

Zwei-Element-Interferometer

geometrisches Delay

$$\tau_g = \frac{1}{c} \mathbf{b} \cdot \mathbf{s}$$

\mathbf{s} : Richtungsvektor, $|\mathbf{s}| = 1$
zeigt in Richtung der Quelle

Interferometer

bestimme Interferenzmuster der beiden Antennen
Multiplikation der Signale, Mittelung

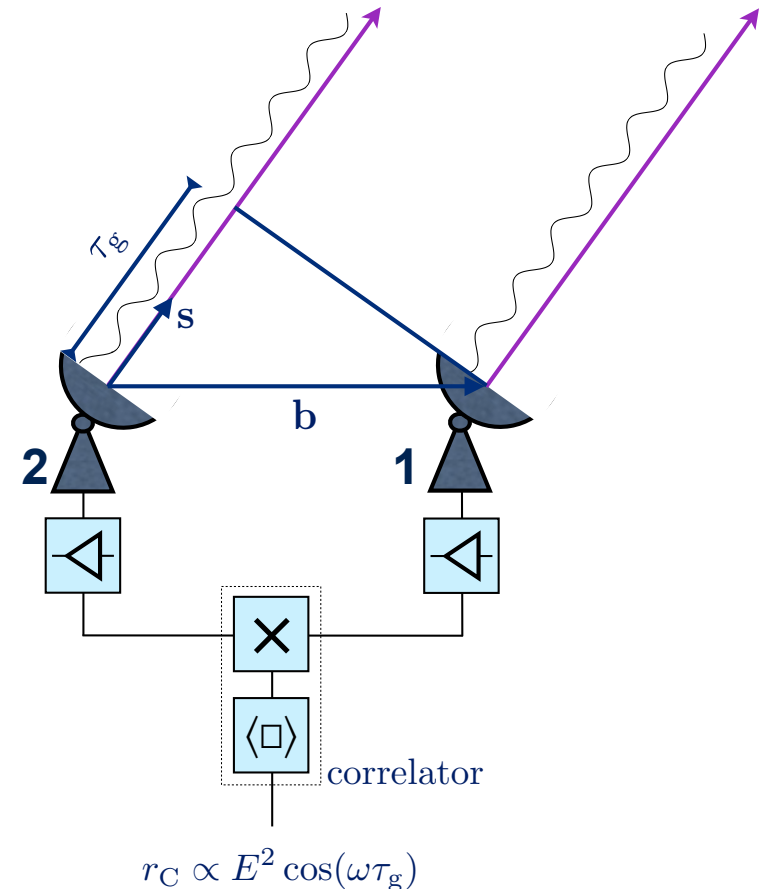
$$V_1 = V_0 \cos(2\pi\nu t)$$

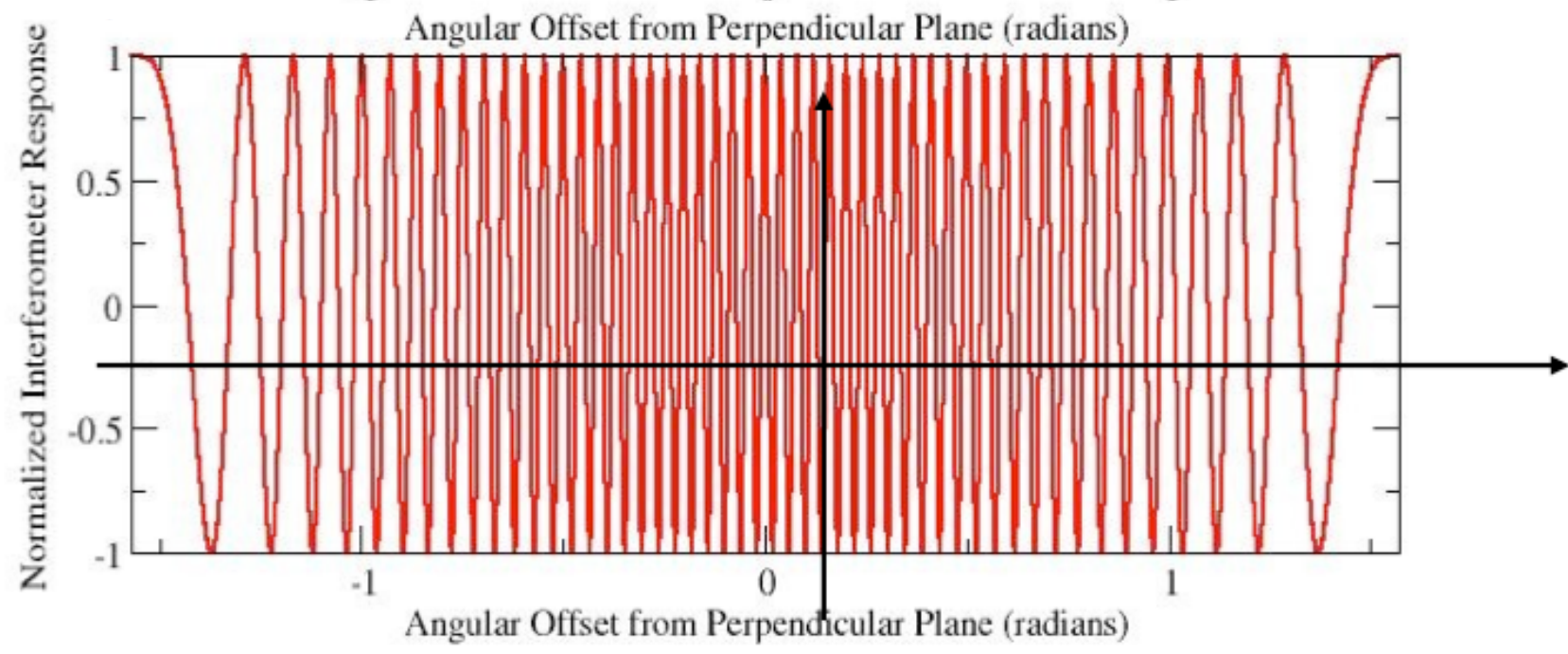
$$V_2 = V_0 \cos(2\pi\nu(t - \tau_g))$$

Response-Funktion

$$R_{12} = \frac{1}{T} \int_0^T dt V_1(t) \cdot V_2(t) = \frac{V_0^2}{2} \cos(2\pi\nu\tau_g) \quad \text{mit} \quad T \gg \frac{1}{\nu}$$

$$V_0^2 \propto B_\nu \quad \text{proportional zu Helligkeit}$$





Mehrere Quellen

$$R_{12}^{\text{multi}} = \sum_{\text{Quellen}} R_{12}^i$$

z.B. zwei Punktquellen, gleiche Helligkeit

