An Introduction to Radio Interferometry

2-1 Aperture Synthesis

You can find relevant material on my personal webpage

NSYSU EMI Online Lecture Series Hauyu Baobab Liu (呂浩宇),
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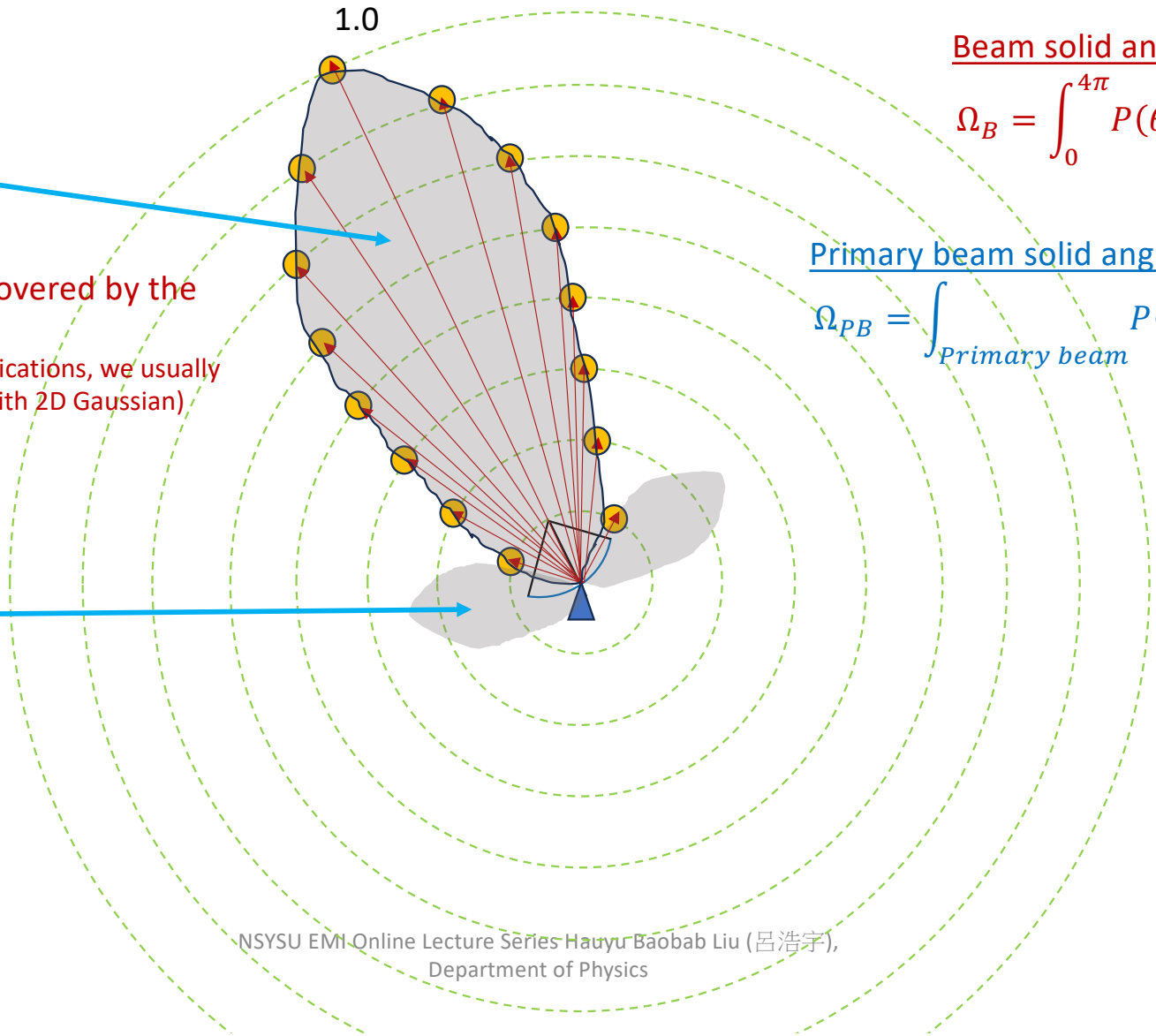


Main lobe

Primary beam:
angular region covered by the main lobe
(in astronomical applications, we usually can approximate it with 2D Gaussian)

