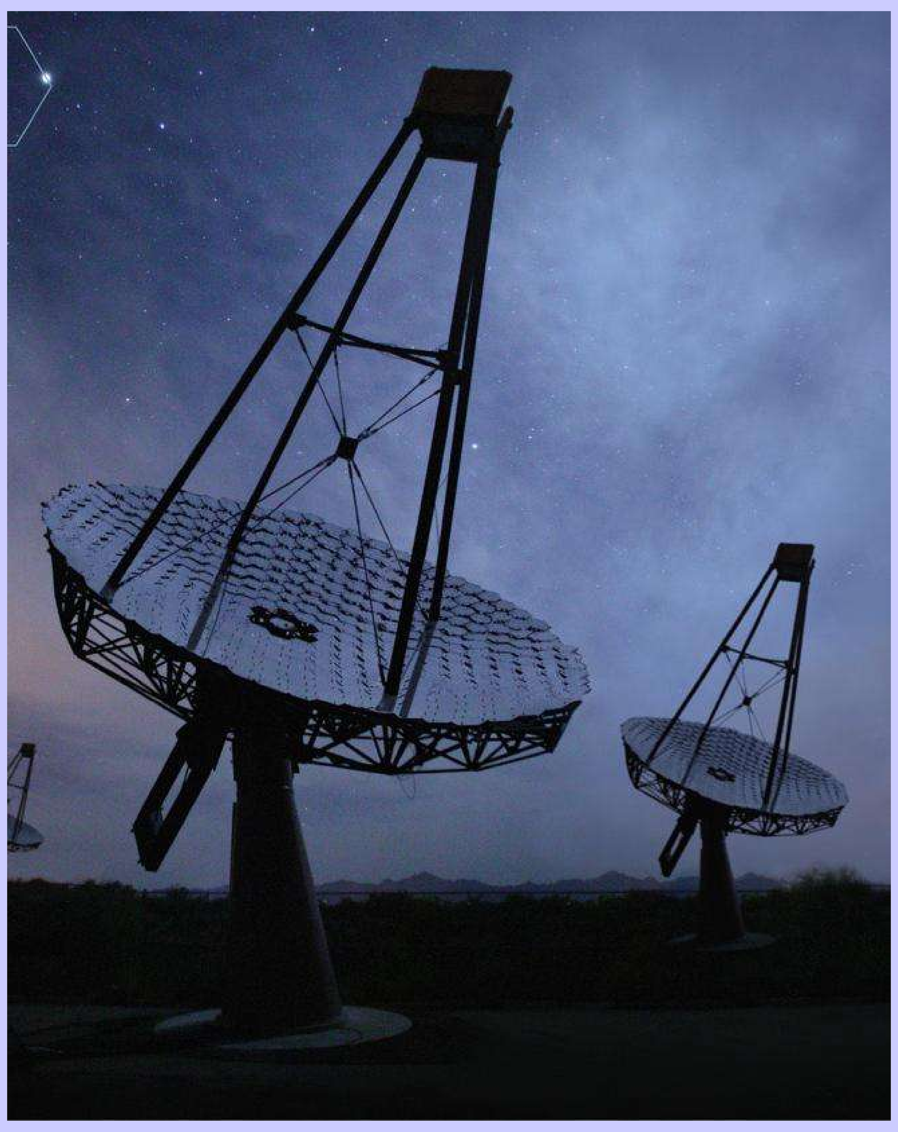
Intensity Interferometry With Atmospheric Cherenkov Telescopes

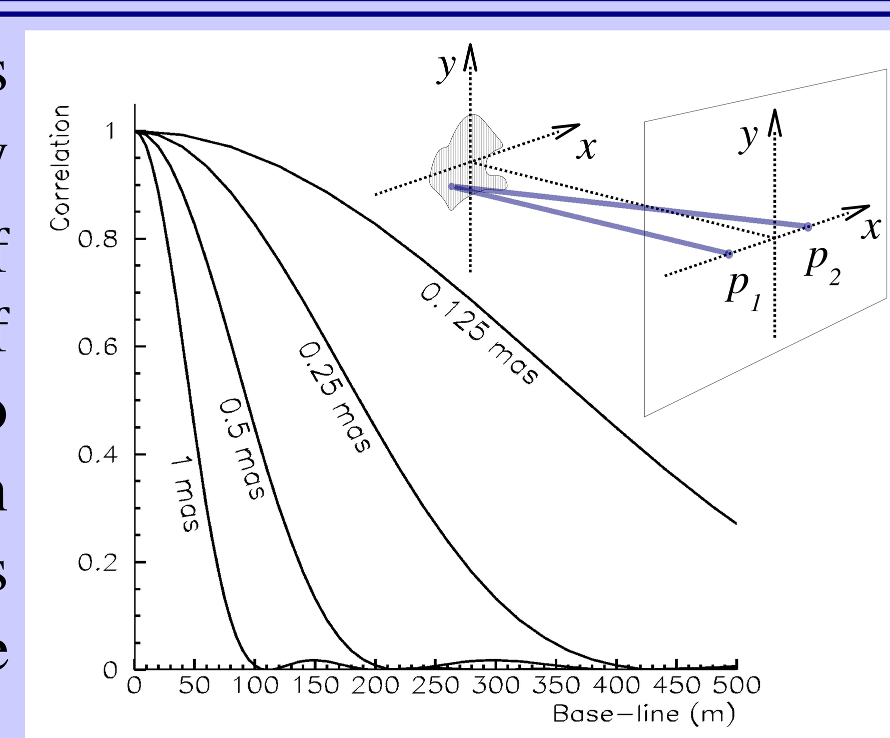
(S.LeBohec and J.Holder)

