Light !

Université de Strasbourg
Kiepenheuer Institut für Sonnenphysik
European Summer School on the physics of light

Stellar Interferometry

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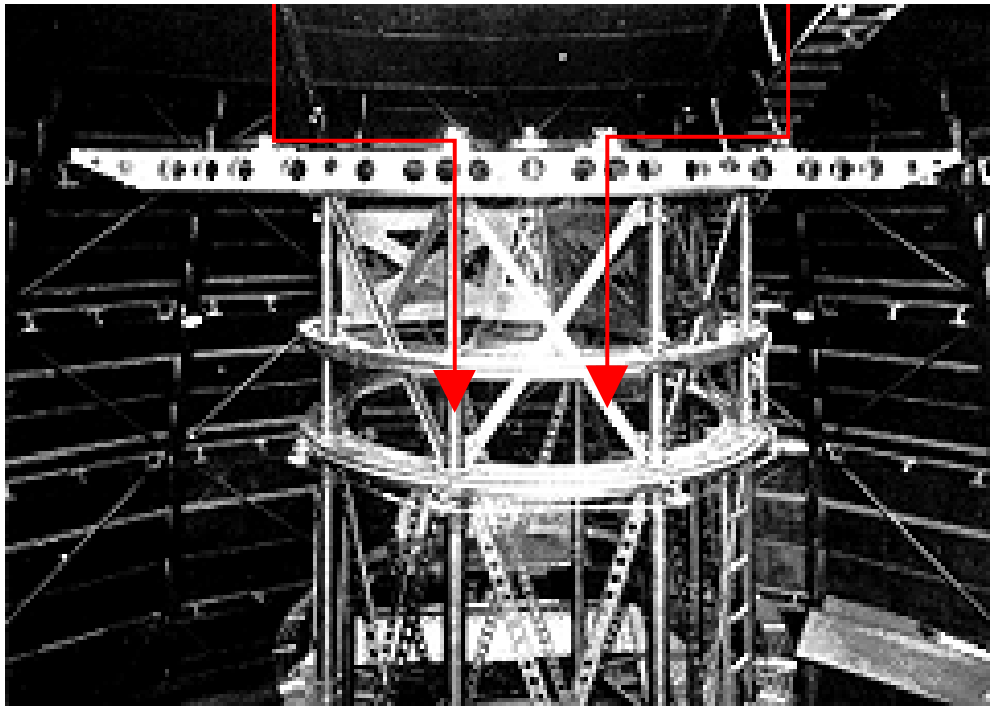
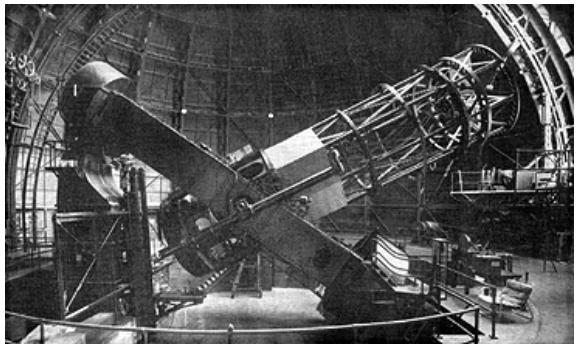
Michelson Stellar Interferometer

- Introduced by Michelson and Pease to increase baselines beyond the telescope diameter (1919)
- Beam with four small, flat mirrors at the entrance of the 2.5m Hooker telescope (Mt. Wilson, CA, USA)
- Max baseline 5 m
- Outer two mirrors act as collectors
- Interference observed in the focal plane where images overlap
- The telescope is pointing device and beam combiner
- Measured some 20 apparent diameters of bright stars
- (i.e., α Ori (Betelgeuze) 44mas)

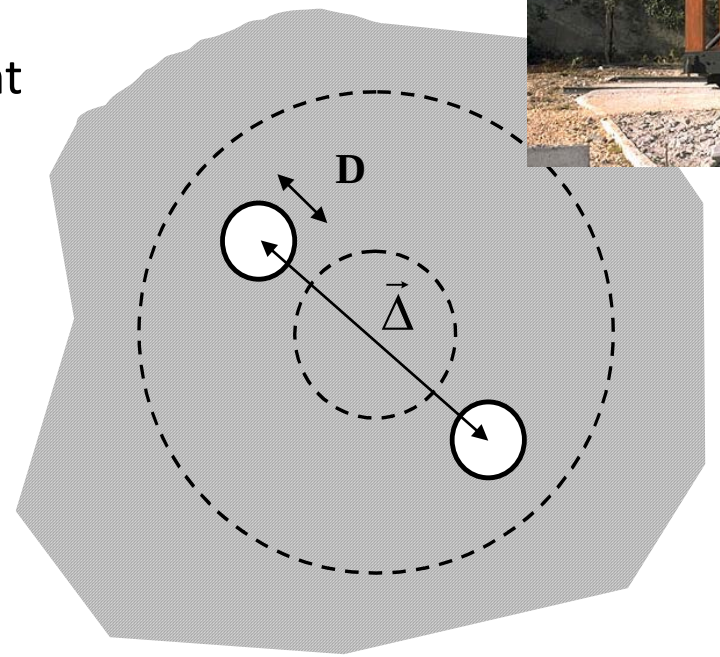




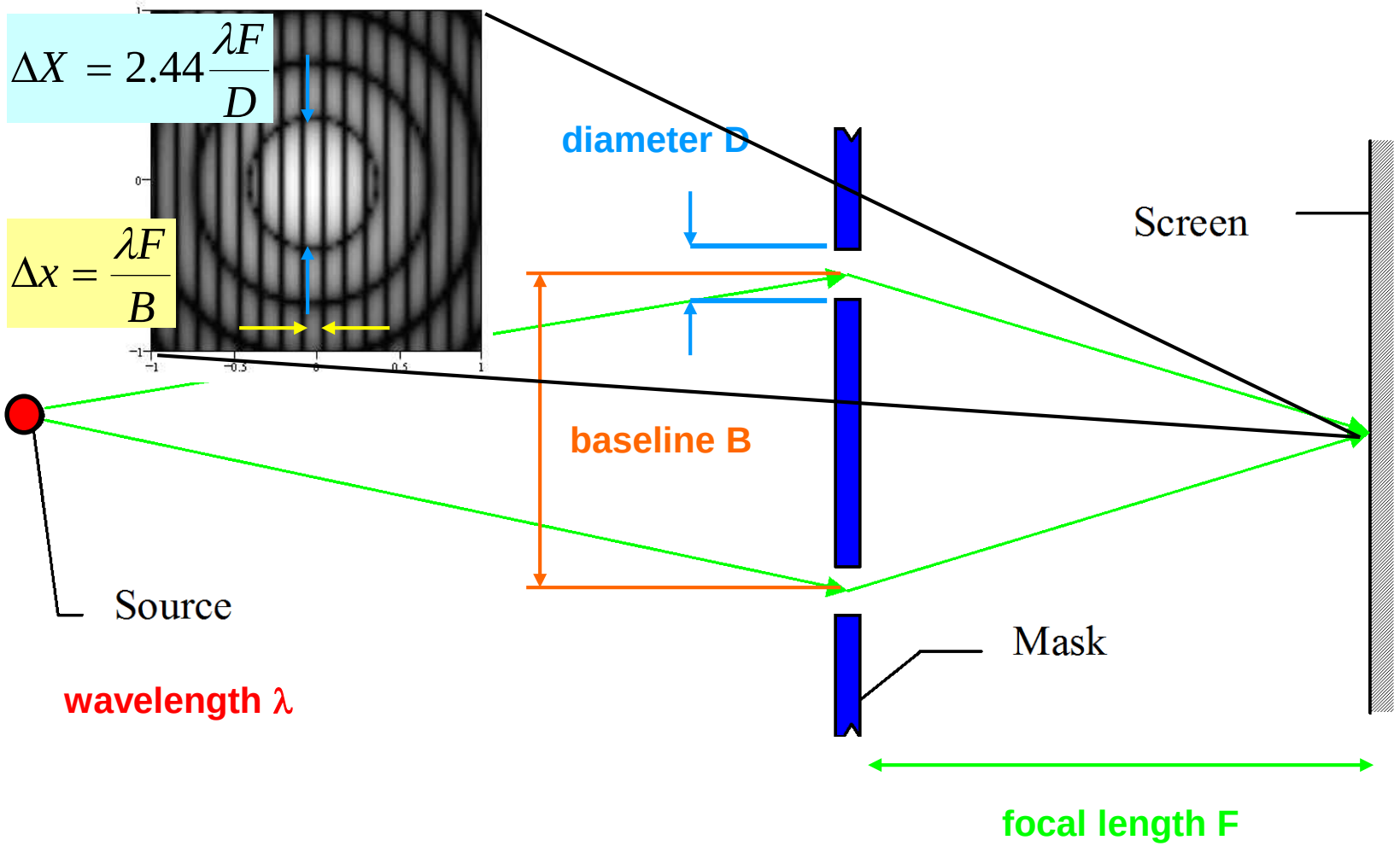
The first attempt to remedy seeing …

- Hippolyte Fizeau (1868): use an aperture mask for large telescopes to reduce seeing effects when measuring stellar diameters
- Realized by E. Stéphan at the Observatory of Marseille using the 80cm Foucault reflector, but without results (1871)
- Variant of a Young‘s interference experiment

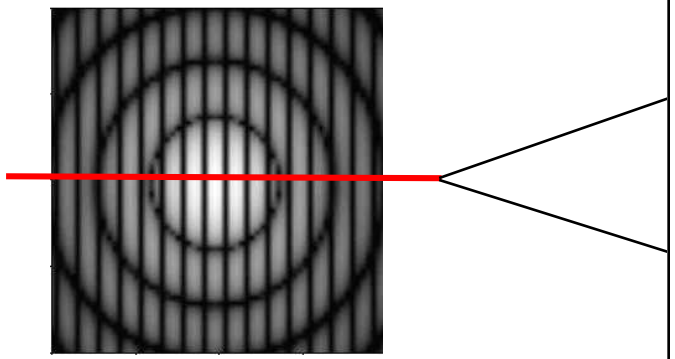
- **Element diameter** *D*
- **Baseline** $\vec{\Delta}$, $\left|\vec{\Delta}\right| >> D$