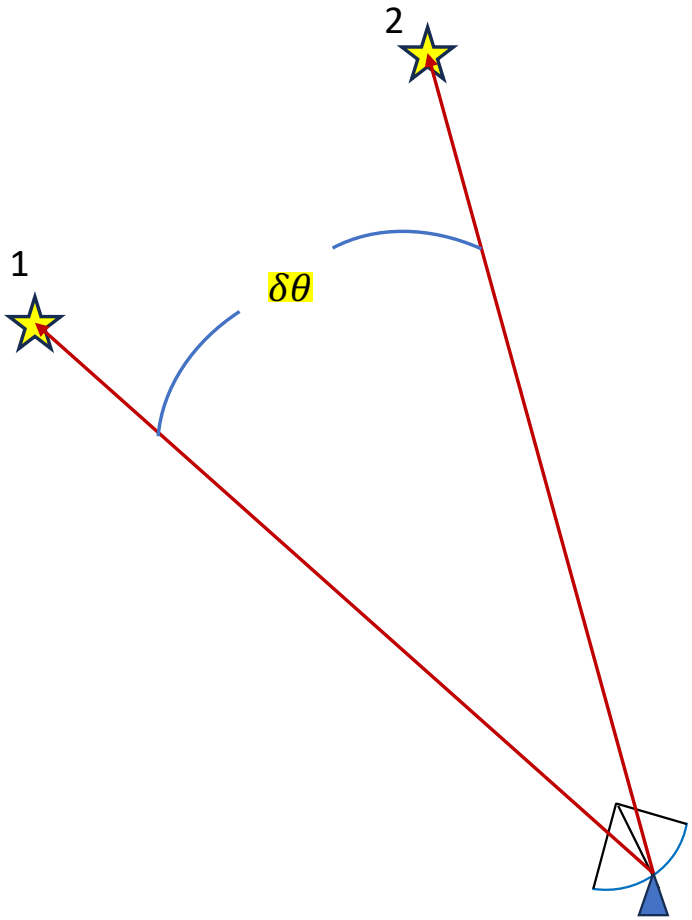
Side lobe(s)

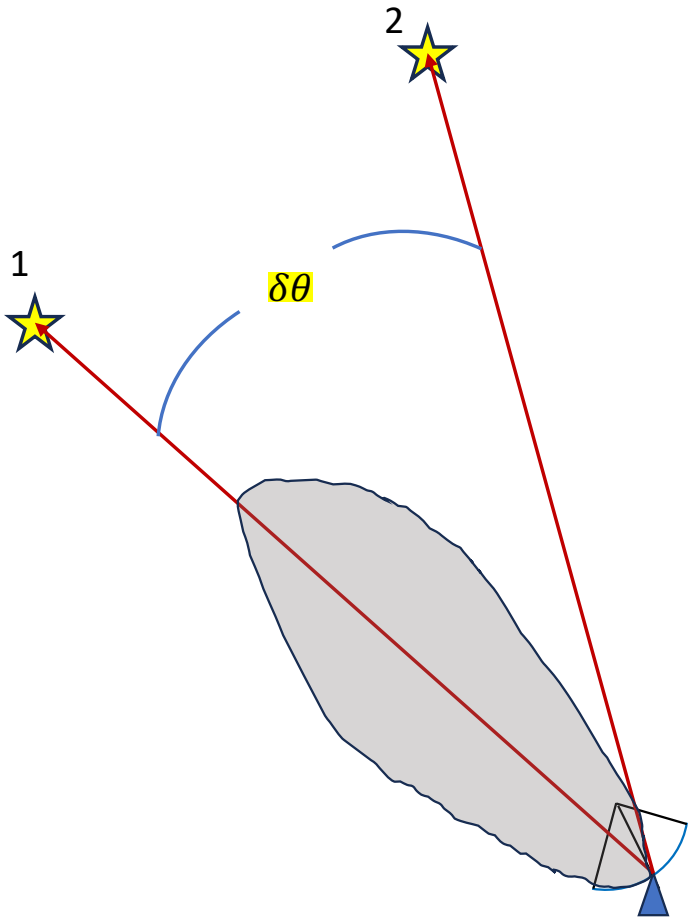
Beam solid angle:

$$\Omega_B = \int_0^{4\pi} P(\theta,\phi)\sin\theta\, d\theta d\phi$$

Primary beam solid angle:

