



Astrophysical measurements with the VERITAS Stellar Intensity Interferometer

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Stellar Intensity Interferometery with Imaging Air Cherenkov Telescope arrays





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> -The large mirror areas and fast photo-detectors make Imaging Air Cherenkov Telescopes suitable for performing Stellar Intensity Interferometry (also known as Hanbury-Brown and Twiss interferometry). [1,2]



-Furthermore, the array arrangement allows for many baselines:

$$N_{pairs} = \frac{N_{tel}(N_{tel} - 1)}{2}$$

[1] LeBohec S., and Holder J., "Optical intensity interferometry with atmospheric cerenkov telescopes", *The Astrophysical Journal*, **645**(1), 399, (2006) [2] Hanbury Brown, R., "*The intensity interferometer. Its application to astronomy*". Taylor and Francis (1975)



Scientific Motivation for SII





Key Point: SII provides a way to spatially resolve stars at unprecedented scales + wavelengths. Topics of study include: stellar diameters, stellar limb-darkening, rapid rotators, cepheid variables, ...



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Figure 5. Image reconstructions using three-point correlation information.

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2-Tel Intensity Interferometry with VERITAS

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SII Augmentation of VERITAS Telescopes





High-speed (250 MS/s) continuous streaming + offline FPGA correlator





- Identical SII system installed on all VERITAS telescopes.
- Digitizers synchronized via central 10 MHz clock using White Rabbit hardware
- Distributed trigger system to start data taking simultaneously (< 4 ns)
- For more details, see D. Kieda's poster PS1-76 and another on the custom-built HV system PS3-51



Observation Summary



	Table 1: O	bservation/Target S	Summary			
Obs. Date Target	Type m	$_B \theta_{UD} \ (mas)$	Obs. Time (h)	Coverage (m)	$ V(d) ^{2}$	
2019-01-19 κ Ori (Sa	iph) B0.5Ia [†] 1.8	$0.44 \pm 0.03^*$	4.74	39.1 - 81.0	0.6 - 0.85	
2019-01-23 γ Ori (Be	ellatrix) B2III [‡] 1.4	42 $0.701 \pm 0.005^*$	5.13	51.6 - 81.5	0.3 - 0.65	Δ

* Richichi, A., Percheron, I., and Khristoforova, M. Charm2: An updated catalog of high angular resolution measurements*. A&A, 491(2):773-777, 2005.

[†] Crowther, P. A., Lennon, D. J., & Walborn, N. R. 2006, A&A, 446, 279de Plaa, J., Kaastra, J. S., Werner, N., et al. 2017

[‡] R. S. Levenhagen, N. V. Leister, Spectroscopic analysis of southern B and Be stars, MNRAS, Volume 371, Issue 1, 1 September 2006, Pages 252-262





Image generated with Stellarium



Typical run length of 20 minutes

Data Reduction (correlator data product)





Data product consists of series of "correlograms" averaged over 'cycle' period over the duration of the run.





Measurements on Gamma Orion from UTC 2019-01-23





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Stellar Diameter Estimates







Summary/Looking Forward





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 Successful SII measurements with IACT telescopes during bright moon conditions!

 \rightarrow Proof of concept for future telescope arrays

- System now setup and tested on 4telescopes, extends coverage for better source characterization.
- ~ 2x improvement in sensitivity possible with existing setup.
 → Improvement in noise rejection + digitization rate
- Extension to multiple optical passbands