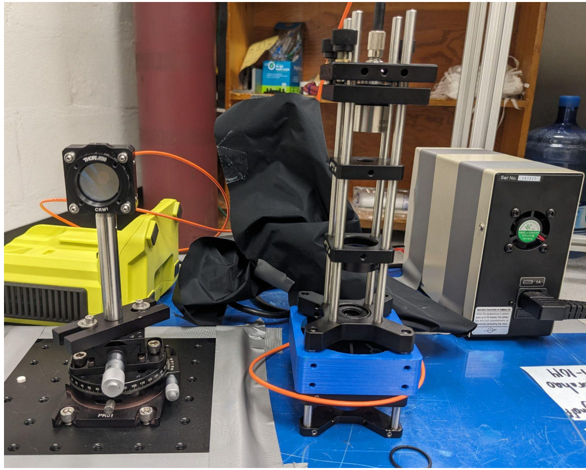

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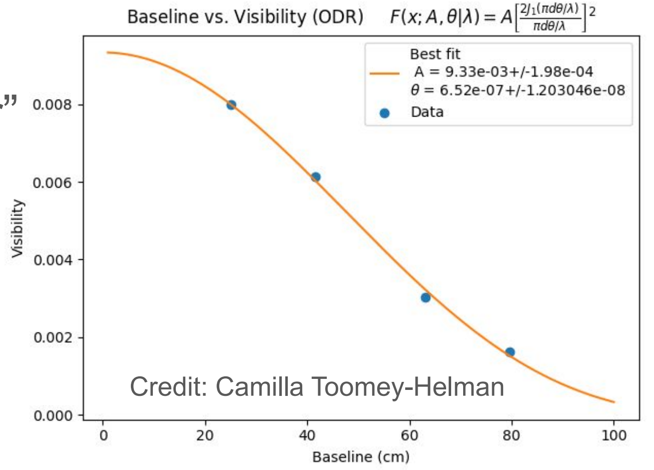
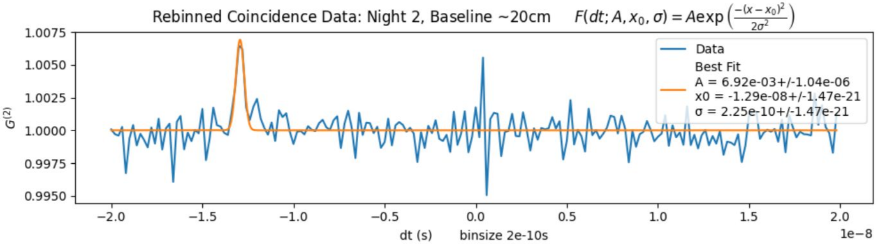
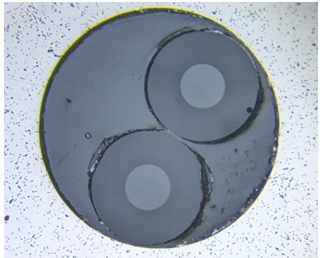
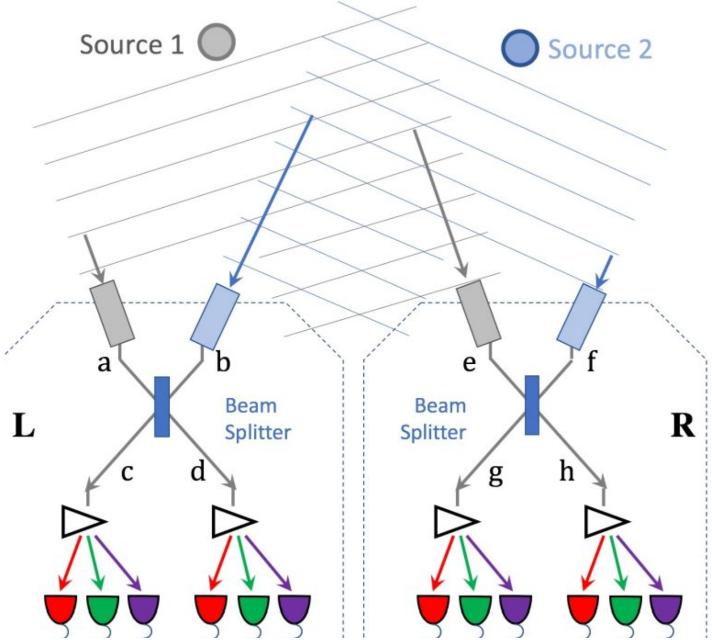