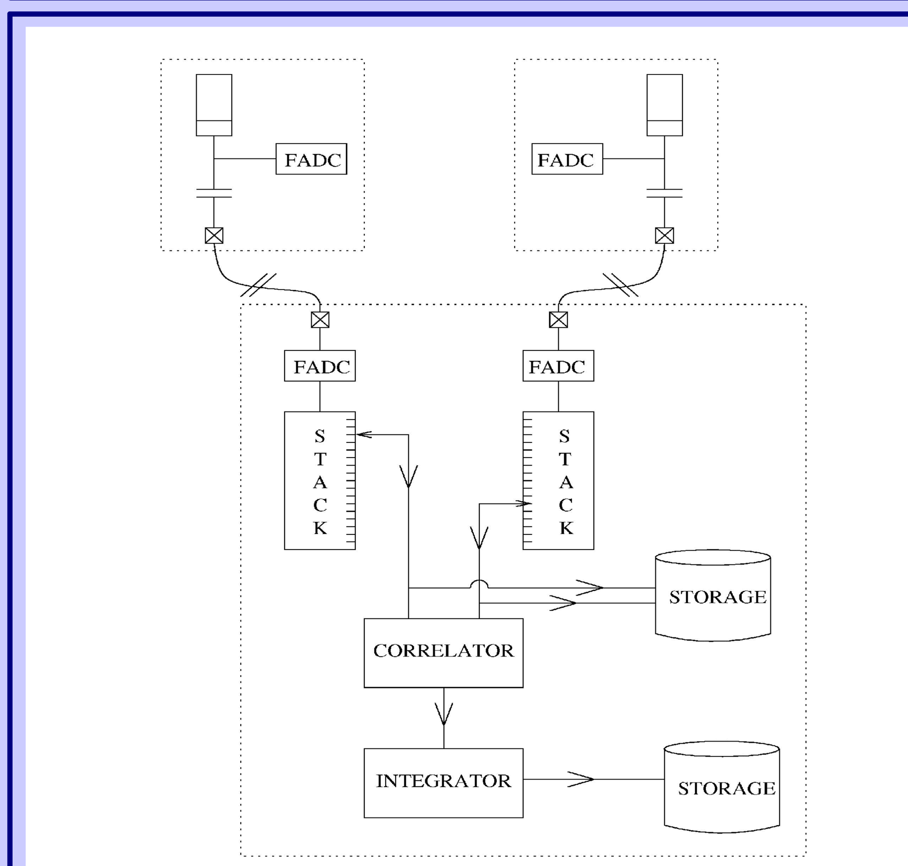
The Narrabri interferometer consisted of two telescopes, 6.5m in diameter, with an 11m focal length ❍ The telescopes were carried on trucks running on a circular railway track 188m in diameter ❍ This gave baselines for interferometry of 10m to 188m to track any star, while keeping the line joining the two telescopes perpendicular to the direction of the star ❍ Signals from the single focal photo-multipliers were sent to a central control building where they were correlated ❍ The Narrabri interferometer was successfully used more than 30 years ago to measure 32 stars all brighter than B=+2.5 among which some were found to have an angular diameter as small as 0.41+/-0.03 milli-arc-seconds (mas).



Imaging Atmospheric Cherenkov Telescopes Arrays (IACTA) consist of telescopes 10 to 17 meters in diameter separated by distances from 80 to 180 meters used to record the Cherenkov light from high energy particles cascades developing in the atmosphere ❍ Used as interferometers, these arrays could perform stellar measurements over several baselines with a sensitivity exceeding that of the Narrabri interferometer and, using modern photo-detector and signal processing technology, approaching that of current major Michelson interferometers ❍ Only the central photo-multiplier in ACT cameras would be modified to be used in interferometric observations, which would not affect gamma-ray observations ❍ Atmospheric Cherenkov observations are restricted to moonless nights. Performed at narrow optical bandwidth intensity interferometry is much less sensitive to diffuse background light, hence the observation programs would be compatible ❍ Possible future IACTAs could involve large number of telescopes over up to kilometer baselines further increasing sensitivity and angular resolution ❍ Intensity interferometry could broaden and increase the scientific output of major IACTA projects.