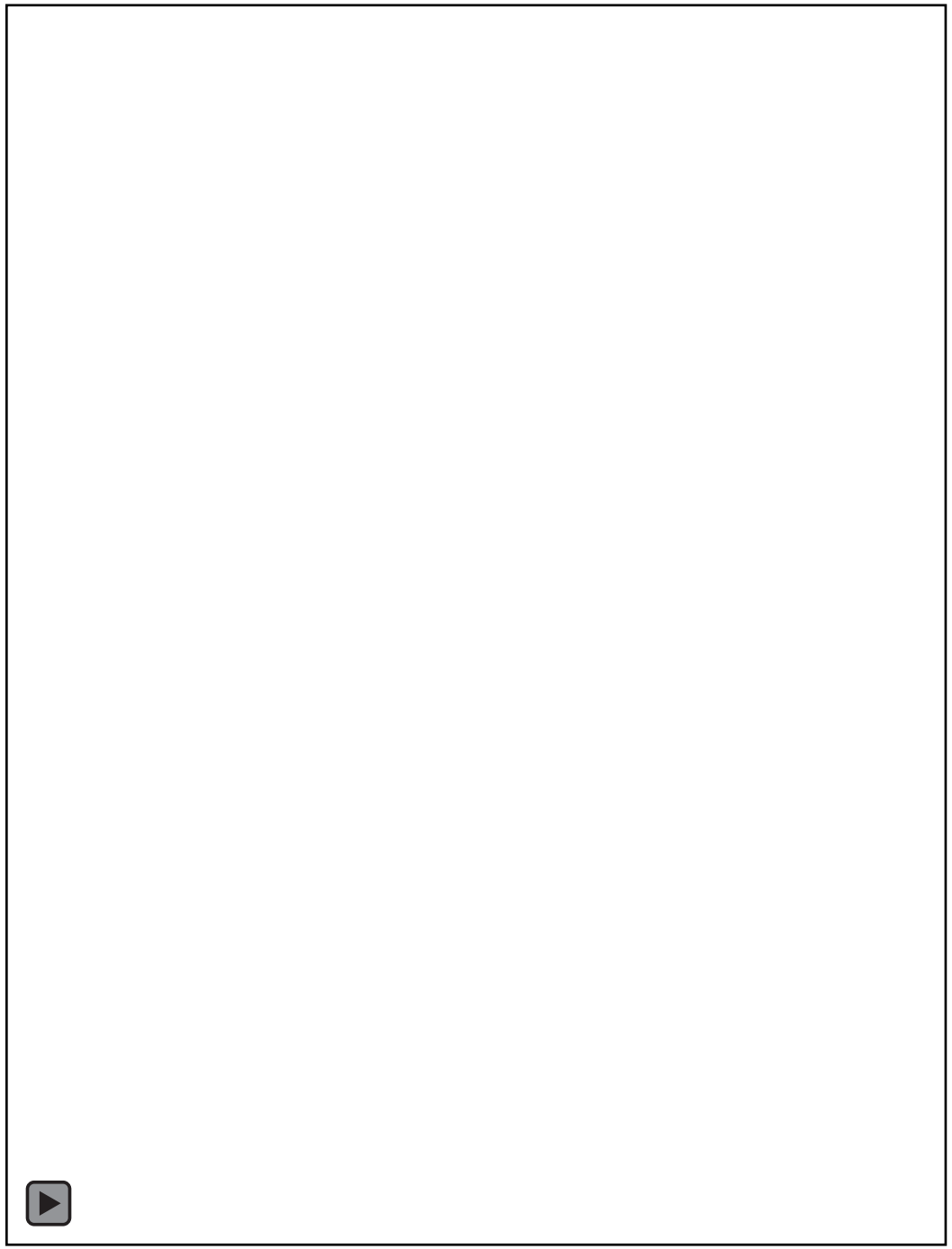
A Young‘s interference experiment



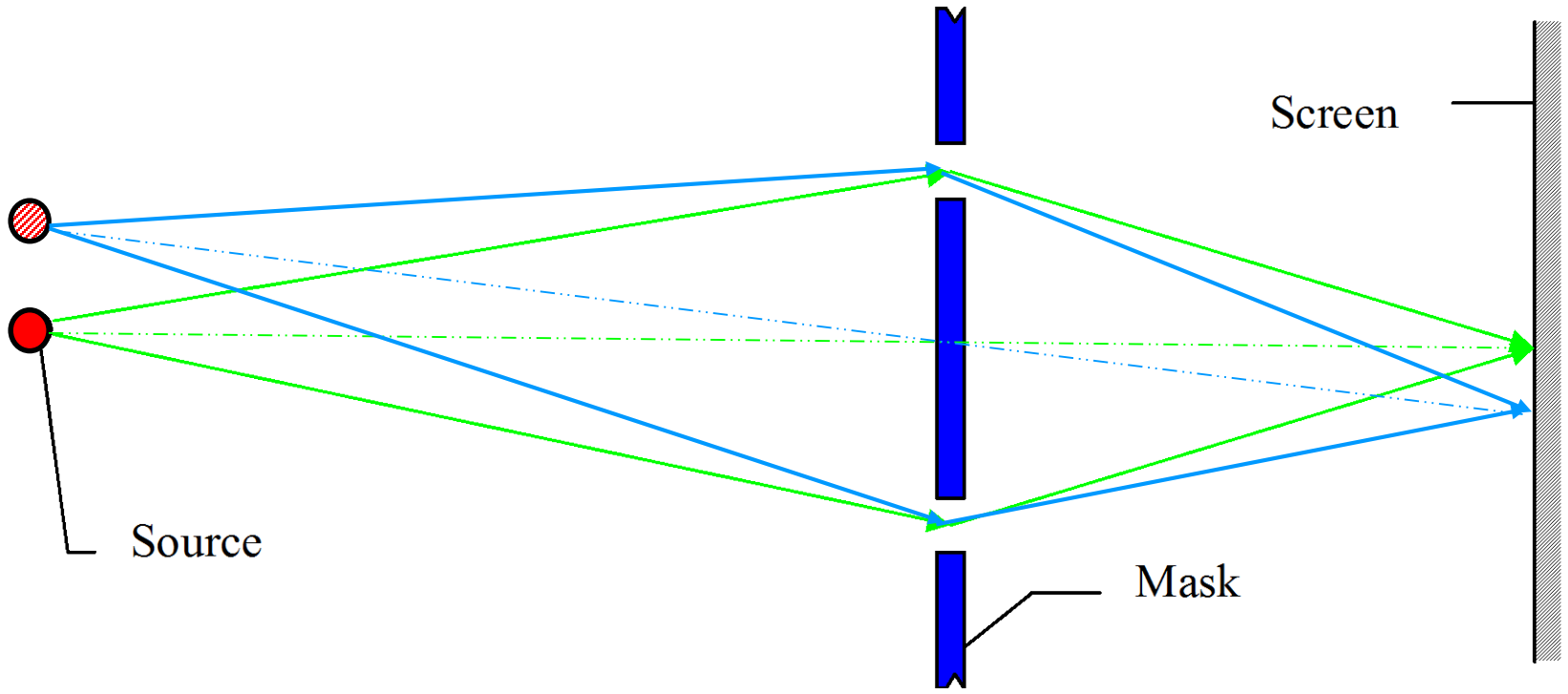
Change of Baseline



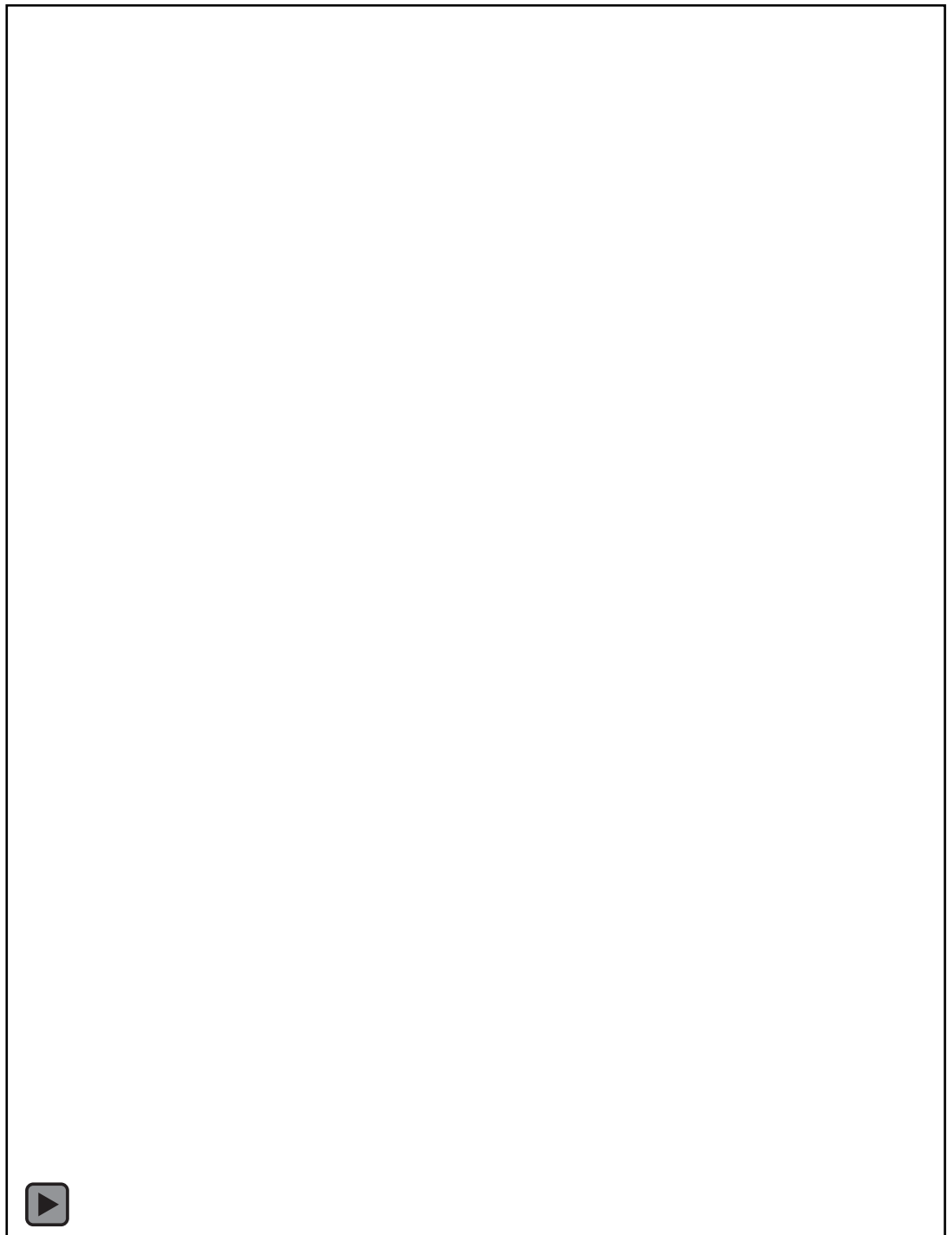
Change of wavelength



Dependence on source position



Dependence on source position



Electromagnetic waves and coherence

- Monochromatic scalar e.-m. wave

$$V(\bar{r},t) = U_{\omega}(\bar{r}) \exp -\left[j\omega t \right]$$

position in space $\vec{r}$, time t $\quad U,V \in \mathbb{C}$

- Kirchhoff-Fresnel integral describes wave propagation

$$U_{\omega}(\bar{r}_o) = \frac{1}{j\lambda} \iint_{\sum} U_{\omega}(\bar{r}_1) \frac{1}{r} \exp\left[2\pi j \frac{r}{\lambda} \right] \chi(\vartheta)\, ds$$