$$\begin{aligned} R_{12}^2 &= \frac{V_0^2}{2} \{ \cos(2\pi\nu\tau_{g1}) + \cos(2\pi\nu\tau_{g2}) \} \\ &= \frac{V_0^2}{2} \cos(2\pi\nu(\tau_{g1} + \tau_{g2})) \cos(2\pi\nu(\tau_{g1} - \tau_{g2})) \end{aligned}$$

Komplexer Korrelator

Delay einfügen, dadurch sin-Korrelator

$$R_{12} = \frac{V_0^2}{2} \sin(2\pi\nu t)$$

Kombination von cos-Korrelator und sin-Korrelator ergibt komplexen Korrelator

$$R_{12}^C = \frac{V_0^2}{2} \{ \cos(2\pi\nu\tau_g) + i \sin(2\pi\nu\tau_g) \} = \frac{V_0^2}{2} e^{2\pi i \nu \tau_g}$$

uvw - Koordinaten

$$\mathbf{e}_w \parallel \mathbf{s}$$

$$\mathbf{e}_v \text{ in Ebene: } \mathbf{s} + \text{NCP}; \perp \mathbf{s}$$

$$\mathbf{e}_u \perp \mathbf{s}; \perp \mathbf{e}_v$$

Längen in Einheiten der Wellenlänge messen

$$\nu \tau_g = \frac{\nu}{c} \mathbf{b} \cdot \mathbf{s} = \frac{1}{\lambda} \mathbf{b} \cdot \mathbf{s} = \mathbf{b}_\lambda \cdot \mathbf{s}$$