$$\Omega_{PB} = \int_{Primary\ beam} P(\theta,\phi)\sin\theta\, d\theta d\phi$$


2
1
$\delta\theta$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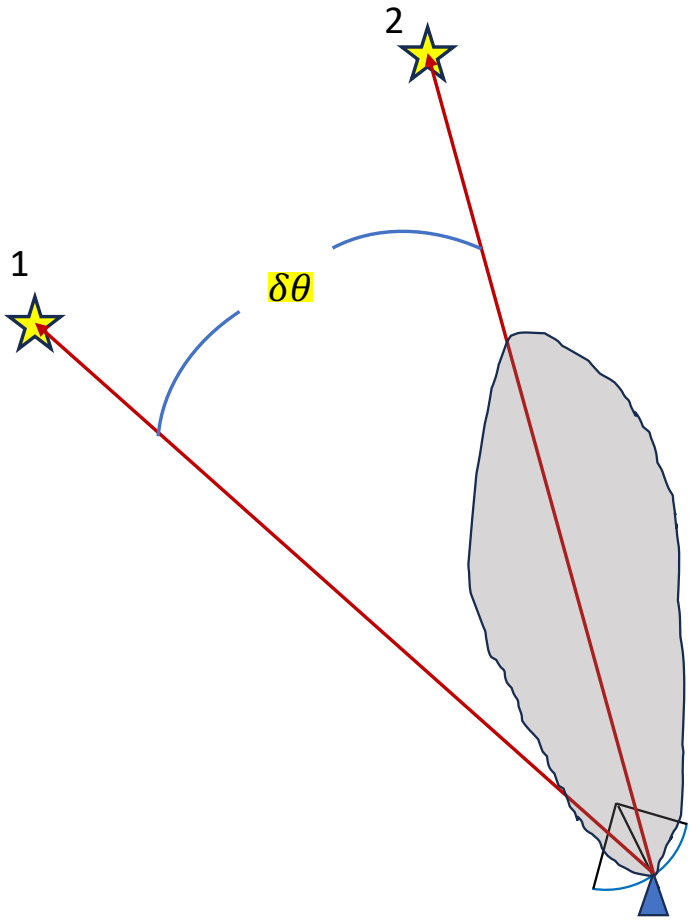