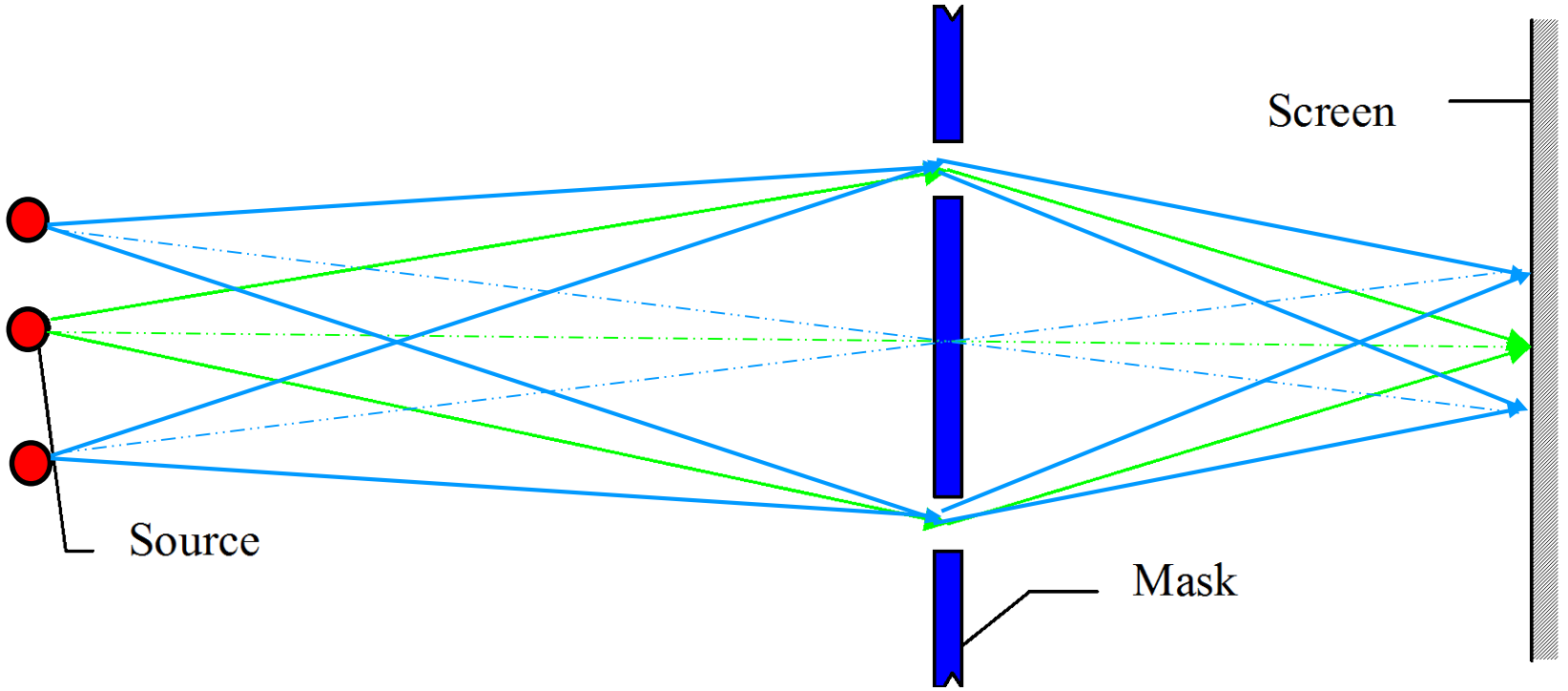
- Intensity at point of superposition in a Young's interferometer

$$\begin{aligned} I(\bar{r},t) &= \left\langle \left| V_1(\bar{r},t) + V_2(\bar{r},t) \right|^2 \right\rangle \\ &= I_1(\bar{r},t) + I_2(\bar{r},t) + 2\,\mathrm{Re}\left\{ \left\langle V_1(\bar{r},t) V_2^*(\bar{r},t) \right\rangle \right\} \end{aligned}$$

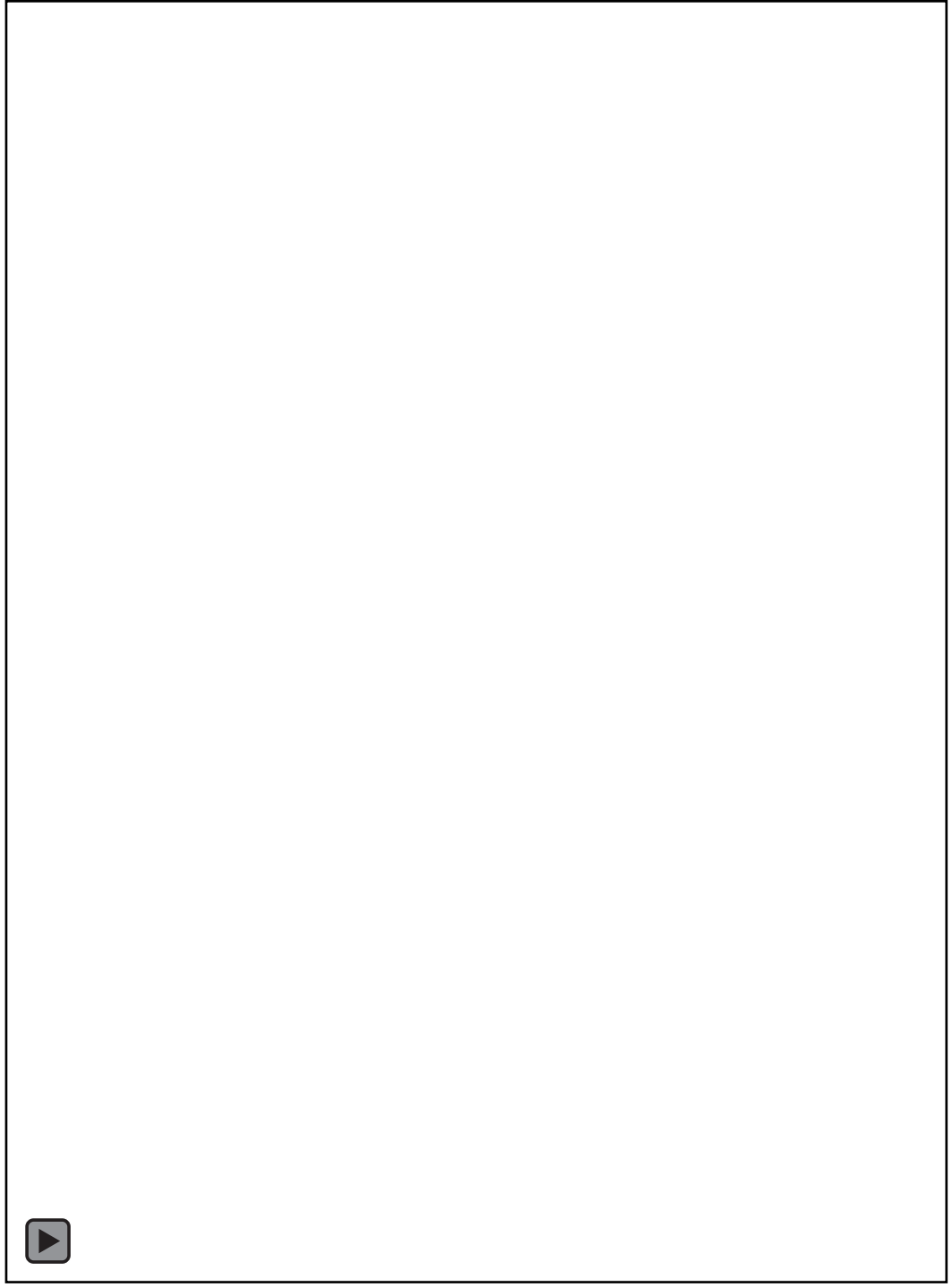
- Mutual intensity (spatial coherence)

$$J_{12} = \Gamma_{12}(0) = \left\langle V(\bar{r}_1,t_1) \cdot V^*(\bar{r}_2,t_1) \right\rangle$$