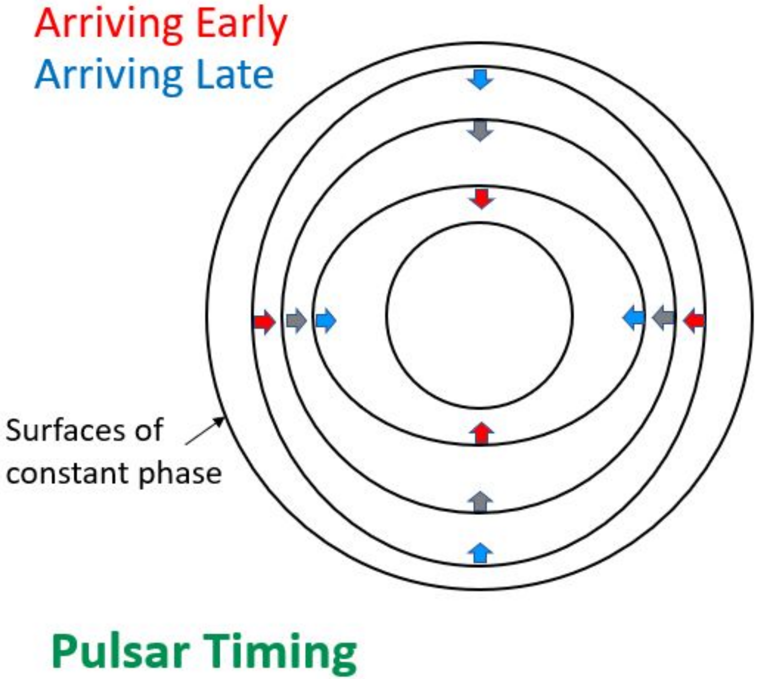
Conclusion

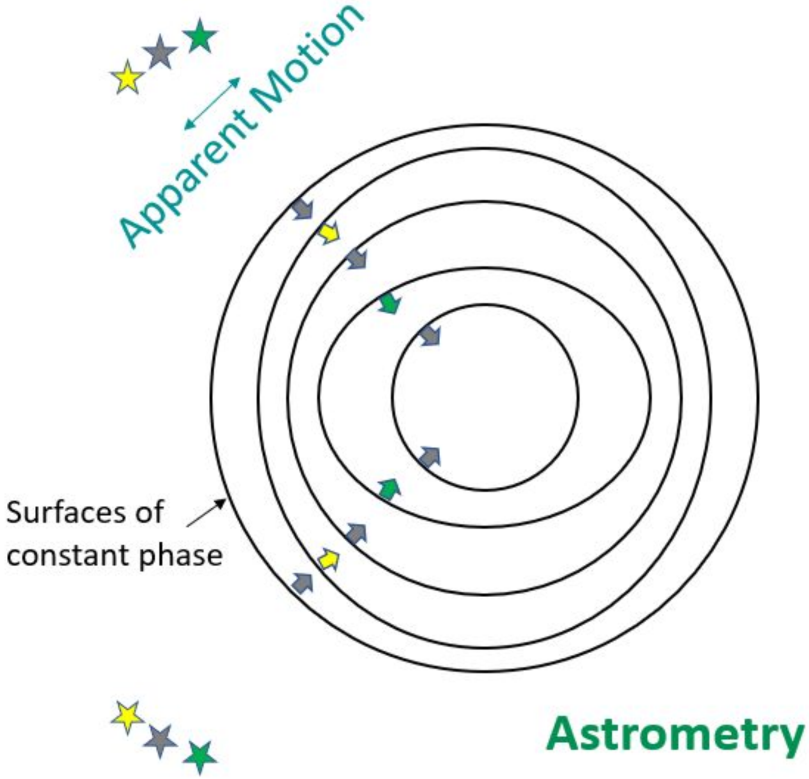
- Intensity Interferometer for wide-angle precision astrometry
  - Requires no optical connection between stations
  - Offline analysis
  - Improved baselines
  - Simplicity and scalability
- Active research:
  - Broadband HBT measurement
  - First-Order Adaptive optics
  - On the ground test measurements



Stankus et al. 2022
https://doi.org/10.21105/astro.2010.09100

Friday 10:45 - Paul Stankus: Two-Photon Methods for Astrometric Gravitational Wave Detection





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Publications

J. Ferrantini, J Crawford, & S. Kulkov et al. 2024. arXiv:2406.13959v1

J. Crawford et al. 2023 *Optics Express* doi:10.1364/oe.486342

M. Keach et al. 2022 *Proc. SPIE 12183* doi:10.1117/12.2632122

P. Stankus et al. 2022 *Open Journal of Astrophysics* doi:astro.2010.09100

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