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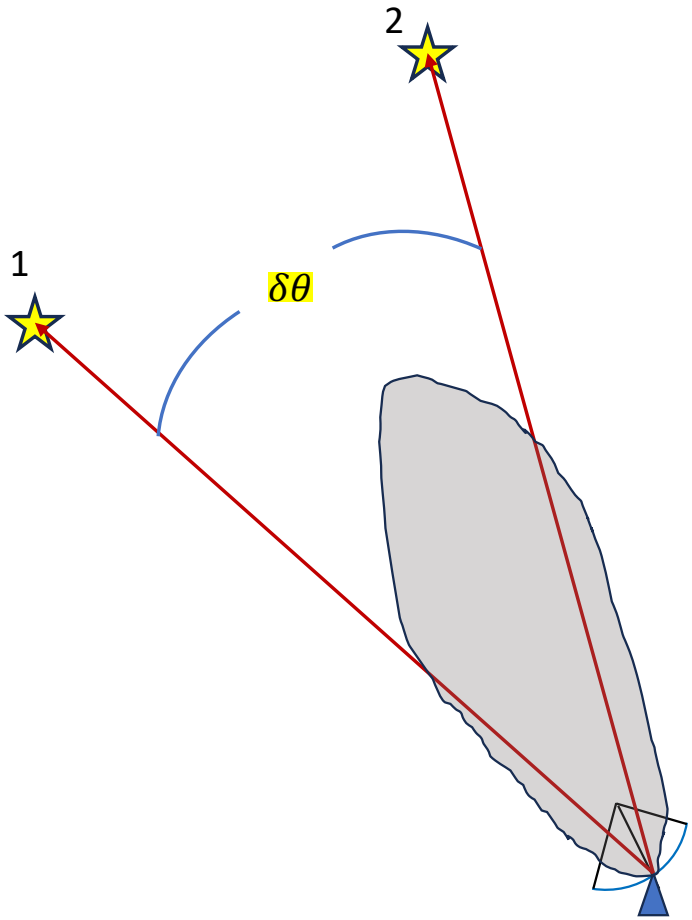
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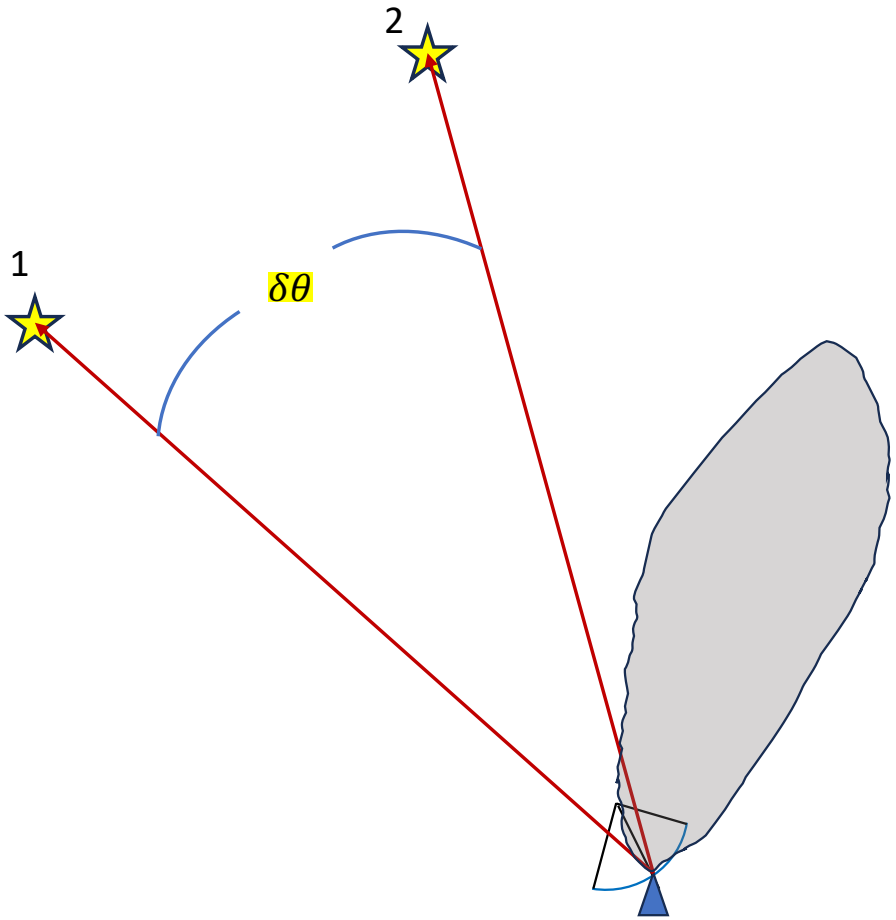