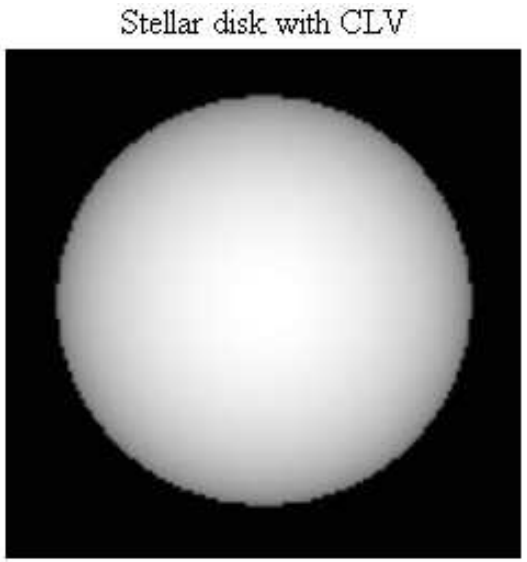
Extended sources



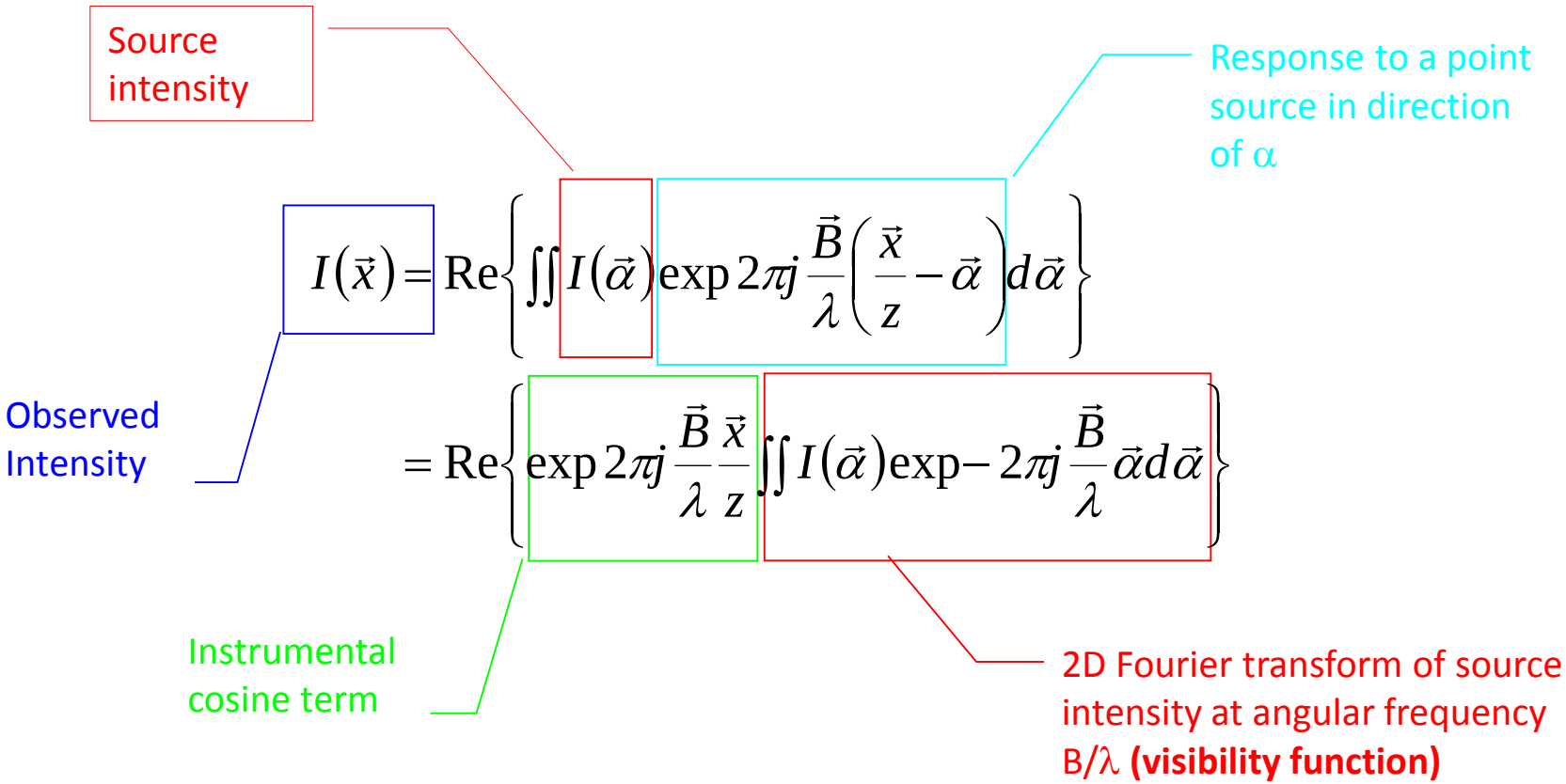
Spatially extended source – double star

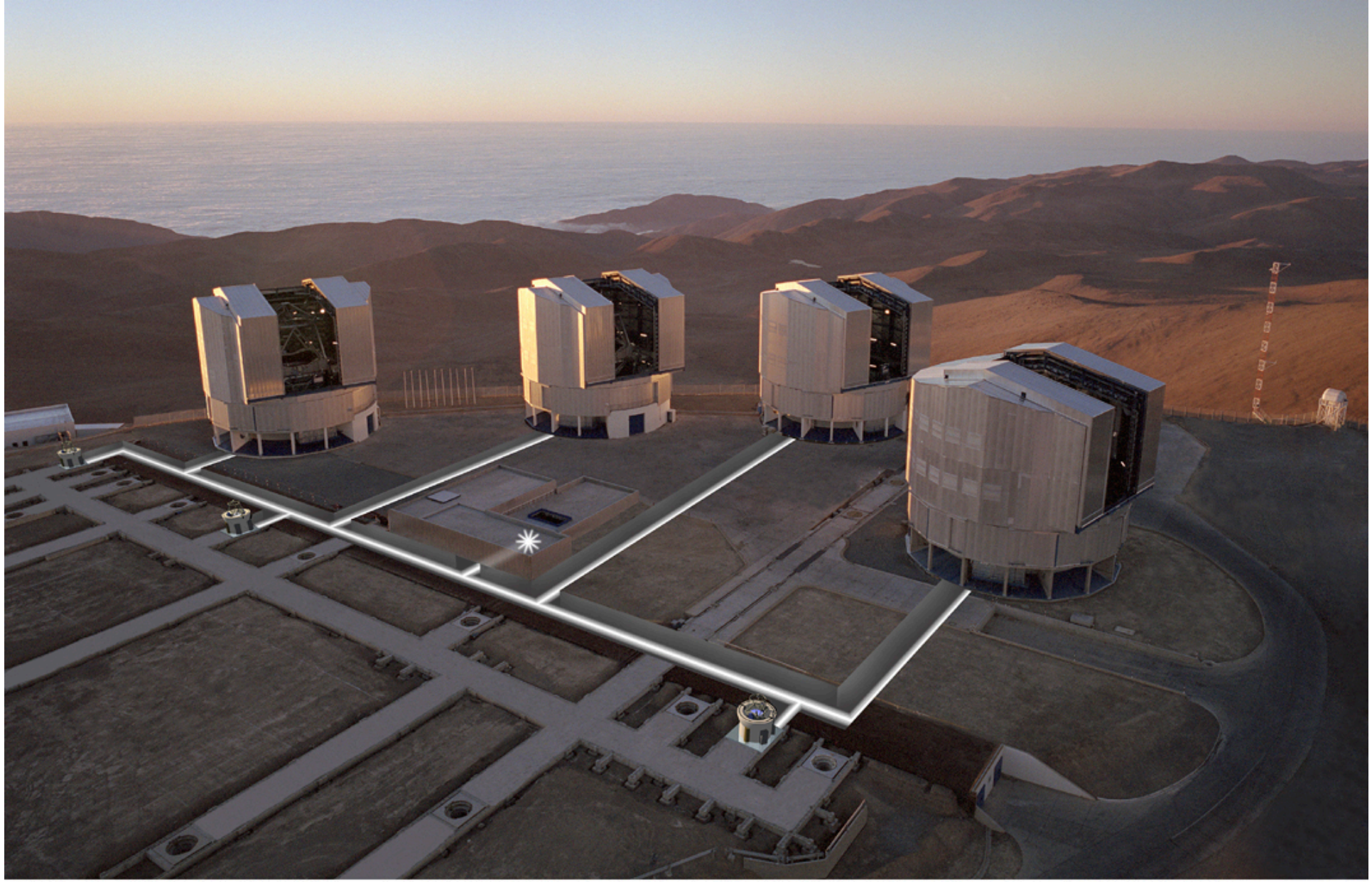


Spatially extended source - limb darkened stellar disk



van Cittert - Zernike theorem

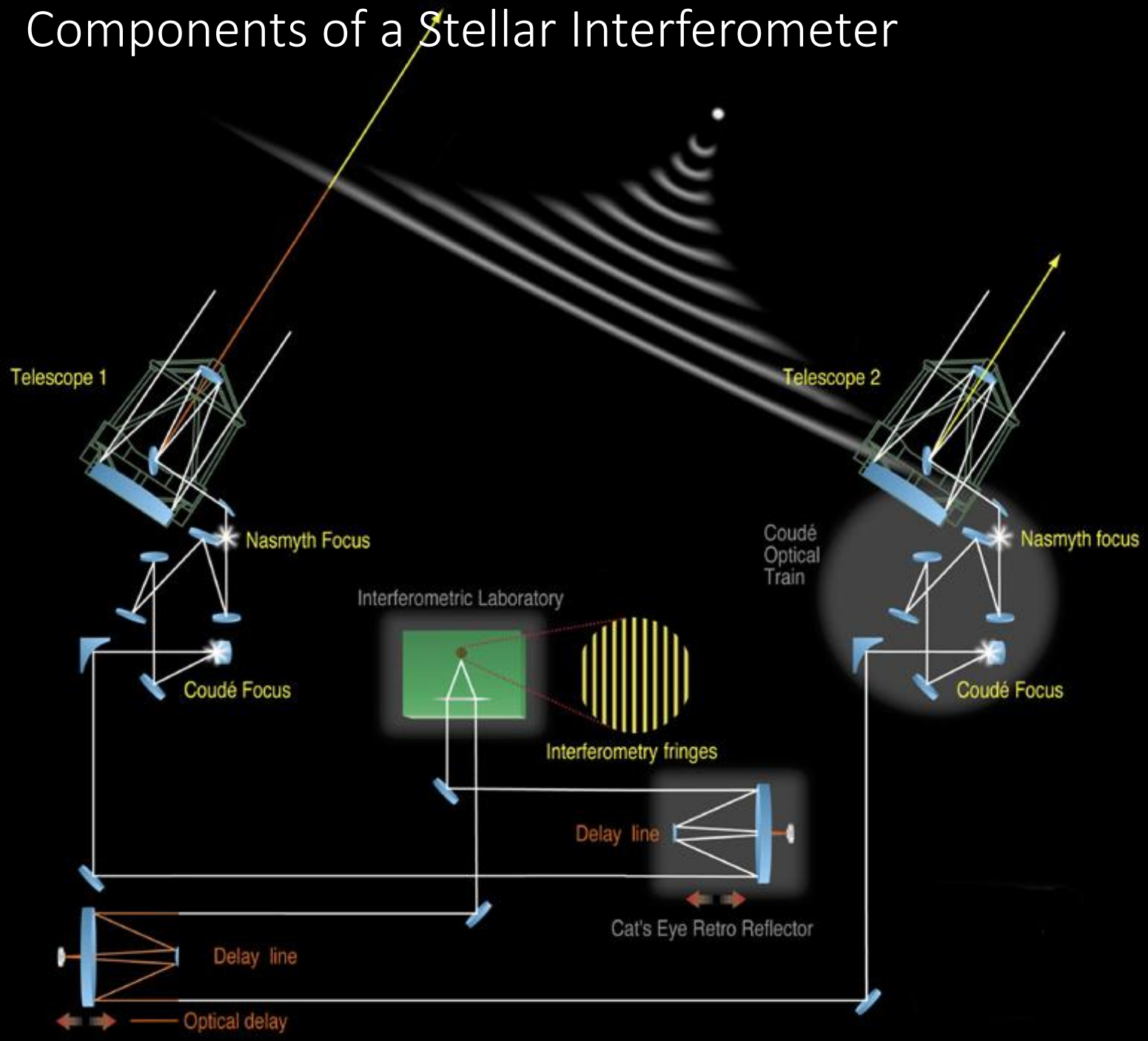




Aerial View of Paranal Observing Platform with VLTI Light Paths

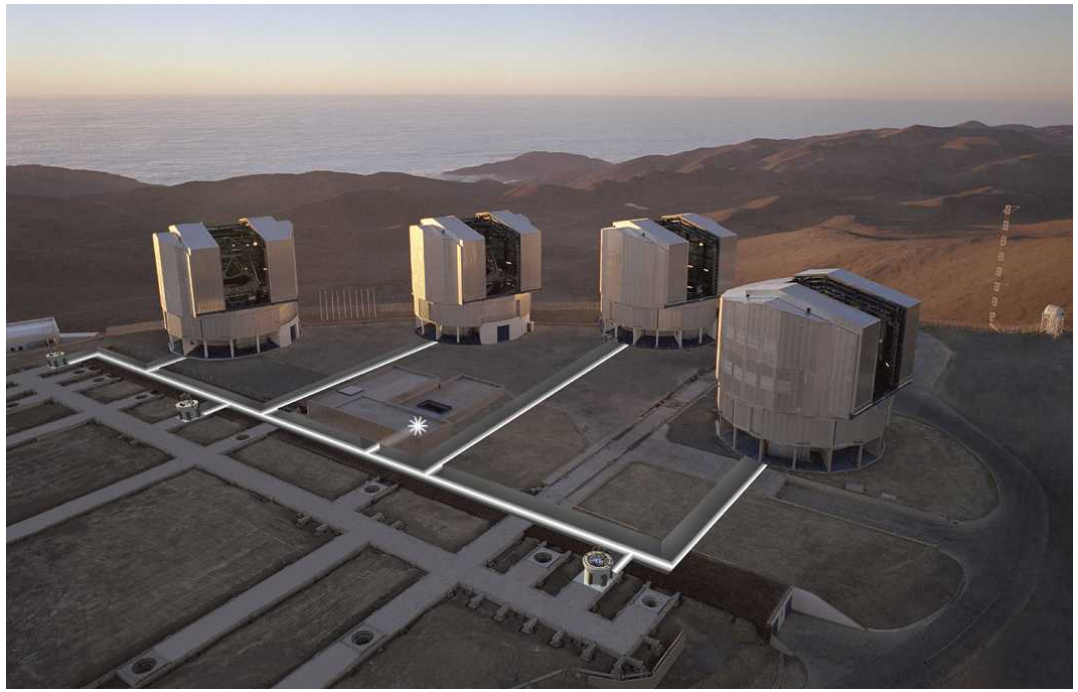
ESO PR Photo 10f/01 (18 March 2001)

