An Introduction to Radio Interferometry

5-2 Atmospheric effect

You can find relevant material
on my personal webpage

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Overview

- Emission
- Absorption
- Refraction

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  Contribute to thermal noise. (Introduce in Lecture Unit 5-3)

- Absorption

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  Attenuate signal.

- Refraction

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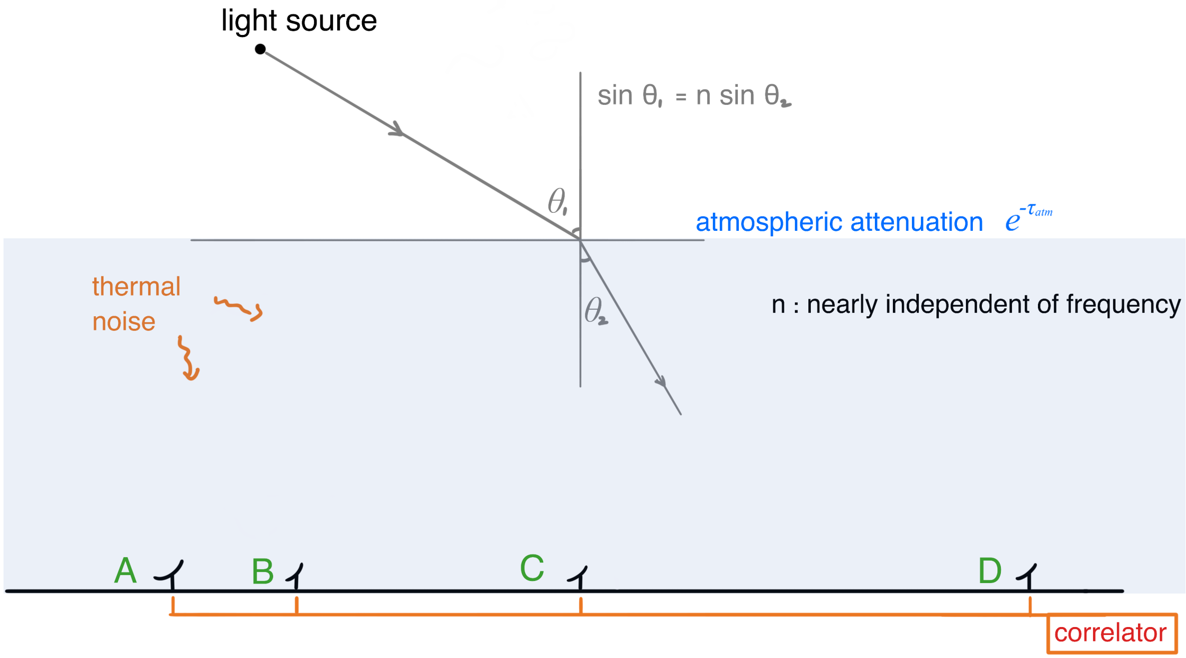
  (i) effectively, leads to source tracking errors