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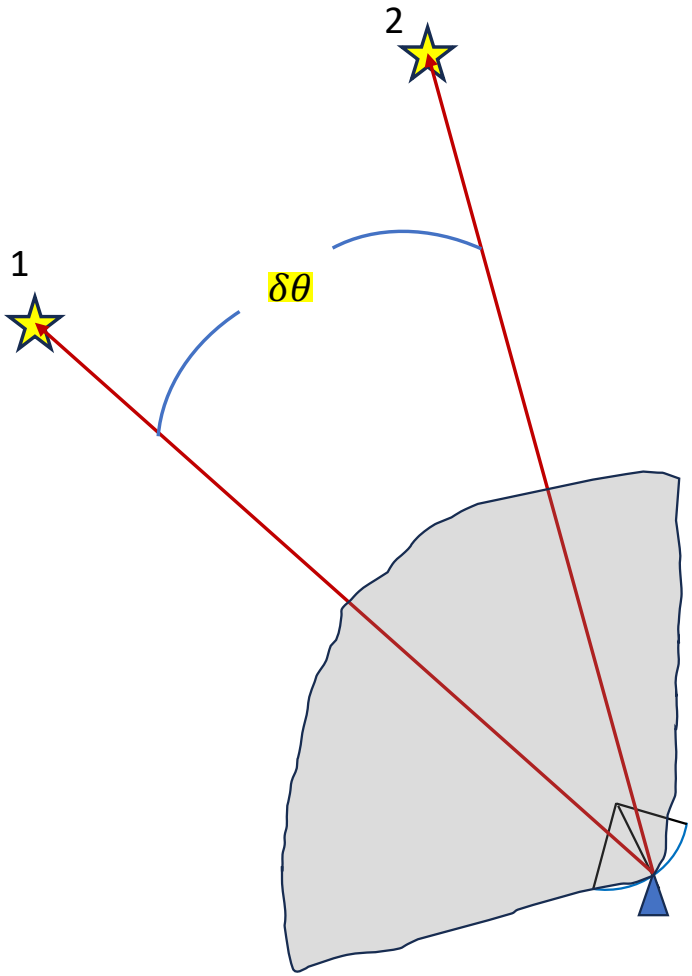
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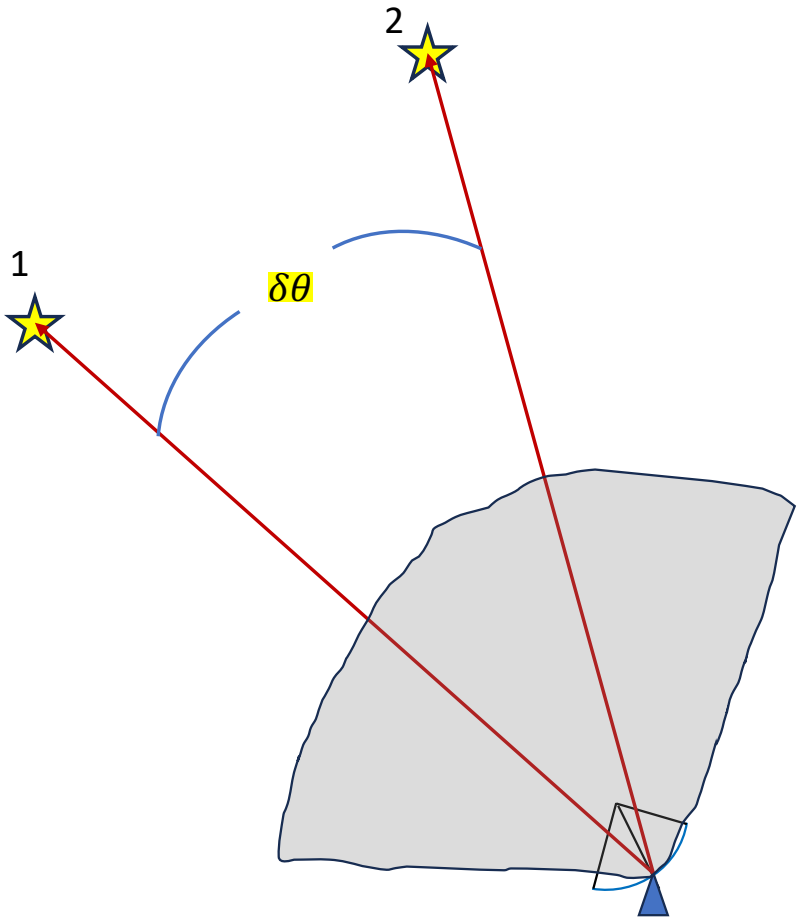