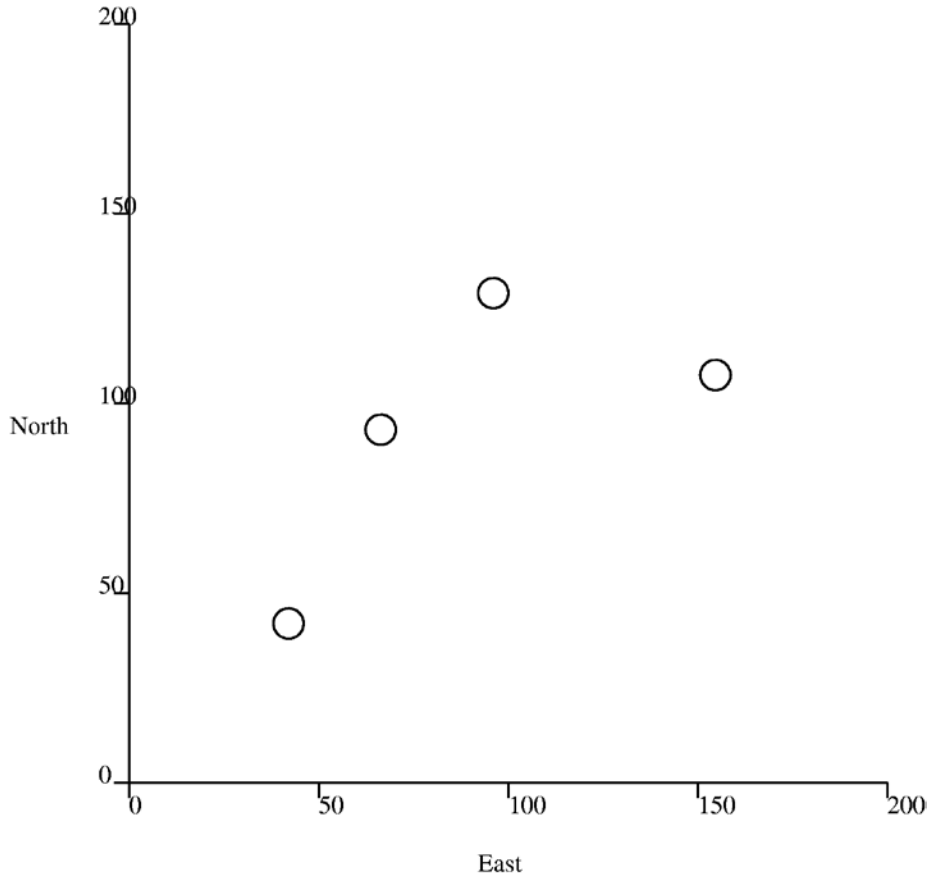
Components of a Stellar Interferometer



Array Configuration and Earth Rotational Synthesis

ESO VLT Interferometer - Cerro Paranal, Chile



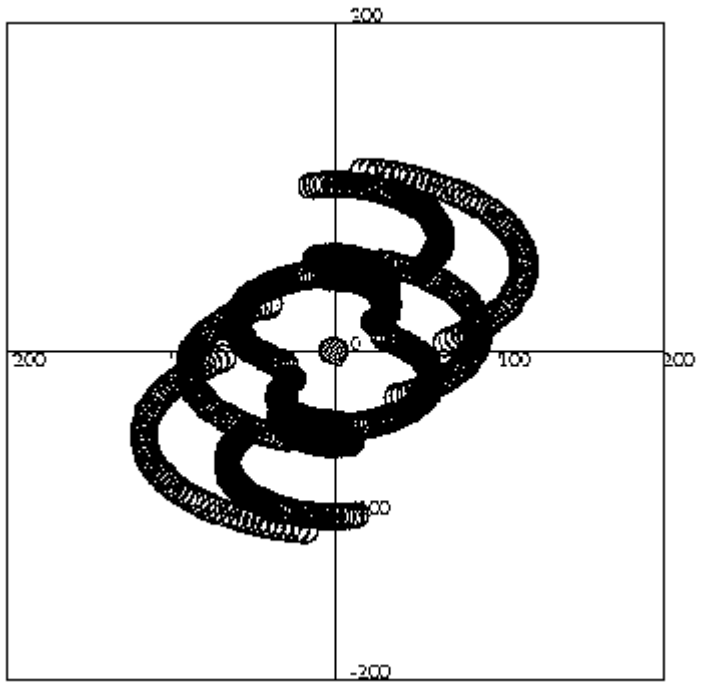


VLT Interferometer Main Array

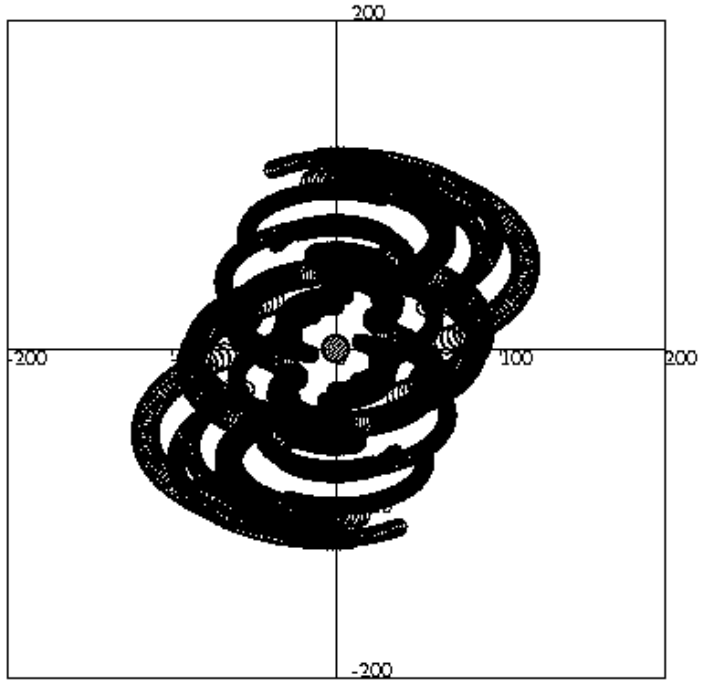
Placement of interferometer elements

Array Configuration and Earth Rotational Synthesis

VLTI - 4 Unit telescopes, Quelle bei δ = -30°



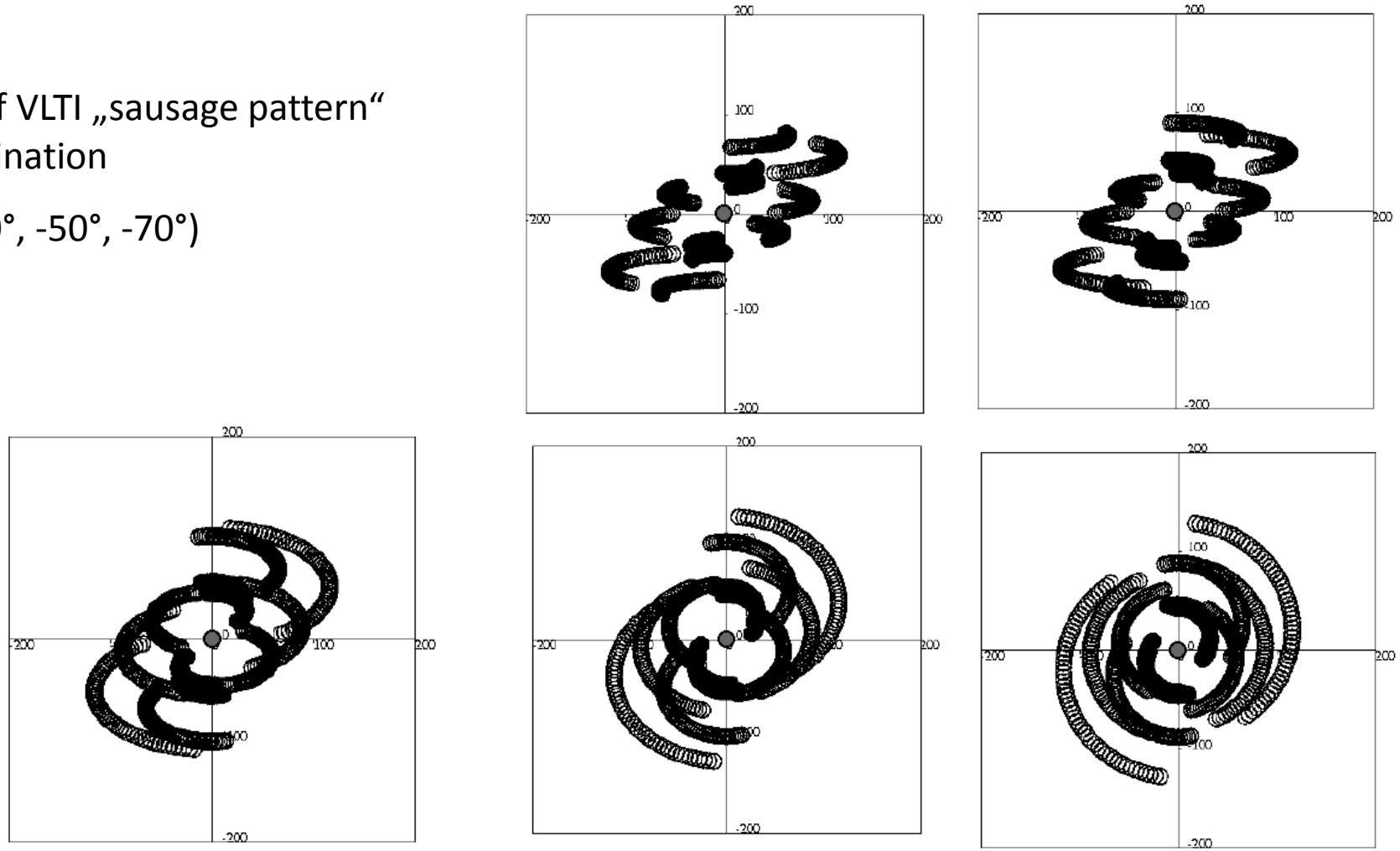
VLTI - 4 Unit telescopes plus 4 Auxiliary telescopes