$$\mathbf{b}_\lambda = u \mathbf{e}_u + v \mathbf{e}_v + w \mathbf{e}_w$$

Richtungscosinus l, m, n

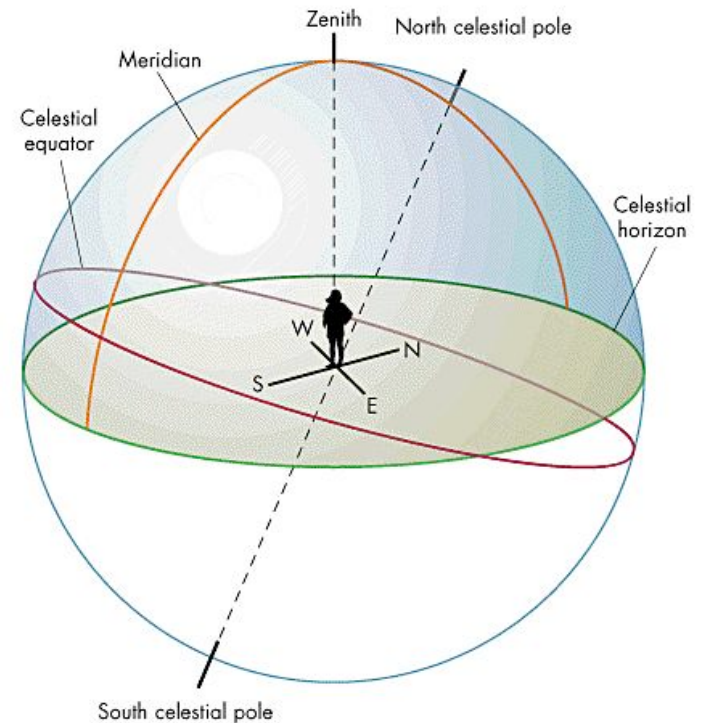
uvw sei durch eine Richtung \mathbf{s}_0 definiert, \mathbf{s} beliebige Richtung

$$\mathbf{s} \cdot \mathbf{e}_u = l$$

$$\mathbf{s} \cdot \mathbf{e}_v = m$$

$$\mathbf{s} \cdot \mathbf{e}_w = n = \sqrt{1 - (l^2 + m^2)}$$

$$\mathbf{b}_\lambda \cdot \mathbf{s} = ul + vm + wn$$



Visibility

Lege Phasenreferenzzentrum \mathbf{s}_0 fest:
feste Richtung am Himmel, wandert mit Quellen

Multipliziere Responsefunktion mit

$$\exp(-2\pi i \nu \tau_{\text{refz}})$$

Für Phasenreferenzzentrum gilt: $(l, m, n) = (0, 0, 1)$

$$\nu(\tau_g - \tau_{\text{refz}}) = \mathbf{b}_\lambda \cdot (\mathbf{s} - \mathbf{s}_0) = ul + vm + w(\sqrt{1 - (l^2 + m^2)} - 1)$$

Für das Raumwinkelement können wir schreiben

$$d\Omega = \frac{dl \, dm}{\sqrt{1 - (l^2 + m^2)}}$$

Für kleine l, m :

