An Introduction to Radio Interferometry

5-3 System temperature

You can find relevant material
on my personal webpage

$T_B^{atm} = T_{atm}(1 - e^{-\tau_{atm}})$ $\Delta\tau \equiv \kappa\,\Delta s, \quad \tau = \int d\tau$ $G_{atm} \equiv e^{-\tau_{atm}}$

Power received by a single dish telescope

(i) Celestial sources: $T_{source}G_{atm} = T_{source}e^{-\tau_{atm}}$

(ii) Thermal noise : T_{rec} and/or T_B^{atm}

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(iii) Noise load : $\underbrace{T}_{} = T_{atm}$

Temperature of the noise load.
This is only observed once in a while for calibration purposes.
Usually, it is a black body that the temperature is comparable to the temperature of the atmosphere.

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Ordinary definition of system temperature T_{sys}.
<u>Noise emitted by atmosphere and receiver</u>

$T_B^{atm} = T_{atm}(1 - e^{-\tau_{atm}})$ $\Delta\tau \equiv \kappa\, \Delta s,\quad \tau = \int d\tau$ $G_{atm} \equiv e^{-\tau_{atm}}$

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Effective system temperature. **This is termed T_{sys} by the SMA and ALMA communities, c.f.**

Ordinary definition of system temperature T_{sys}

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Lecture Unit 4-4

Reliability weight $R(u_k) \propto \frac{1}{{T_{sys}^{eff}}^2}$

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Ordinary definition of system temperature T_{sys}

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$$\boxed{\text{RMS noise} \sim \frac{T_{sys}^{eff}}{\sqrt{\Delta\nu t_{int}}}}$$

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Some sense of the typical values of quantities in

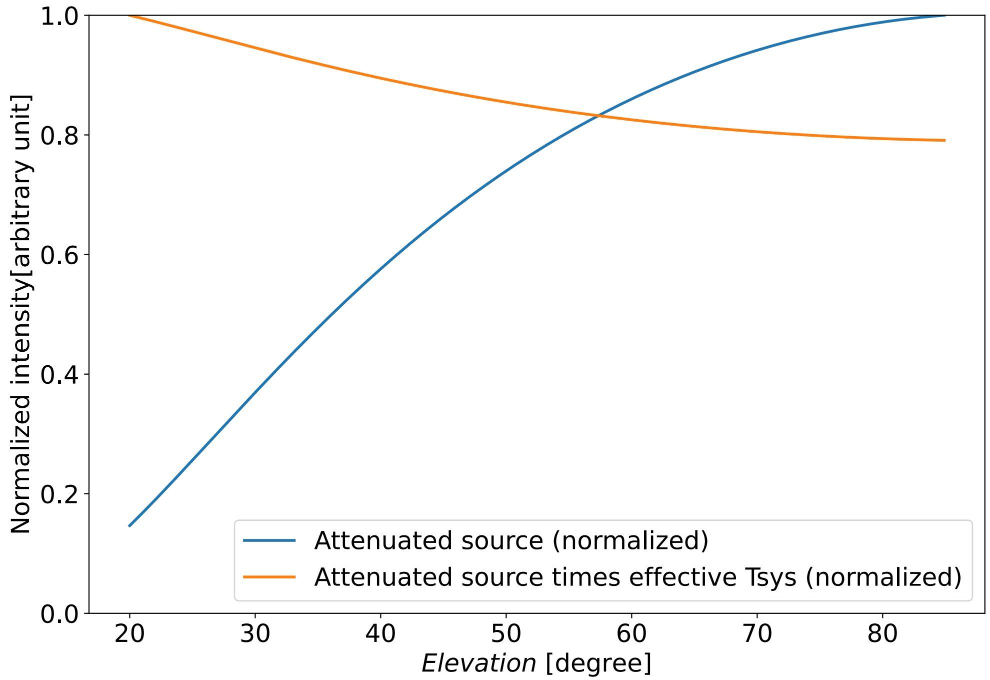
$$T_{sys}^{eff} = e^{\tau_{atm}}[\overbrace{(1 - e^{-\tau_{atm}})T_{atm} + T_{rec}}^{T_{sys}}]$$