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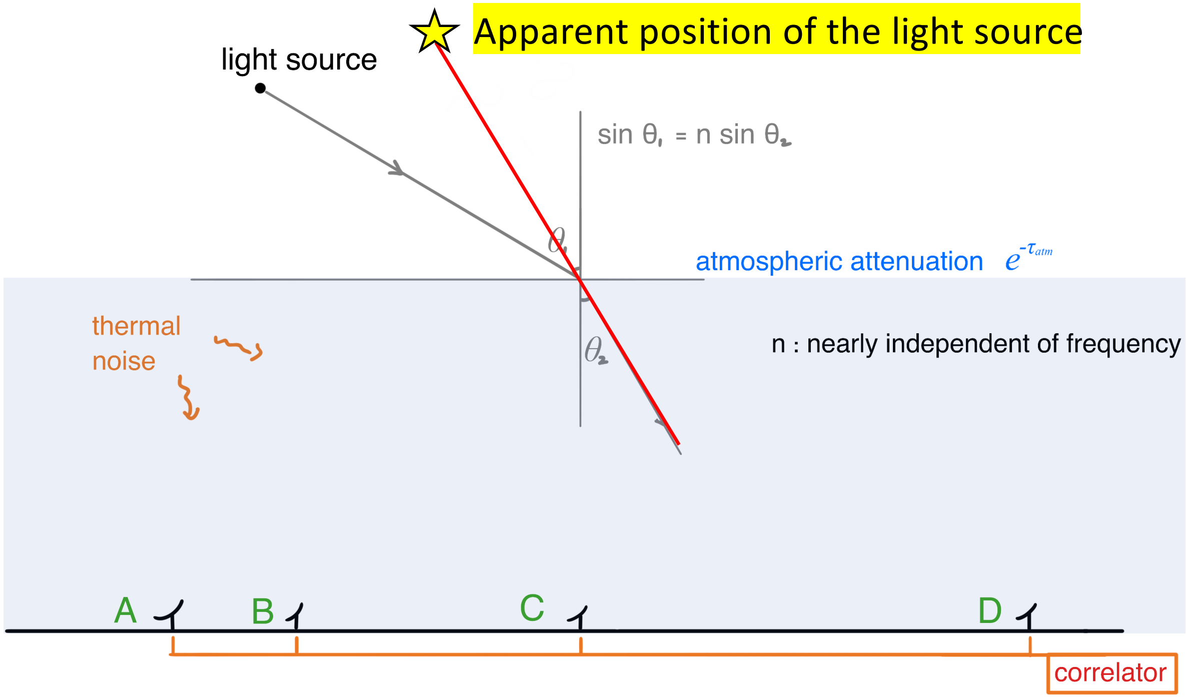


Overview

- Emission

    Contribute to thermal noise.

- Absorption

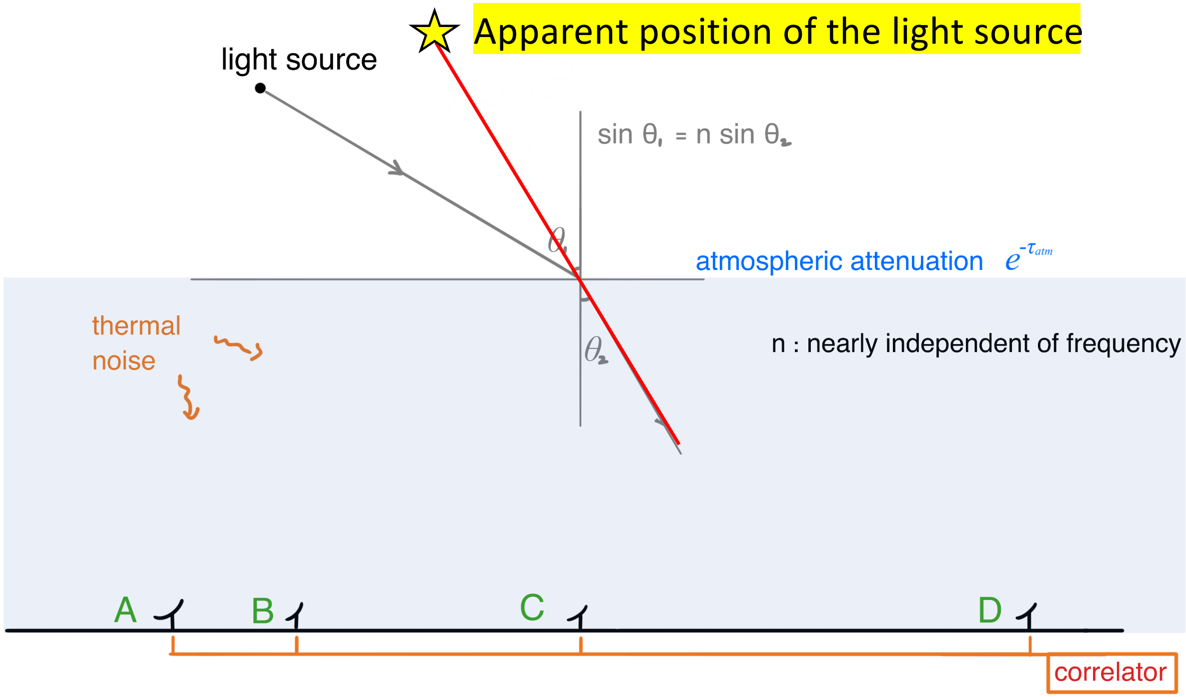
    Attenuate signal.