Array Configuration and Earth Rotational Synthesis

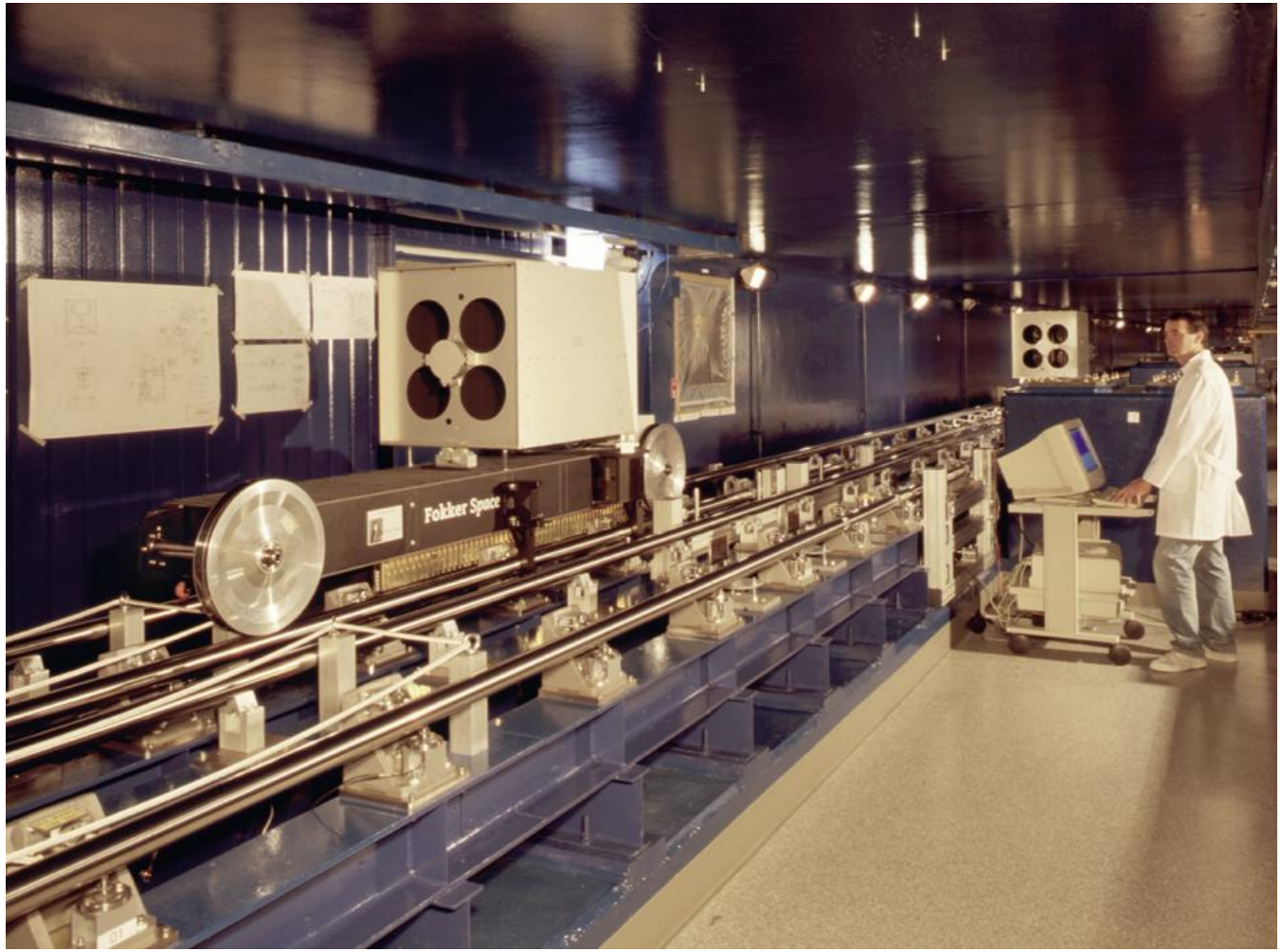
Dependence of VLTI „sausage pattern“ on source declination

(+10°, -10°, -30°, -50°, -70°)