$$w(\sqrt{1 - (l^2 + m^2)} - 1) \approx 0$$

$$\sqrt{1 - (l^2 + m^2)} \approx 1$$

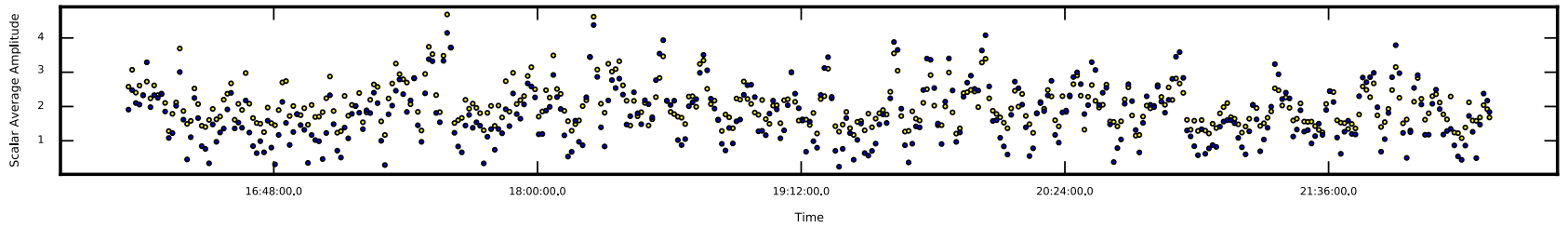
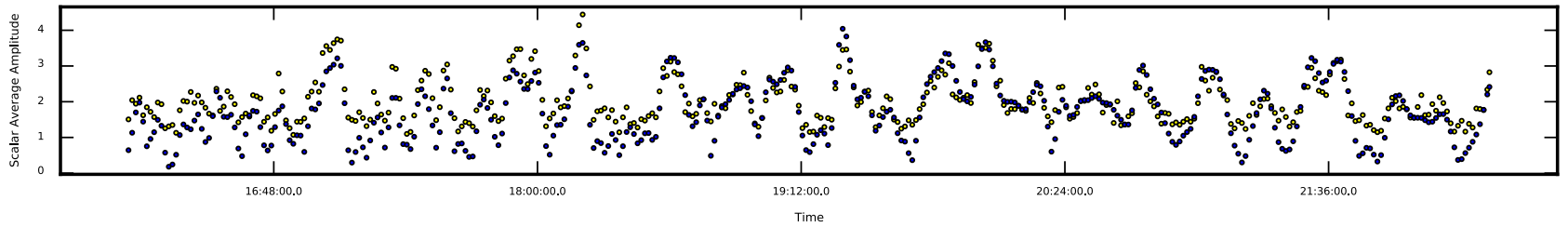
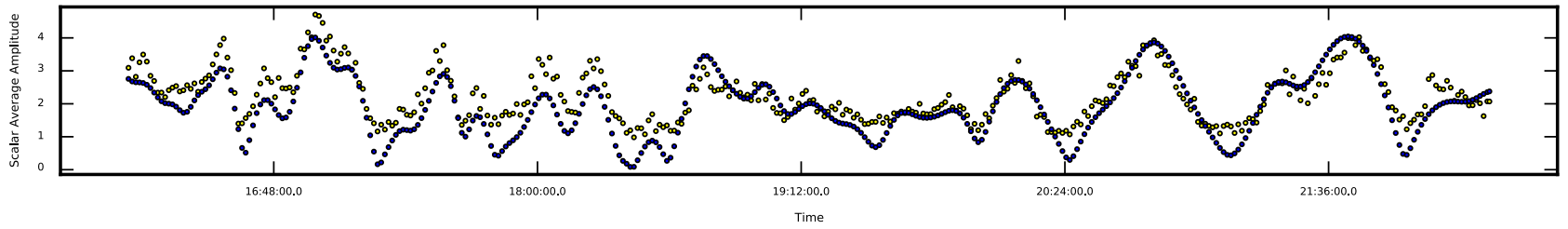
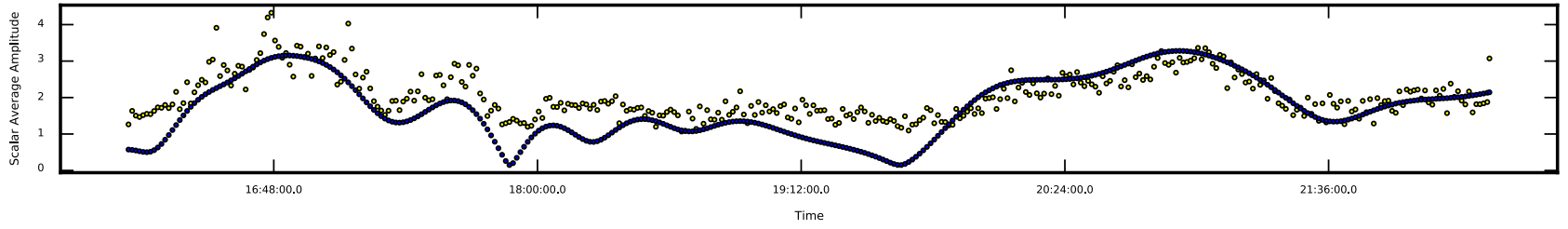
Die Visibility wird damit zu

$$V(u, v) = \int dl dm A(l, m) B_\nu(l, m) \exp(-2\pi i (ul + vm))$$

Antennen-Beam Himmelshelligkeit

Visibility und Himmelshelligkeit*Antennenbeam sind Fouriertransformierte
(wenn l,m klein!)

$$V(u, v) \xleftrightarrow{\text{FT}} A(l, m) B_\nu(l, m)$$



Major steps in synthesis imaging

Editing

- remove bad data, e.g. affected by radio interferences (RFI)

Calibration

- gain and reference phase of each antenna may vary with time, needs to be corrected for
- low frequency: ionosphere causes delays
- strategies: noise source, calibrator sky object, sky image, self-calibration

Imaging and deconvolution

- basically Fourier transform of visibility data

$$I(\mathbf{s}) \approx \frac{1}{A(\mathbf{s})} \int_{\text{all } \mathbf{b}} \mathcal{V}(\mathbf{b}_\lambda) e^{2\pi \mathbf{b}_\lambda \cdot \mathbf{s}} d\mathbf{b}$$

- usually insufficient information for unique solution (in particular with self-calibration)