Intensity Stellar Interferometry

Stars are objects similar to our Sun but located at such tremendous distances from the Earth, they are seen millions of times smaller. Because they are so small and because of scintillation and diffraction (Figure 7) of light waves, even the largest telescopes can not reveal the details on their surfaces. At the end of the 19th century, A. Michelson invented an instrument (the Michelson interferometer) which allows to observe the size and shape of stars. In a Michelson interferometer, the light waves received at two telescopes are combined to produce *interferences*. The visibility of interferences depends on the distance separating the two telescopes and on the size and shape of the star. All stellar interferometers in use today are Michelson interferometers. However, in the 50's, Robert Hanbury Brown invented an alternative type of interferometer, the Intensity Interferometer, in which the light intensity fluctuations recorded by two telescopes are combined instead of the light waves. This type of interferometers is easier to construct, but requires much larger telescopes than a Michelson interferometer. At StarBase, we are testing Intensity Interferometry electronics to prepare interferometric observations in the visible with future large air Cherenkov high energy observatories.

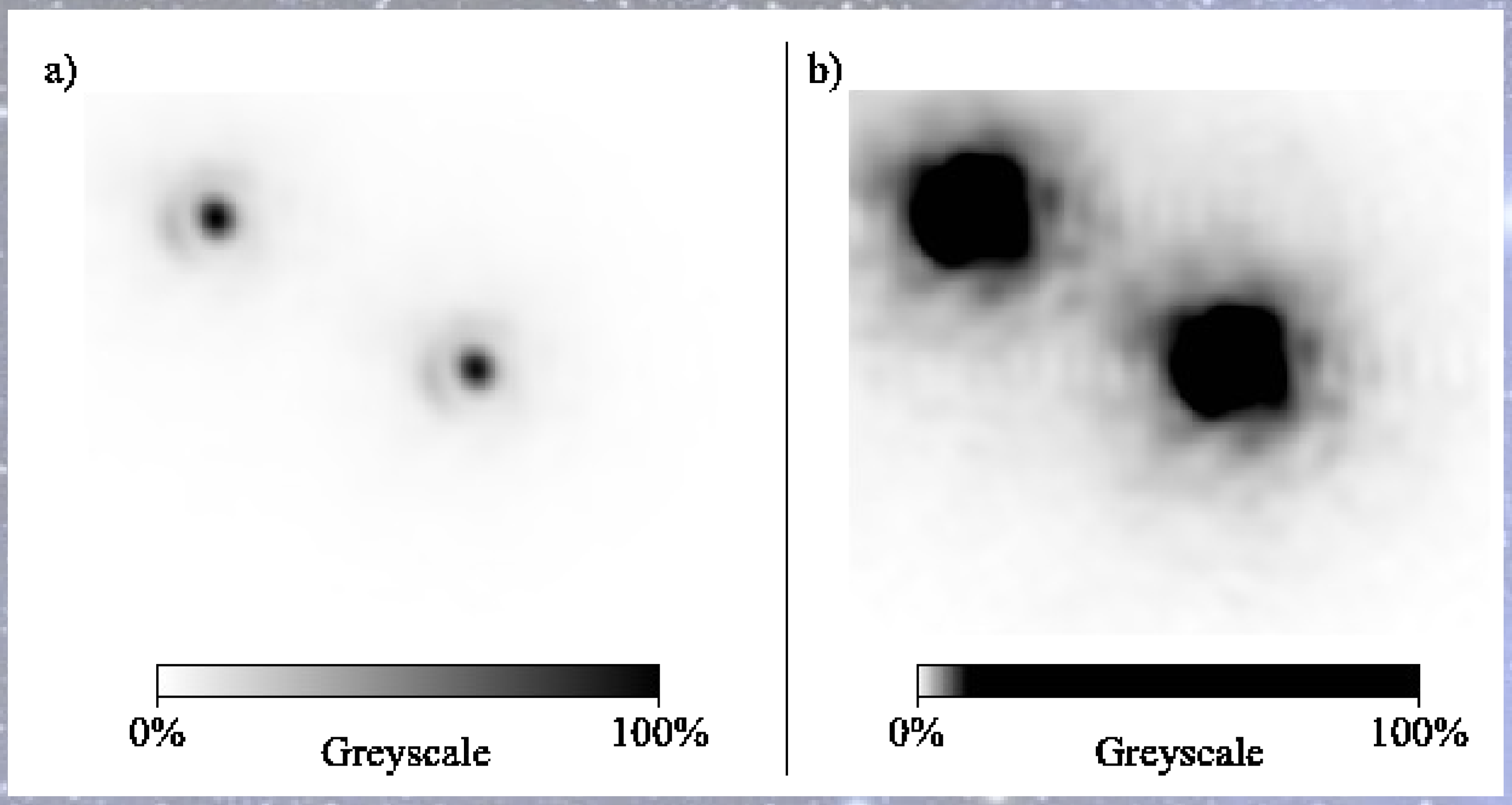

Figure 7: The double star is pictured twice. On the left, the exposure was very short and the stars appear with surrounding rings. The rings results from ***diffraction*** in the telescope. When light waves go through an opening, some of the light changes direction, creating the ring pattern. On the right, the exposure was longer. The rings are not visible anymore and the images are smeared by ***scintillation***. Scintillation results from the light changing direction randomly as it travels through turbulent atmosphere. It is a little like watching stars from under water. The waves at the surface of the water are responsible for random changes in the direction of the light. ***Diffraction*** and ***scintillation*** prevent regular telescopes from providing stellar surface images.

Intensity Interferometers

In an Intensity Interferometer, such as the one constructed by Robert Hanbury Brown 1965 (Figure 8), light intensity from a star is recorded in two large telescopes. The ***photo-detectors*** need to be very fast so individual ***photons*** can be recorded at a rate close to a billion every second. The electric signals are then collected in a central building where special electronics search for correlations in the intensity fluctuations at both telescopes. There is a correlation when both telescopes receive photons at the same time more often than would be expected just by random chance. The intensity correlation depends on the distance between the two telescopes as well as on the size and shape of the star. Hence an image of the star can be obtained.

Figure 8: The Narrabri Intensity Interferometer was constructed in 1965 and operated until 1971. Each telescope was 6m in diameter, twice as large as the StarBase telescopes.

How does it work?

Imagine a star that would shine in just two points with slightly different frequencies of the light waves (different colors). Then, at one telescope the two waves combine and because of their difference in frequency they create a beating effect (Figure 9), like an off tune piano. This beating effect corresponds to an excess of intensity fluctuation. If we now consider another telescope at some distance from the first one, it will record the same excess of intensity fluctuations but the beats will be shifted in time, the beats will not arrive at the same time in both telescopes. The more the beats arrive at the same time, the greater the correlation between the intensity fluctuations are. The difference in time and, therefore, the intensity correlation depend on the distance between the two points on the star and on the distance between the two telescopes.