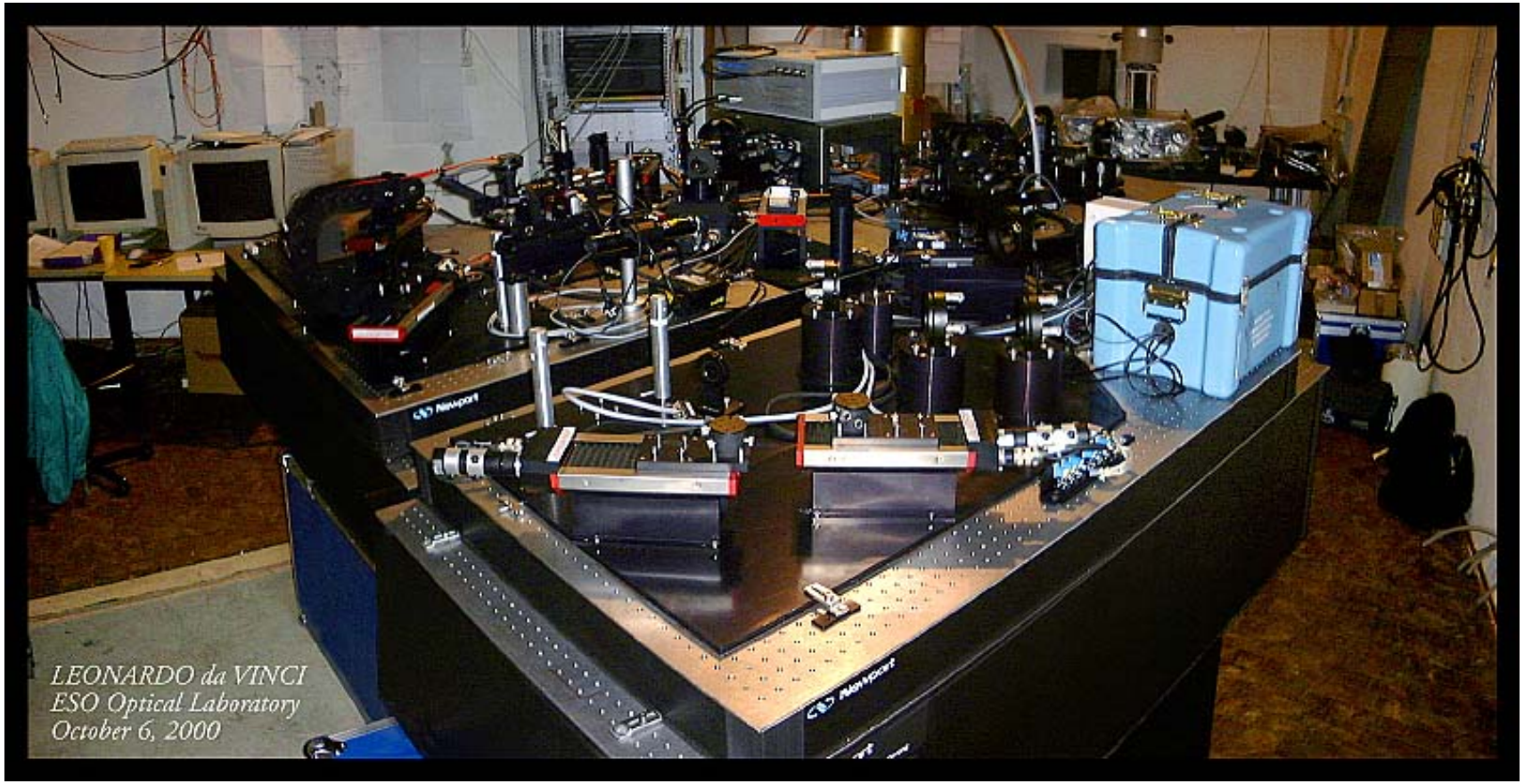


VLT Interferometer, EUR

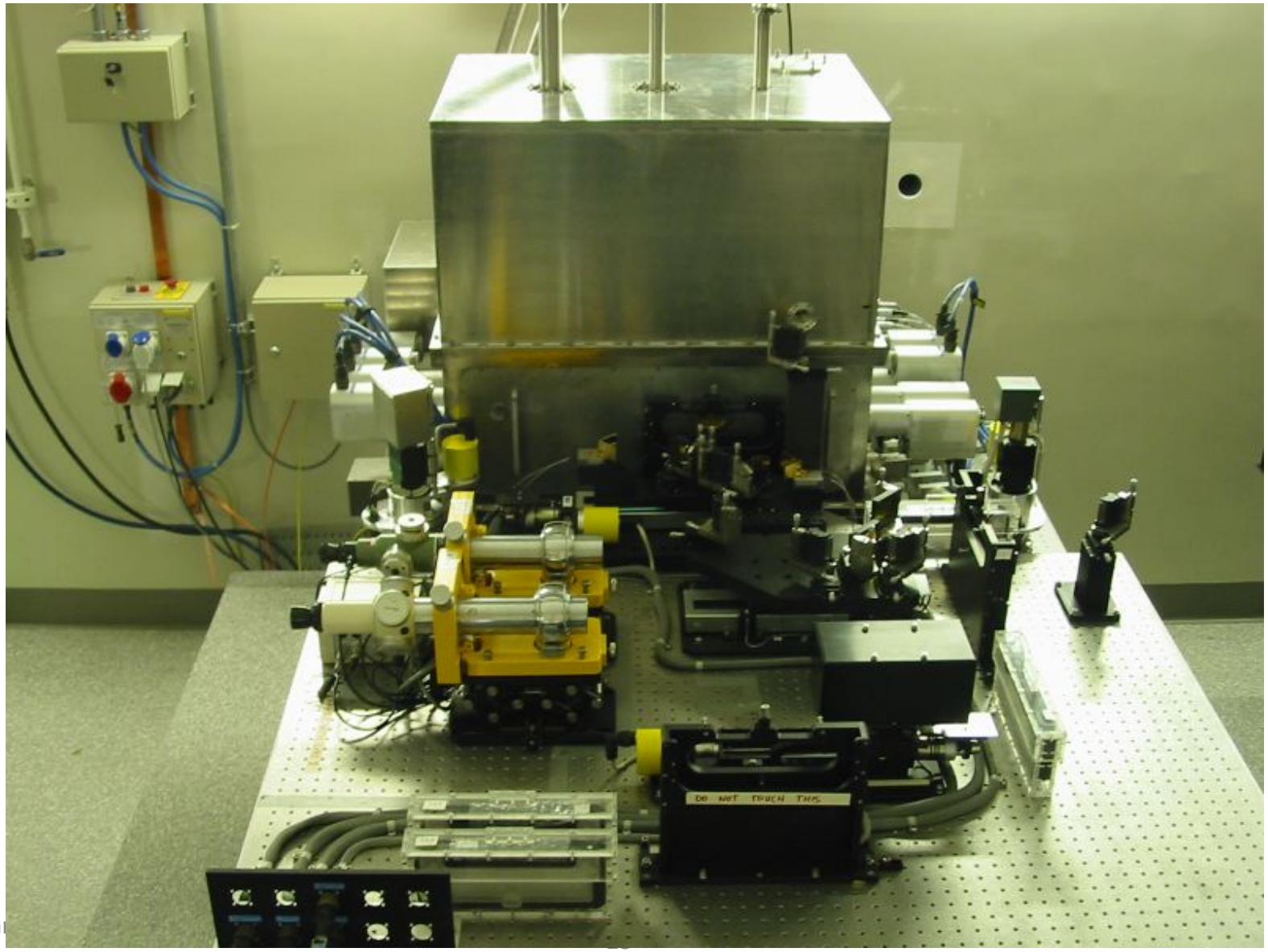
VLTI Delay Lines



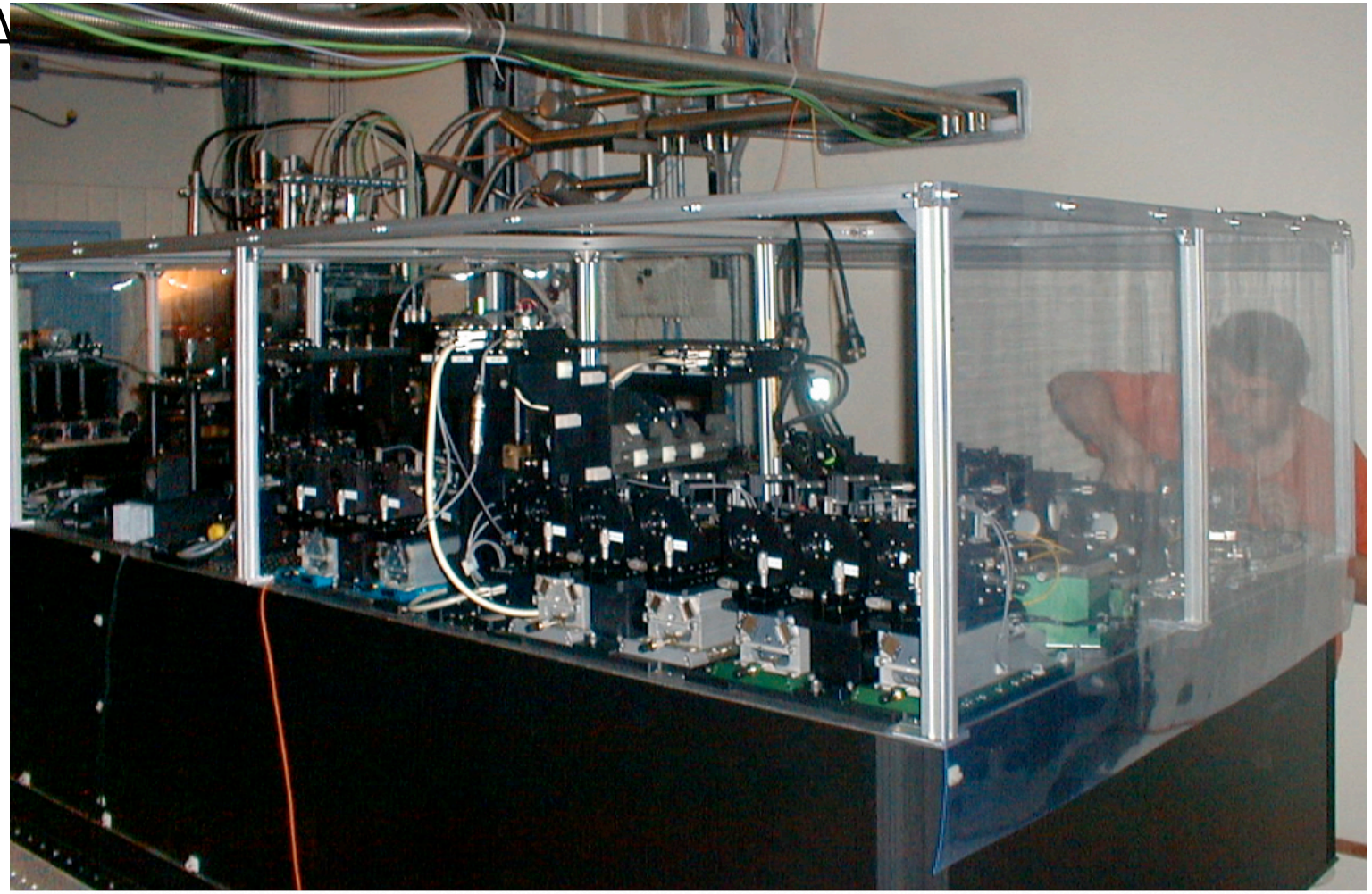
VINCI - VLTI Commissioning Instrument



VLTI - Mid-Infrared Instrument (MIDI)

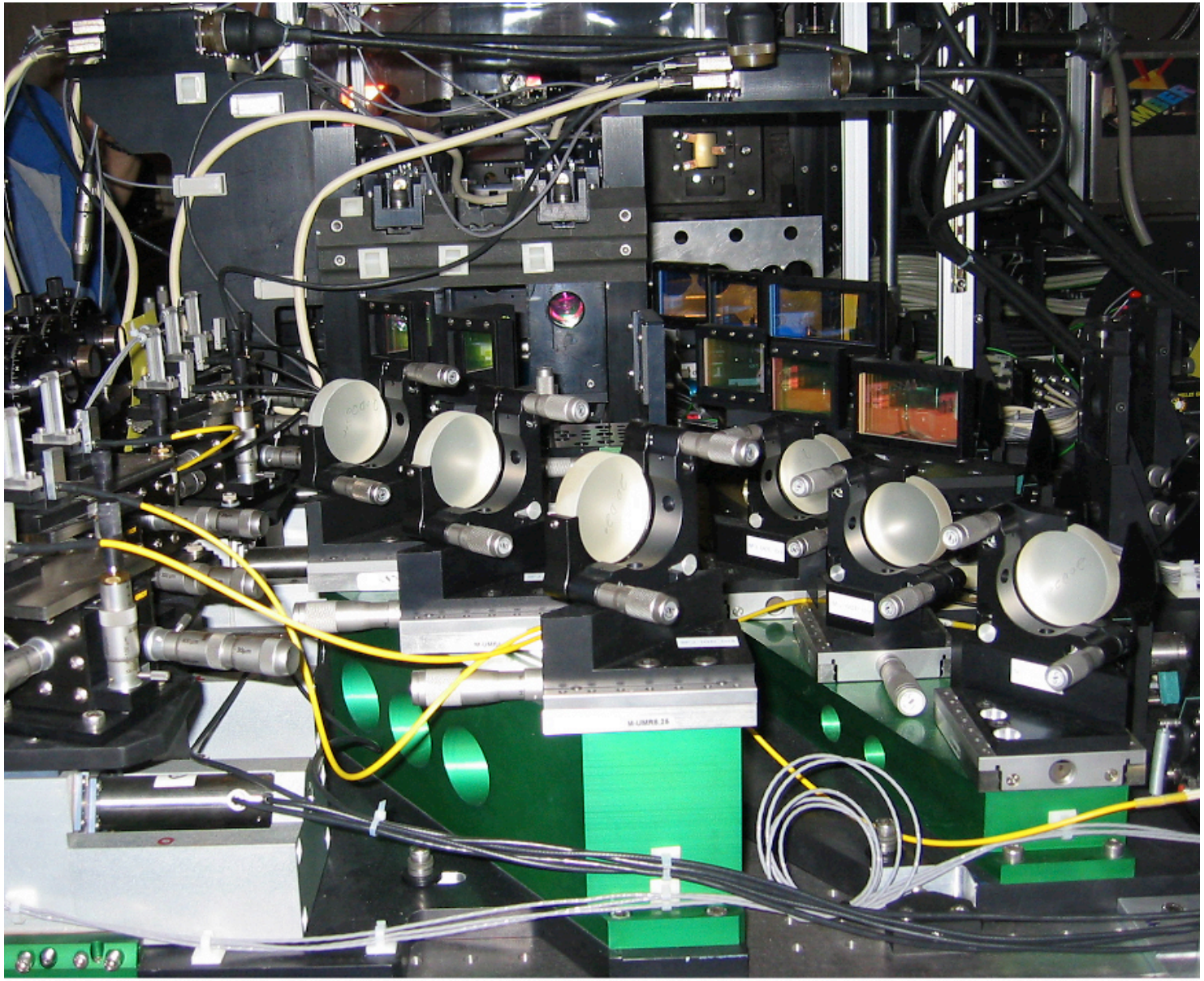


A



The AMBER Instrument at the VLT Interferometer

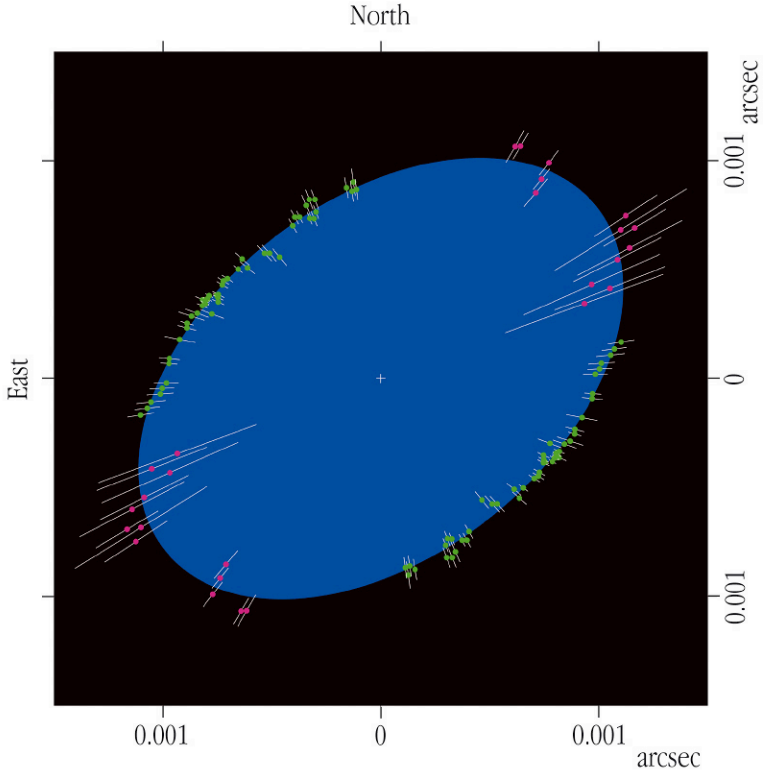
ESO PR Photo 09a/04 (5 April 2004)



The AMBER Instrument (Detail)

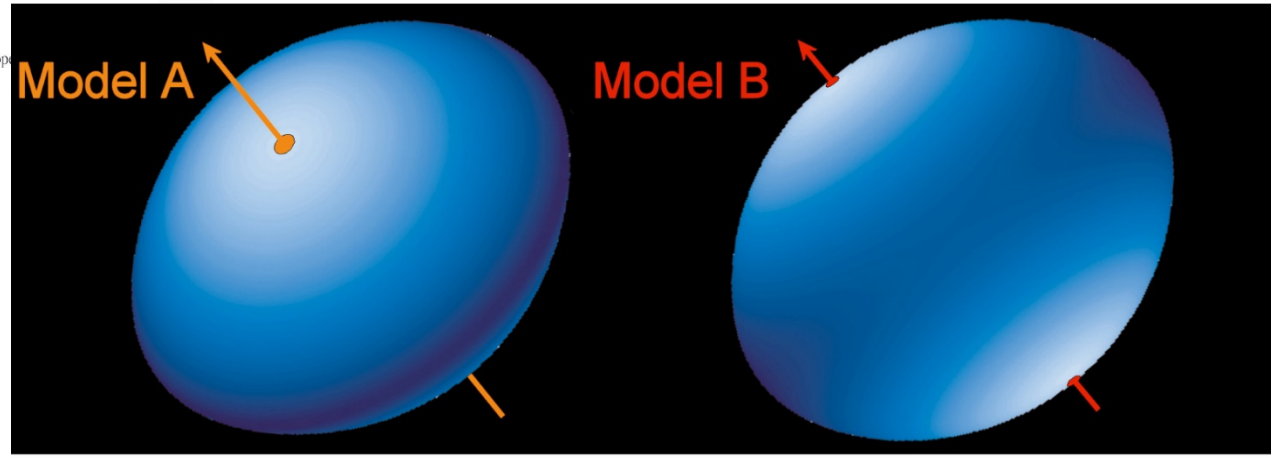
ESO PR Photo 09b/04 (5 April 2004)