- Refraction

    (i) effectively, leads to source tracking errors

    (ii) leads to variations of path length difference to each telescope

    (i.e., changes visibility phase) [Introduce in Lecture Unit 5-4]



Atmospheric absorption

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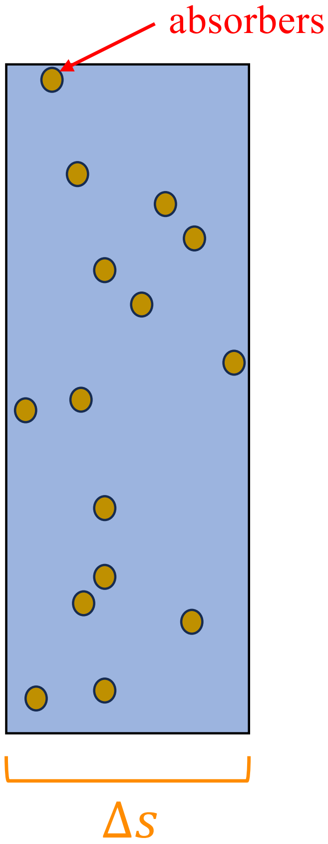

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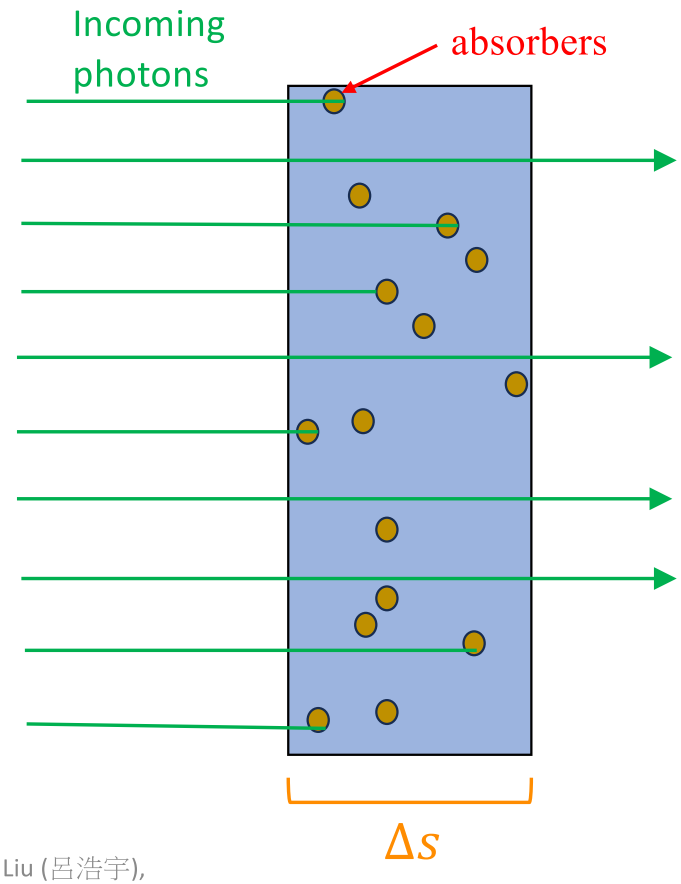
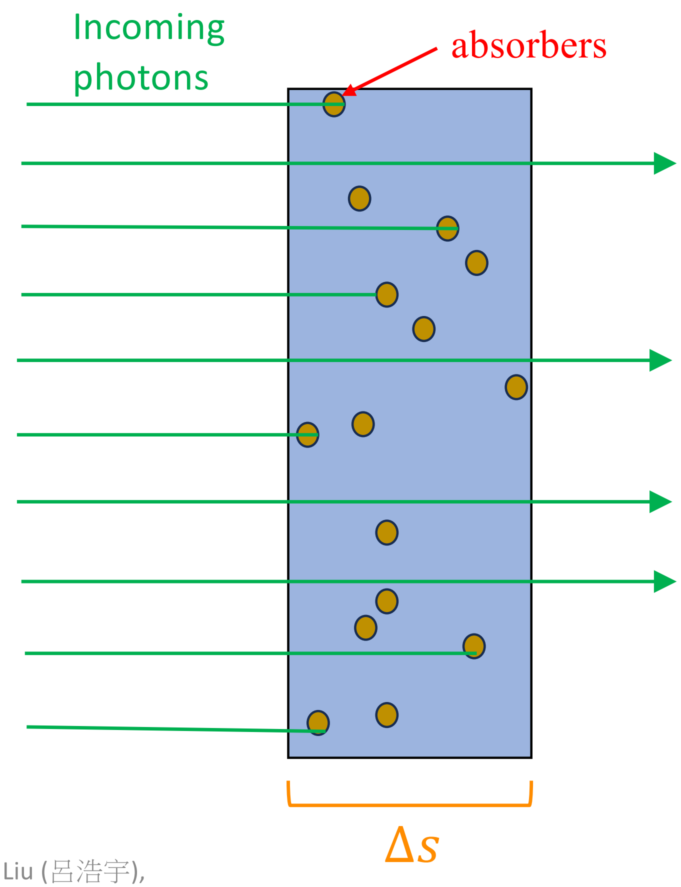