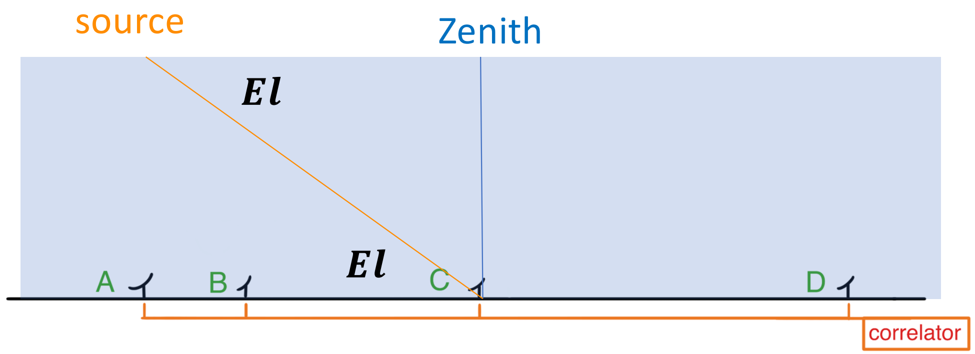
$$\left\{\begin{array}{l} \tau_{atm} \sim 0.1 \\ T_{atm} \sim 273\ K \\ T_{rec} \sim 100\ K \end{array}\right. \Longrightarrow \left\{\begin{array}{l} e^{-\tau_{atm}} \sim 0.9,\ (1 - e^{-\tau_{atm}}) \sim 0.1, (1 - e^{-\tau_{atm}})T_{atm} \sim 26\ K, \\ T_{sys} \sim 126\ K,\ T_{sys}^{eff} \sim 139\ K \end{array}\right.$$

$T_B^{atm} = T_{atm}(1 - e^{-\tau_{atm}})$ $\Delta\tau \equiv \kappa\,\Delta s, \quad \tau = \int d\tau$ $G_{atm} \equiv e^{-\tau_{atm}}$

Compensating atmospheric attenuation (T_{sys} application)

$$T_{sys}^{eff} = e^{\tau_{atm}}[\overbrace{(1 - e^{-\tau_{atm}})T_{atm} + T_{rec}}^{T_{sys}}]$$





$$\tau_{atm} \equiv \tau_{atm}(El) \sim \tau_{atm}^{zenith}\frac{1}{\sin(El)}$$

Lecture Unit 5-2

$T_B^{atm} = T_{atm}(1 - e^{-\tau_{atm}})$ $\Delta\tau \equiv \kappa\, \Delta s, \quad \tau = \int d\tau$ $G_{atm} \equiv e^{-\tau_{atm}}$

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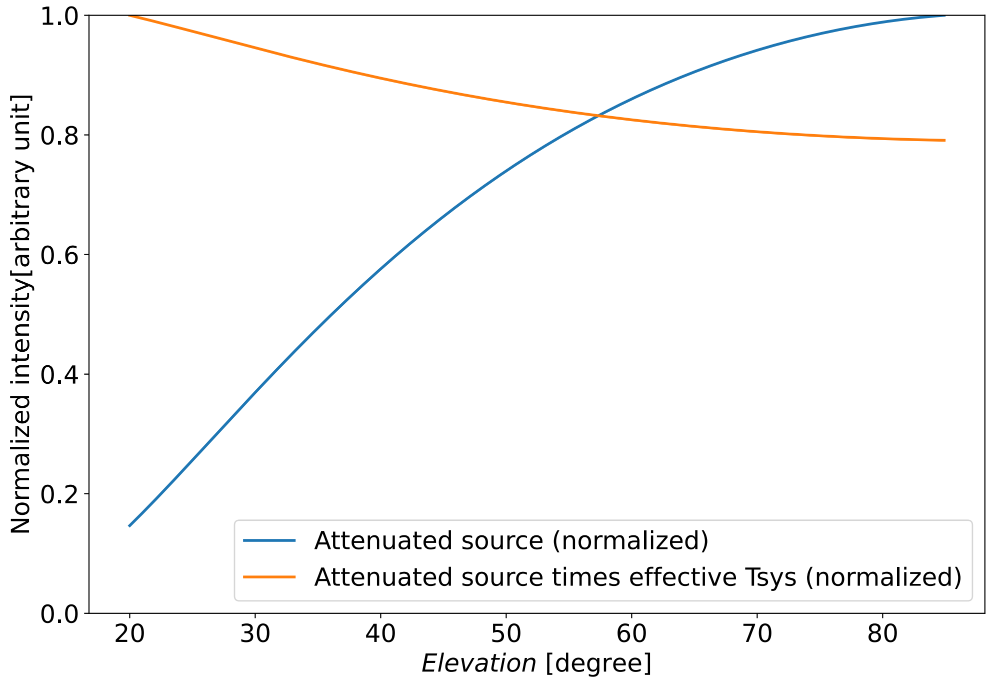