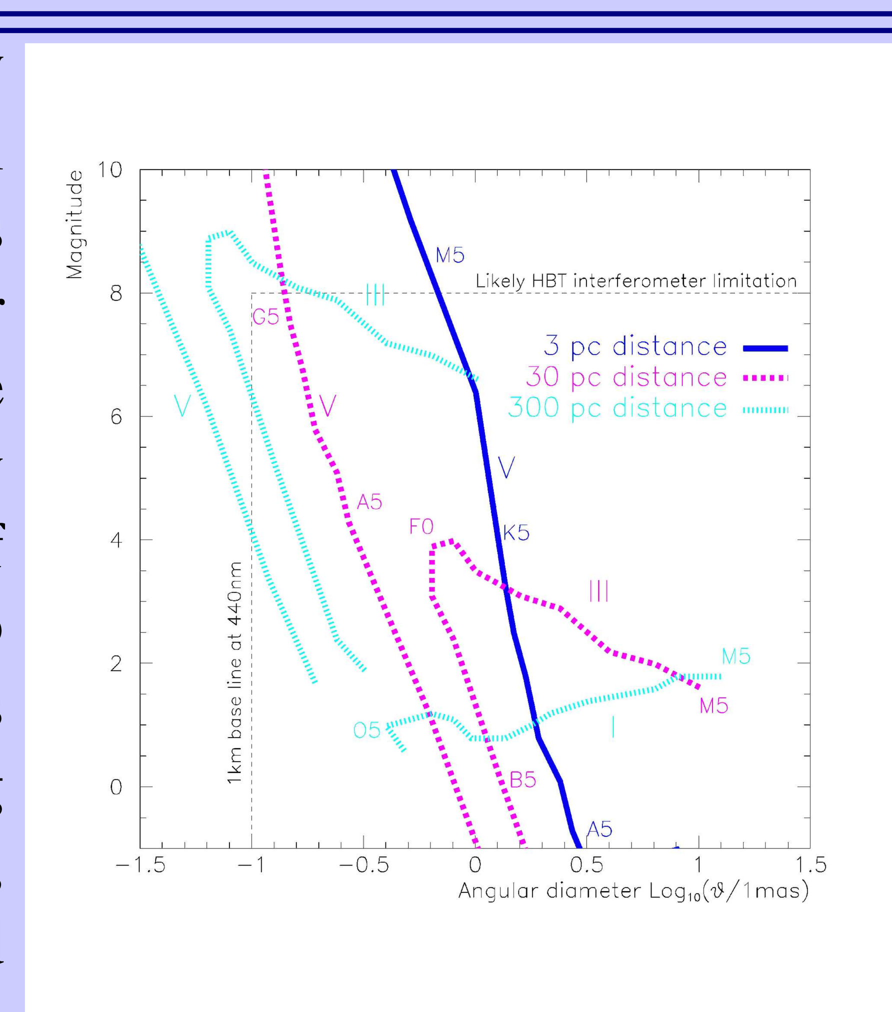
Intensity interferometry is based on the fact that the signal fluctuations at two detectors (p_1 and p_2) are partially correlated ❍ The degree of correlation can be measured by integrating over time the product of the two signals ❍ It can be shown that the degree of correlation is equal to the square of the degree of spatial coherence ❍ The absolute value of the degree of coherence is the fringe visibility measured with Michelson interferometers ❍ The relation between the the degree of coherence and the structure of the source is given by the van Cittert-Zernike theorem: the degree of coherence of the light at two receivers is given by the normalized Fourier transform of the distribution of intensity across the source along a line parallel to the line joining the 2 receivers.





Possible Implementations of intensity interferometer could be based on a central digital correlator collecting analog signals from each telescopes ❍ The photo-detector DC output current could be measured at each telescope ❍ The AC component could be transmitted by a high band-width cable to the central station where it would be digitized ❍ The correlator could be easily implemented on an FPGA ❍ The FPGA could be also programmed to apply the delay necessary to bring signals from different telescopes in time ❍ The correlated signal could be integrated and stored at regular interval or recorded at high rate for off-line analysis ❍ A great advantage of a digital system is that once the signals are digitized they can be used in as many correlations as one needs with out any information loss ❍ A 100 telescope array would allow simultaneous measurements over 4950 baselines, with a corresponding increase in sensitivity.

Astrophysics that can be addressed covers many of the areas currently being explored by Michelson interferometers ❍ The catalog of directly measured stellar diameters is still limited to a few hundreds , and only a few measurements have been made of lower-mass dwarf stars and hot main sequence stars ❍ Such direct measurements are important for models of stellar atmospheres and stellar evolution, and can be used to calibrate surface brightness relations ❍ Other applications include measuring the parameters of binary systems, measurements of the circumstellar environment – particularly in the case of variable stars (e.g. Cepheids or Mira variables) or stars with high mass loss (e.g Be stars) ❍ It may even be possible to resolve simple features on the surface of giant stars such as Betelgeuse ❍ The specifics of the technique make certain applications more attractive; long baseline measurements at short wavelengths are very difficult for Michelson instruments, but relatively easy for intensity interferometers ❍ Long term monitoring of sources and studies over a wide range of wavelengths are also simple with this technique.



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