Stellar Diameters



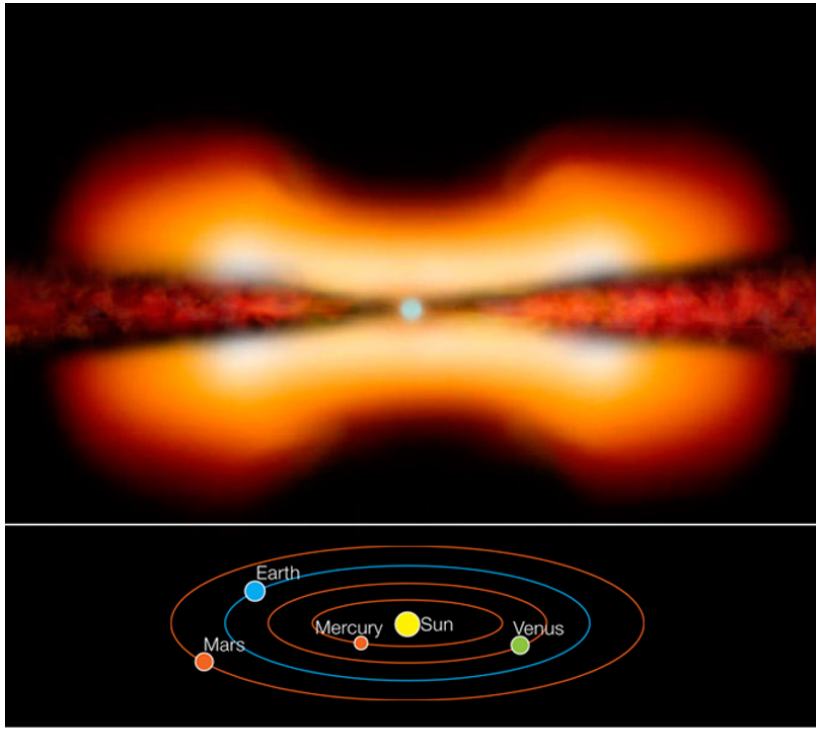
The Shape of Achernar
(VLTI + VINCI)

ESO PR Photo 15b/03 (11 June 2003)



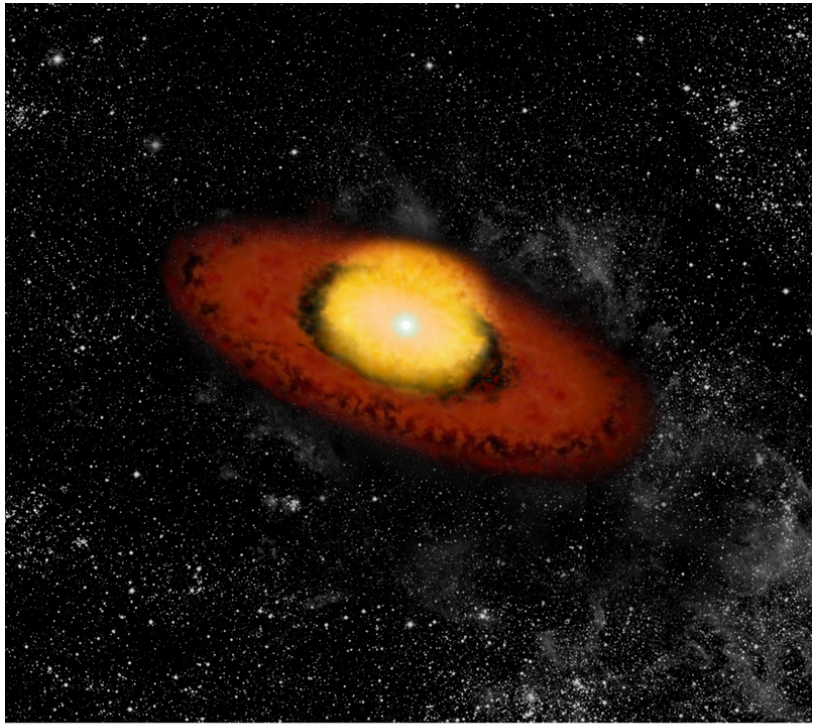
3-D Shape of Achernar (Models)

ESO PR Photo 15c/03 (11 June 2003)



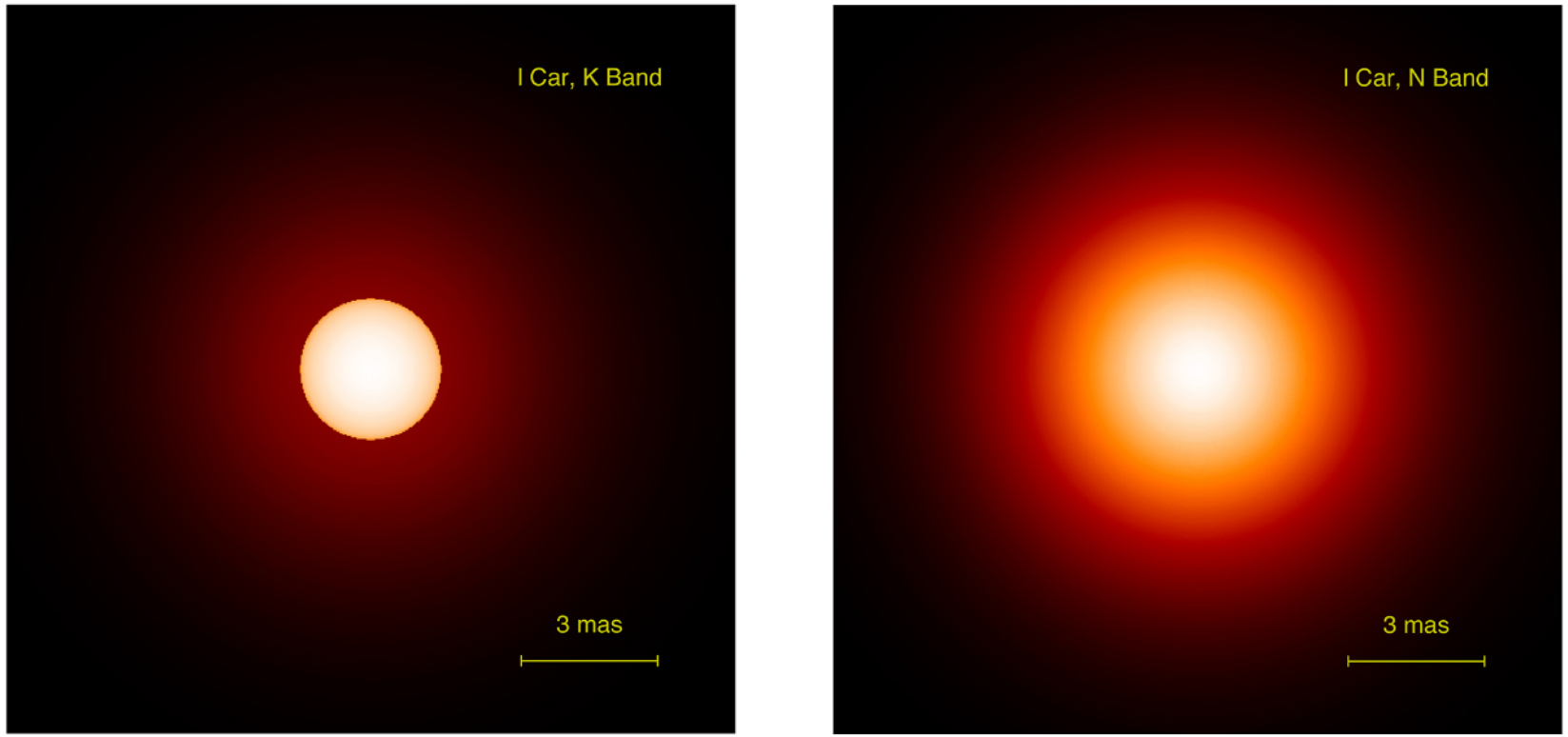
The Young Stellar Object MWC 297 (Artist View)

ESO PR Photo 36a/05 (November 24, 2005)



The B[e] Supergiant CPD-57°2874 (Artist View)

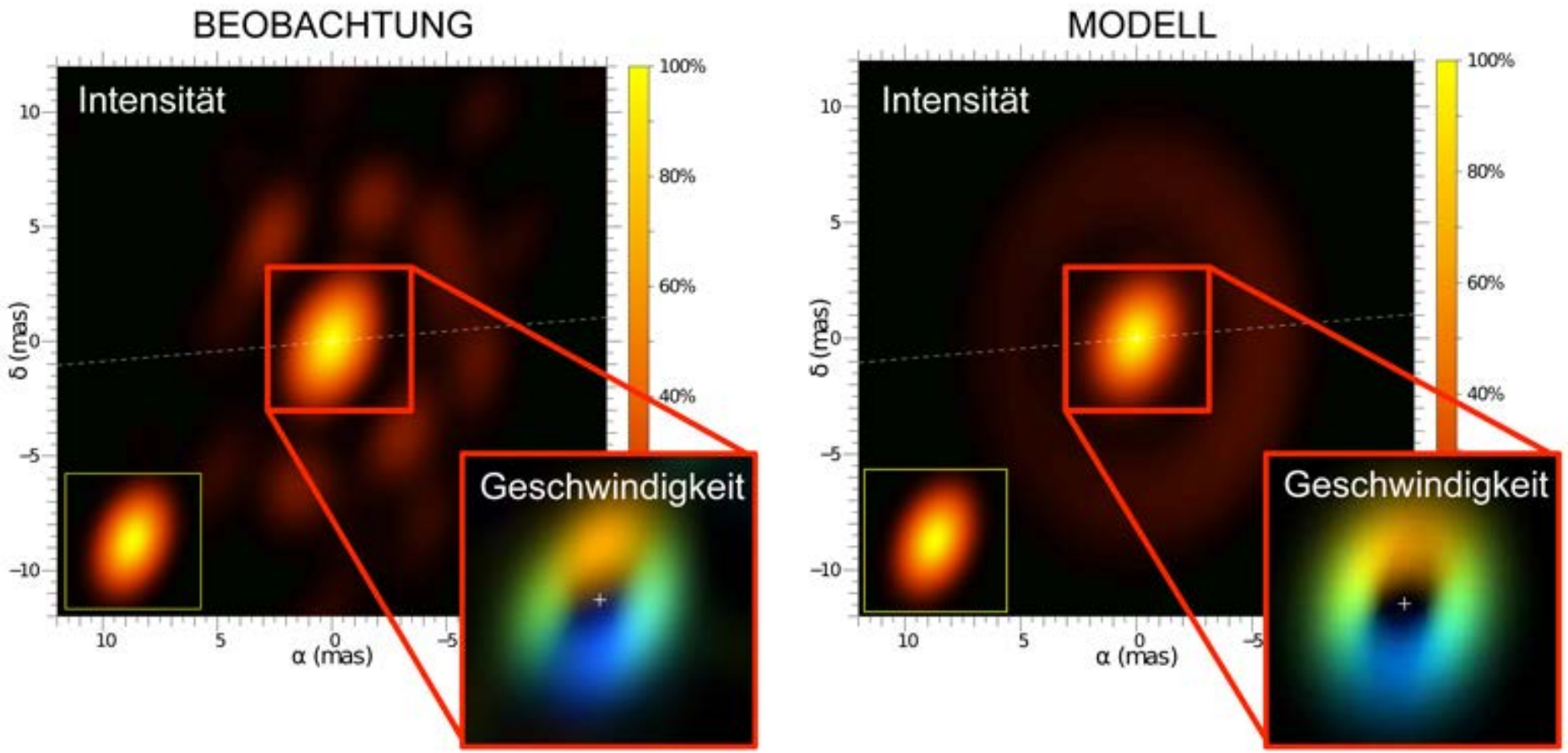
ESO PR Photo 36b/05 (November 24, 2005)



Model Image of Cepheid L Carinae
(VINCI, MIDI/VLTI)

ESO PR Photo 09/06 (28 February 2006)

Rotating envelope of a giant star – VLTI AMBER



Millour et al., Astronomy & Astrophysics, DOI: 10.1051/0004-6361/201016193 (2011)