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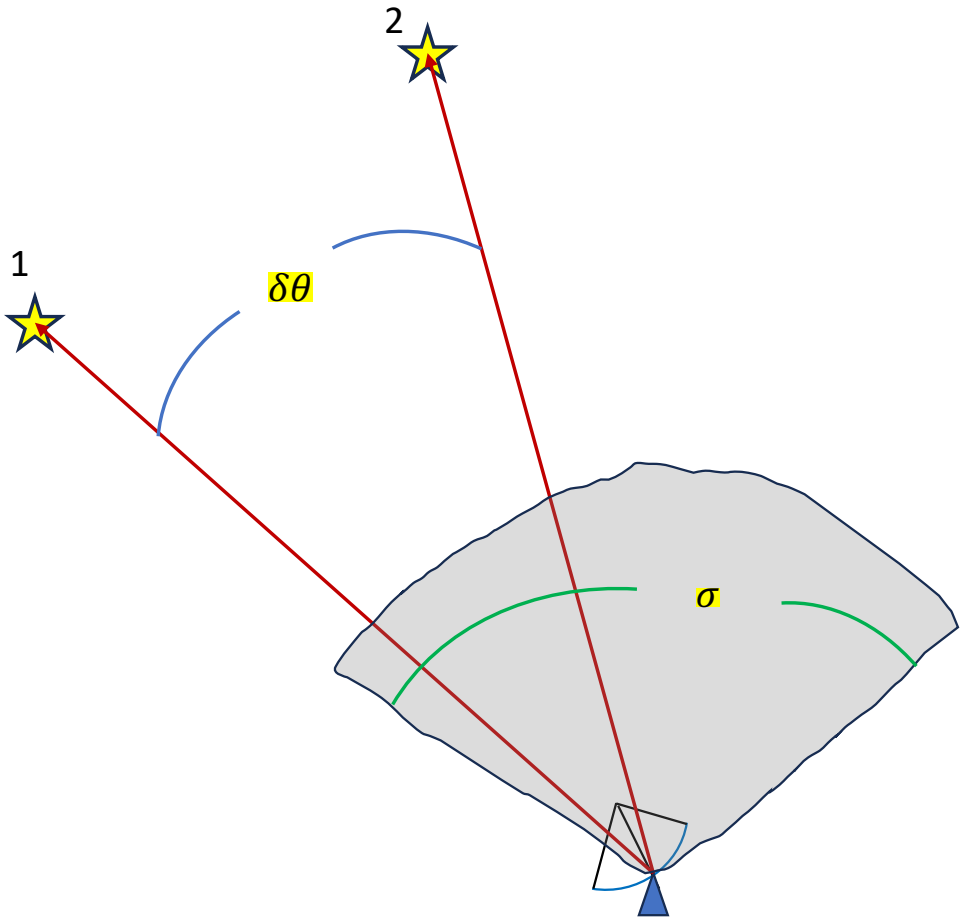
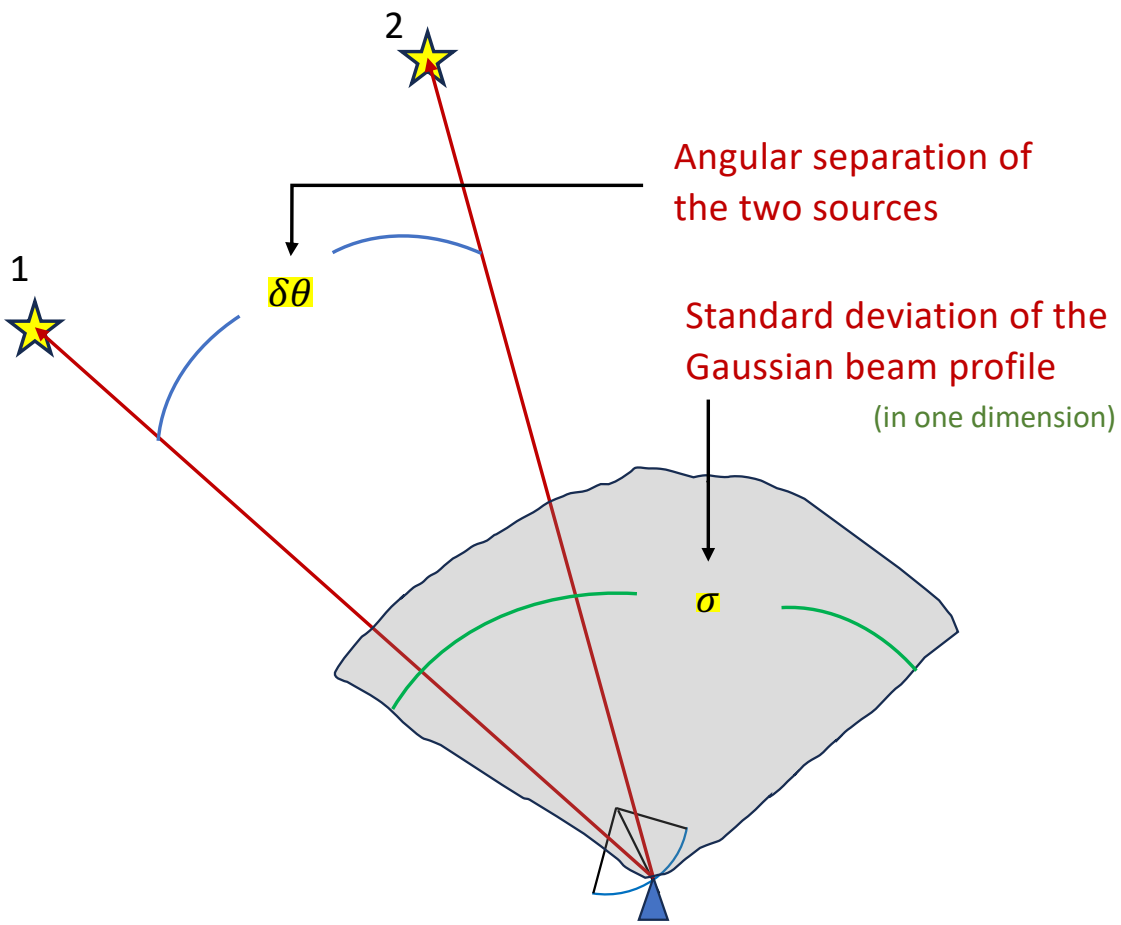
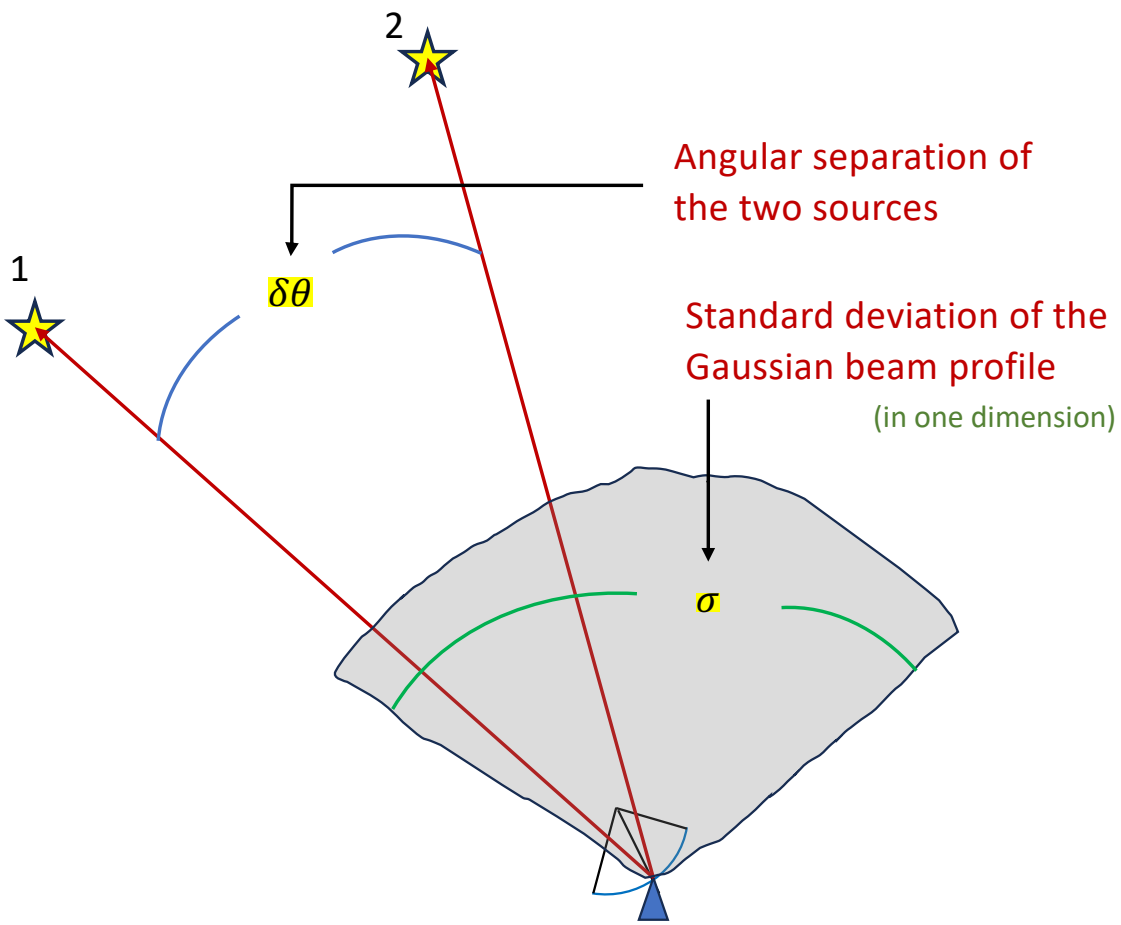