Atmospheric absorption

$$-\frac{\Delta I}{\underbrace{I}_{\text{intensity}}} = \overbrace{\kappa}^{\text{Proportional constant related to absorbers' mean cross-section and density}}\ \underbrace{\Delta s}_{\text{thickness}}$$



Atmospheric absorption

Proportional constant related to absorbers' mean cross-section and density

$$-\frac{\Delta I}{I} = \kappa \, \Delta s$$

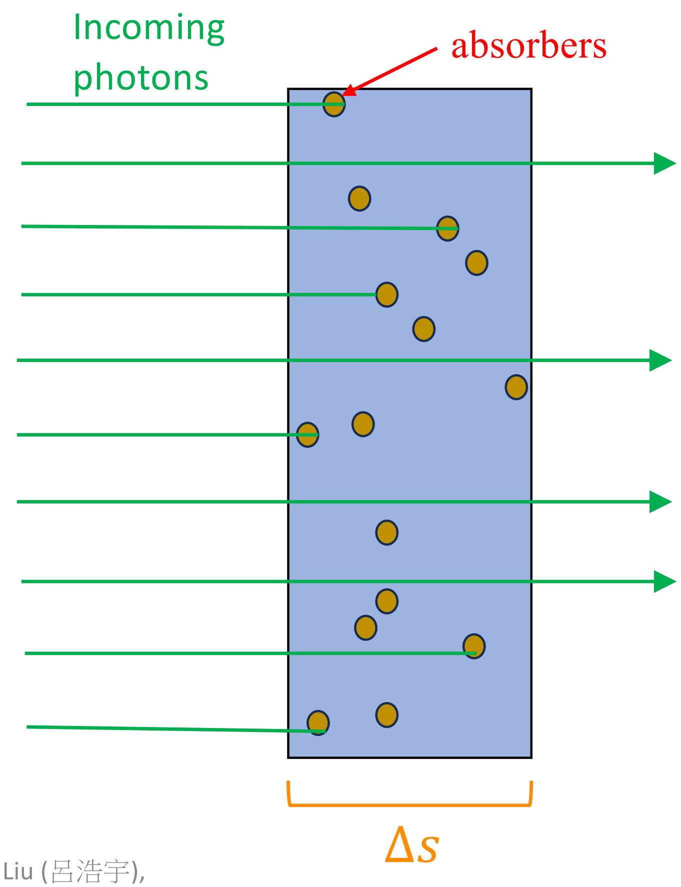
intensity

thickness

$$\Delta \tau \equiv \kappa \, \Delta s$$

Optical depth

Incredibly important to remember!