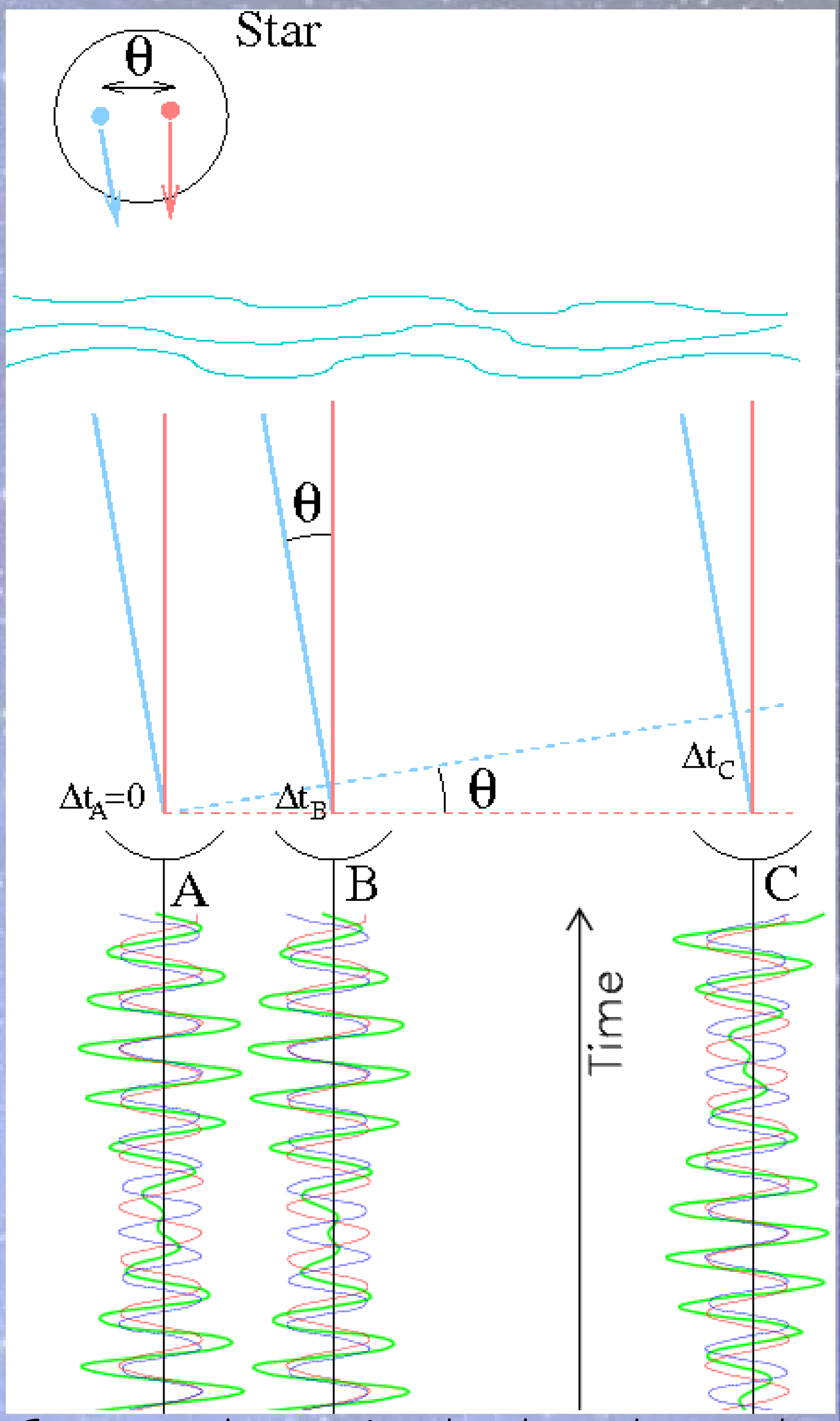

Figure 9: Telescopes A and B being close together receive beats almost at the same time resulting in a high degree of correlation. Telescopes A and C being further apart, do not receive beats at the same time and the correlation is low.

What can we learn?

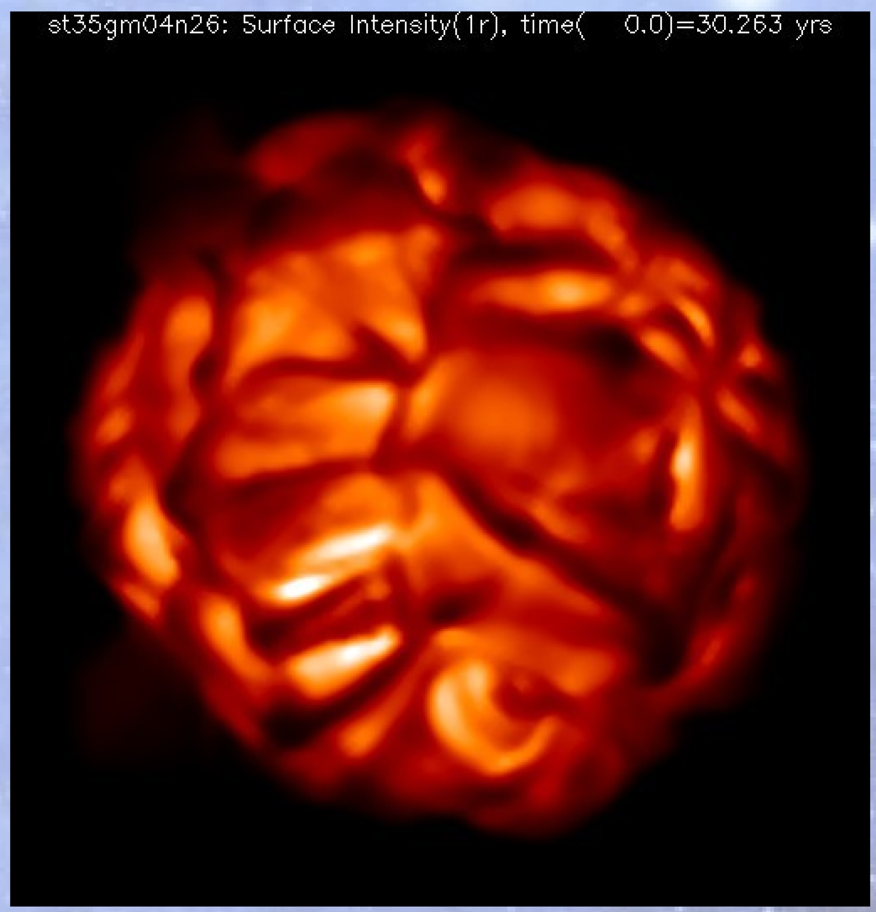

Figure 10: A theoretical numerical simulation of what a red super-giant star like Betelgeuse might look like

Stars exist in a broad range of varieties with different features that have been predicted but never directly observed. Large arrays of telescopes with Intensity Interferometry capability could achieve this breakthrough and reveal hot and cool spots (Figure 10) that are expected in young and old stars, show effects of mutual interactions in ***close binary*** systems and identify disks and rings around stars that might be forming ***planetary systems***.

At StarBase, with only two telescopes, we can only observe binaries and measure a few stellar diameters. Our main goal is to develop a modern version of Intensity Interferometry technology that will be used in larger observatories.

Background: "Pleiades and stardust" from NASA Astronomy Picture of the Day, credit: Tony Hallas