2
1
$\delta\theta$
σ

(Gaussian) deconvolution theorem



When $\delta\theta \lesssim \sigma$, we fundamentally cannot distinguish whether there are two stars or a (slightly elongated) celestial object.

(Gaussian) deconvolution theorem



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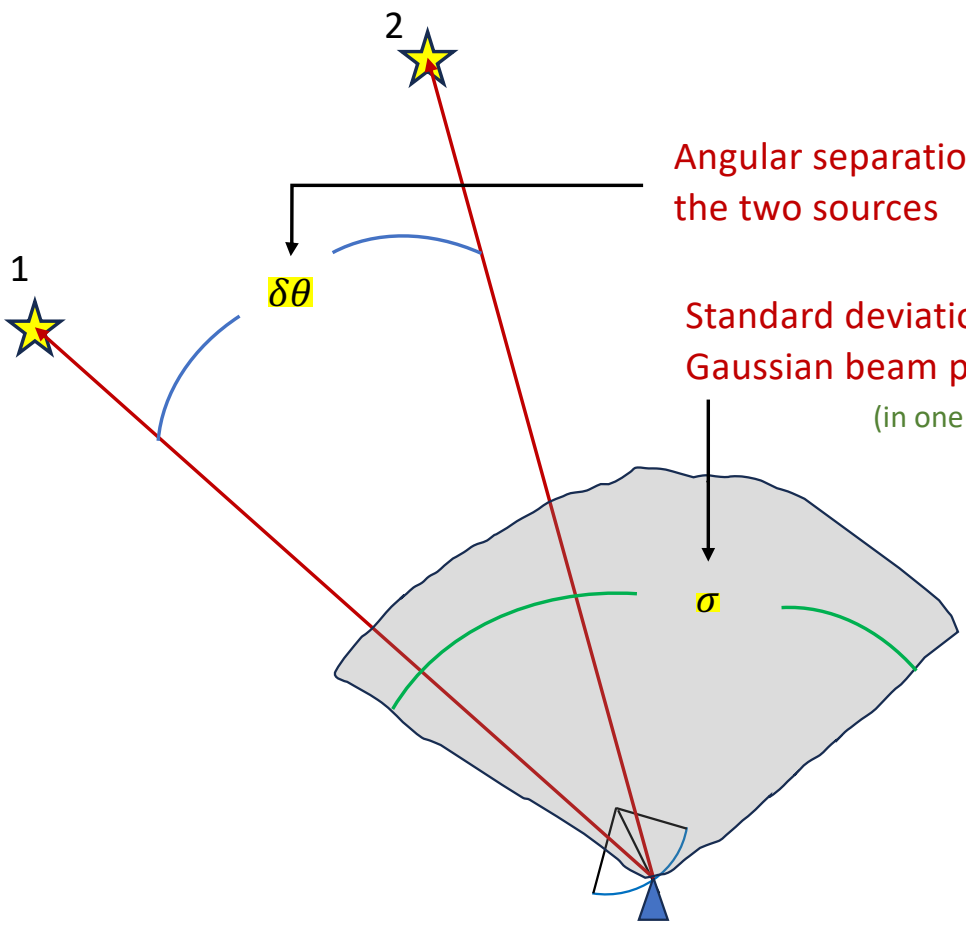
$$\sigma \sim \frac{\lambda}{D}$$

Observing wavelength

Size of the reflector (in one dimension)

(Gaussian) deconvolution theorem



Angular separation of the two sources

Standard deviation of the Gaussian beam profile (in one dimension)

When $\delta\theta \lesssim \sigma$, we fundamentally cannot distinguish whether there are two stars or a (slightly elongated) celestial object.

Observing wavelength

$$\sigma \sim \frac{\lambda}{D}$$

Size of the reflector (in one dimension)

Large D → small σ, i.e.,
collecting light from a smaller angular area
that is proportional to $(\lambda/D)^2$
(i.e., we receive smaller flux density)
but we can collect photons from a bigger surface area,
which is approximately D^2.

arcminute

$1^\circ = 60' = 3600''$

arcsecond

Human eyes at visible band ($\lambda \sim 0.5 \cdot 10^{-6}\ m$): $\sigma \sim 1'$

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To achieve $\sigma \sim 10''$ at (sub)millimeter band ($\lambda \sim 10^{-3}\ m$):

Requires $D \sim 2{,}000\ cm = 20\ meter$

Applications: cosmic microwave background anisotropy,
black hole imaging and quasar (jet) physics,
interstellar moleculalar lines and dust emission, etc

JCMT 15-m telescope, IRAM-30m telescope, etc

To achieve $\sigma \sim 10''$ at centimeter band ($\lambda \sim 10^{-2}\ m$):

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Applications: cosmic microwave background anisotropy,
complex organic molecules,
hyperfine line transitions (e.g., HI, NH_3)
chondules and pebbles in protoplanetary disks

Greenbank 100-m telescope, Effelsberg 100-m telescope,
Arecibo 300-m telescope (cannot move), FAST 500-m telescope (cannot move), etc