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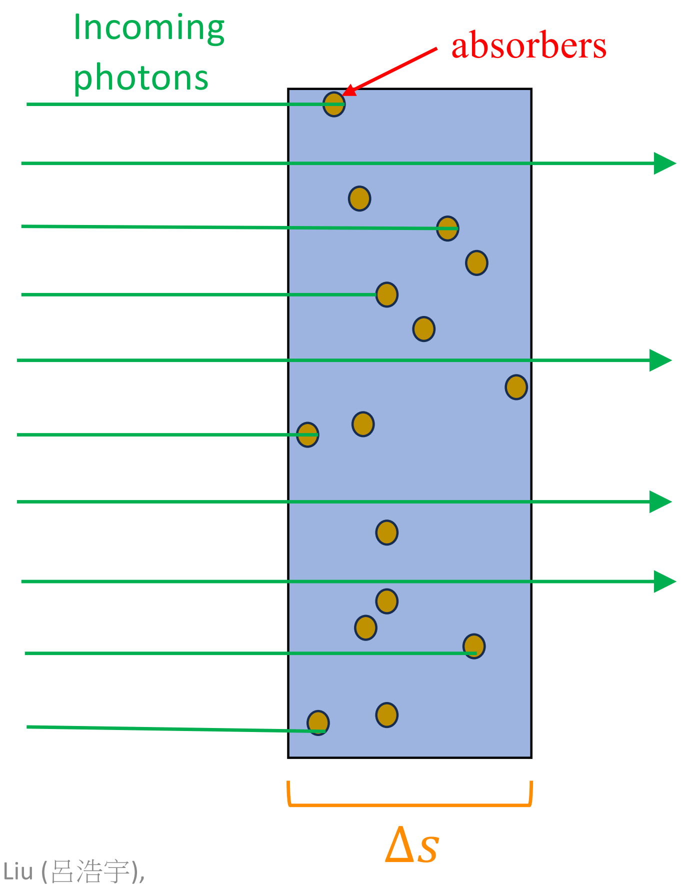

$$\Delta\tau \equiv \kappa\ \Delta s$$

Incredibly important to remember!

$$-\frac{dI}{d\tau} = I \implies \int \frac{dI}{I} = \int -d\tau$$

$$\implies lnI = -\tau + const.$$

$$\implies I = e^{const.} e^{-\tau}$$

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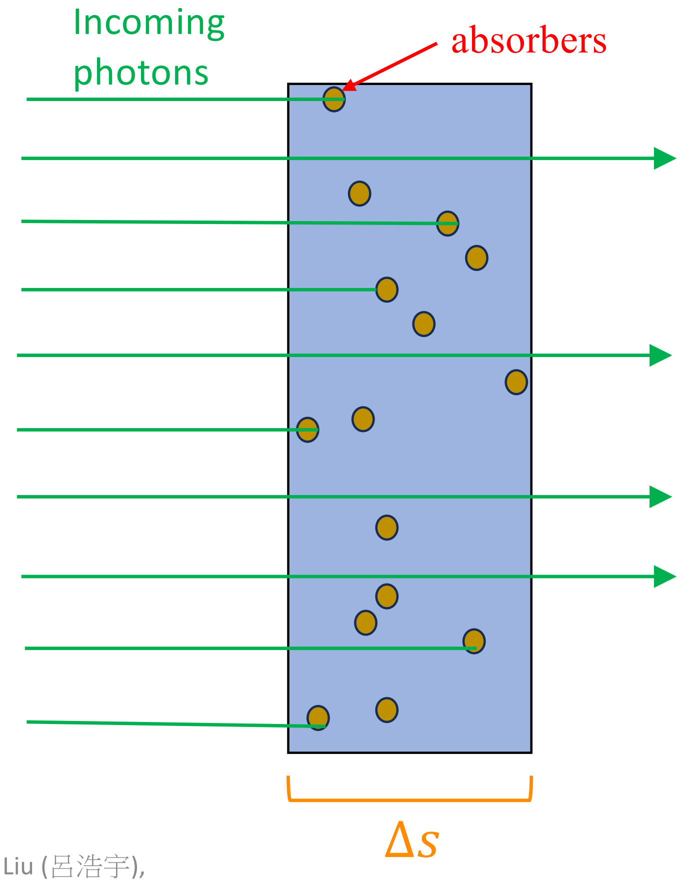
$$I = \overbrace{I_0}^{\text{Incoming intensity}} \text{ when } \tau = 0$$