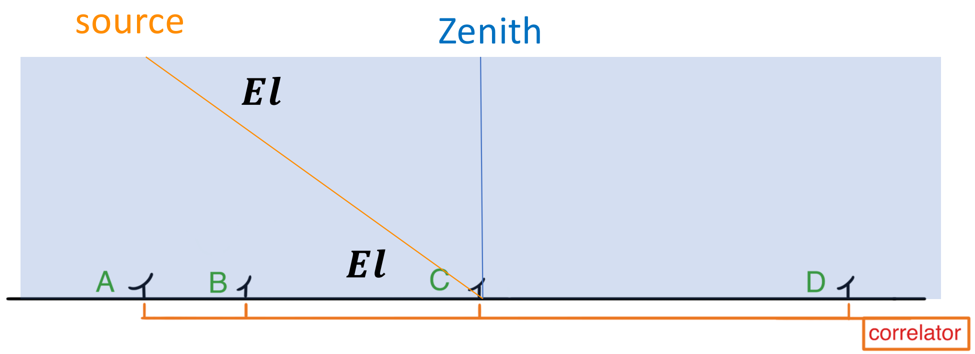

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Residual errors in visibility amplitude are taken care of with the complex gain calibration (lecture unit 5-4)

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Measuring T_{sys} (the basic concept)

Measurement-1: observing a noise load (black body) that as temperature $T = T_{atm}$

$$\underbrace{P_{BB}}_{\text{Power obtained from observing a black body}}/\overbrace{g}^{\text{Instrumental gain}} = \mathrm{T} + T_{rec} = T_{atm} + T_{rec} = T_{atm} \overbrace{- G_{atm}T_{atm} + G_{atm}T_{atm}}^{\text{zero}} + T_{rec}$$

$$= \underbrace{(1 - G_{atm})T_{atm} + T_{rec}}_{T_{sys}} + G_{atm}T_{atm} = T_{sys} + G_{atm}T_{atm}$$

$$= G_{atm}\underbrace{G_{atm}^{-1}T_{sys}}_{T_{sys}^{eff}} + G_{atm}T_{atm} = G_{atm}(T_{sys}^{eff} + T_{atm})$$

Measurement-2: observing on blank sky

$$P_{CMB}/g = G_{atm}T_{CMB} + T_{sys} = G_{atm}(T_{CMB} + T_{sys}^{eff})$$

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Measurement-2: observing on blank sky

$$P_{CMB}/g = G_{atm}T_{CMB} + T_{sys} = G_{atm}\left(T_{CMB} + T_{sys}^{eff}\right) \Longrightarrow \frac{P_{CMB}}{gG_{atm}} = (T_{sys}^{eff} + T_{CMB})$$

$$\frac{(P_{BB} - P_{CMB})}{g} = G_{atm}(T_{sys}^{eff} + T_{atm} - T_{sys}^{eff} - T_{CMB}) = G_{atm}(T_{atm} - T_{CMB}) \Longrightarrow \frac{1}{gG_{atm}} = \frac{T_{atm} - T_{CMB}}{P_{BB} - P_{CMB}}$$

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Measurement-2: observing on blank sky

$$P_{CMB}/g = G_{atm}T_{CMB} + T_{sys} = G_{atm}(T_{CMB} + T_{sys}^{eff}) \Rightarrow \frac{P_{CMB}}{gG_{atm}} = (T_{sys}^{eff} + T_{CMB}) \Rightarrow T_{sys}^{eff} = \frac{P_{CMB}}{gG_{atm}} - T_{CMB}$$

$$\frac{(P_{BB} - P_{CMB})}{g} = G_{atm}(T_{sys}^{eff} + T_{atm} - T_{sys}^{eff} - T_{CMB}) = G_{atm}(T_{atm} - T_{CMB}) \Rightarrow \frac{1}{gG_{atm}} = \frac{T_{atm} - T_{CMB}}{P_{BB} - P_{CMB}}$$

$$T_{sys}^{eff} = \frac{T_{atm} - T_{CMB}}{P_{BB} - P_{CMB}} P_{CMB} - T_{CMB}$$

1. We use the measurement of effective system temperature to characterize the thermal noise of our observations.
2. Effective system temperature also contains the information of how the emission from the celestial source is attenuated by the atmosphere.