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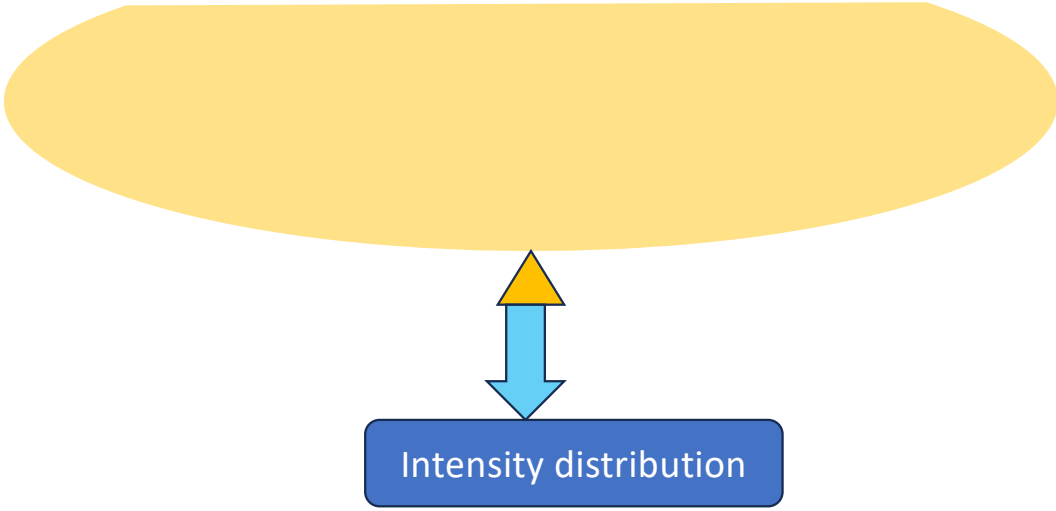

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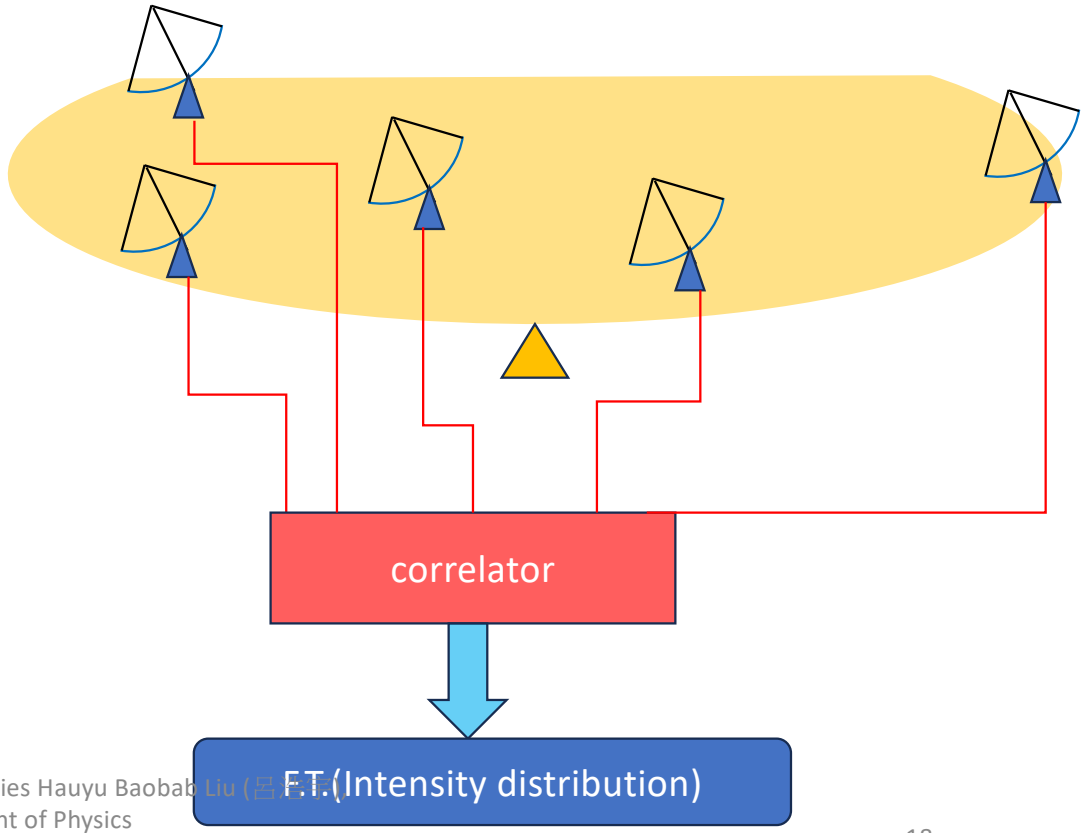

1. Angular resolution of a telescope: $\sigma \sim \frac{\lambda}{D}$
2. An interferometric array is an observing device that the D corresponds to the largest separation of antennae.
3. Interferometer measure the fourier transformed intensity distribution