$$I = I_0 e^{-\tau_{atm}}$$



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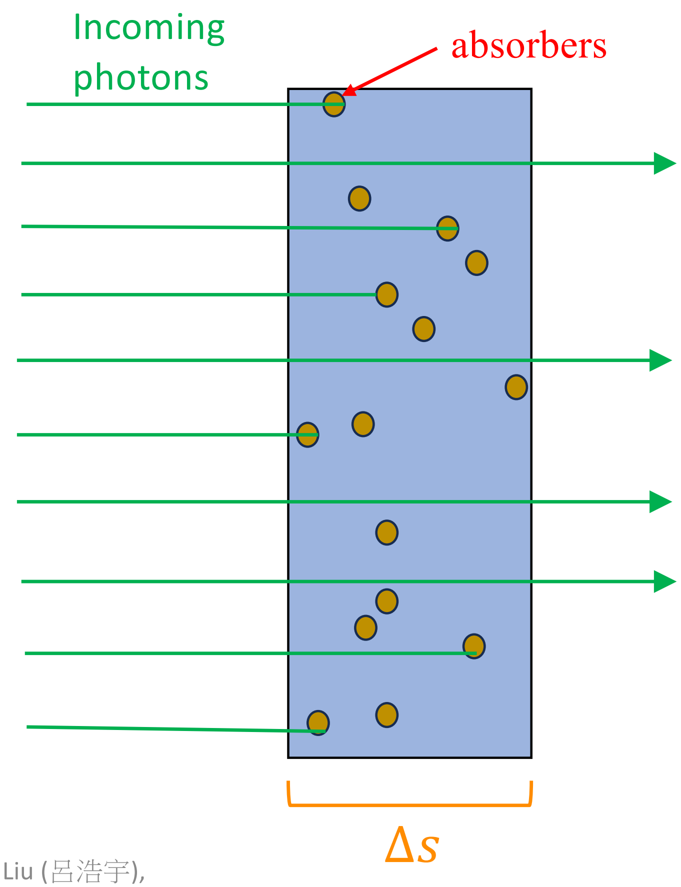
Incoming intensity

$I = I_0$ when $\tau = 0$

$$I = I_0 e^{-\tau_{atm}}$$

$$G_{atm} \equiv e^{-\tau_{atm}}$$

Extinction coefficient



Atmospheric emission

c.f. George B. Rybicki & Alan P. Lightman, Radiative Processes in Astrophysics

Incredibly important to remember!

$$\underbrace{T_B^{atm}}_{\text{Brightness temperature of the atmosphere}} = \overbrace{T_{atm}}^{\text{Temperature of the atmosphere}}(1 - e^{-\tau_{atm}})$$

$$\boxed{\Delta\tau \equiv \kappa\,\Delta s, \quad \tau = \int d\tau}$$

$$\boxed{G_{atm} \equiv e^{-\tau_{atm}}}$$

[check lecture unit 1-4 if necessary]

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[check lecture unit 1-4 if necessary]

High optical depth limit ($\tau_{atm} \rightarrow \infty$) :
- $G_{atm} \rightarrow 0$: Strong attenuation. Celestial source cannot be seen.
- $T_B^{atm} \rightarrow T_{atm}$: The atmosphere looks like an ideal black body.

Low optical depth limit ($\tau_{atm} \rightarrow 0$) :

$$T_B^{atm} \sim T_{atm}\left[1 - \underbrace{\left(1 - \tau_{atm} + \frac{1}{2!}\tau_{atm}^2 + \cdots\right)}_{\text{Taylor expansion}}\right] \sim \underbrace{T_{atm}\,\tau_{atm}}_{\text{Ignore higher order of } \tau_{atm}}$$

1. The atmosphere effects the observations of the celestial objects by emission, absorption, and refraction.
2. Intensity of a celestial object is attenuated by $\boxed{G_{atm} \equiv e^{-\tau_{atm}}}$, where τ_{atm} is the optical depth of the atmosphere during the time of the observation and at the observing frequency.
3. The emission of the atmosphere can be approximated by $T_B^{atm} = T_{atm}\,(1 - e^{-\tau_{atm}})$