Numerical Treatment of Polarisation

Or:

Do numerical models of the first cosmological sources of light give any physical meaning?

and:

Can these (sensible?) models predict the degree of polarisation?

or, in other words:

What happened after big bang?

tl;dr:

What *is* out there?

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What is out there?

Probing the universe?

Big Bang

Dark ages

Epoch of Reionisation

The first light

The Epoch of Reionisation (*EoR*)

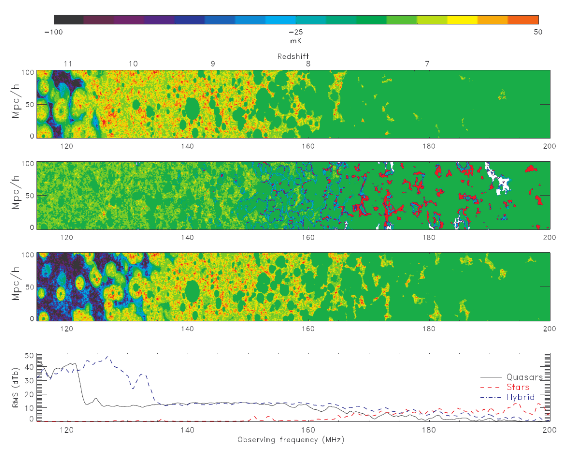

Figure: Evolution of the differential brightness temperature $\delta T_b \equiv T_b - T_{\mathrm{CMB}}$, where T_b: brightness temperature, T_{CMB}: CMB temperature. *Top case: Mini-qsos, Middle case: Thermal sources (stars), Bottom case: Hybrid*. From Zaroubi (2013).

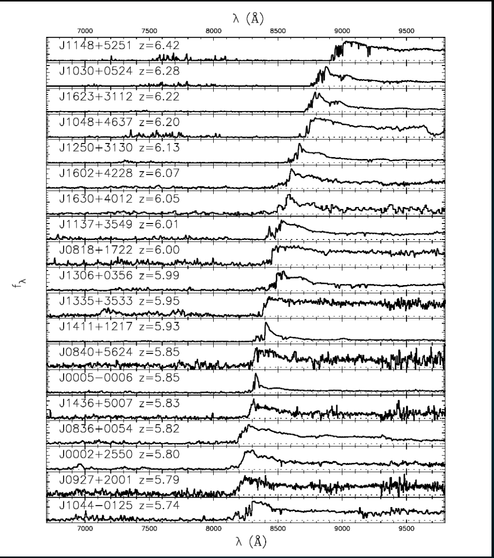

Figure: Displacement of the Gunn-Peterson through with increasing redshift z. From Zaroubi (2013).

Change in optical depth τ_ν along a line of sight s (Rutten 2003):

$$d\tau_\nu(s) \equiv \alpha_\nu(s)\, ds \tag{1}$$

with α_ν: the frequency-dependent (ν) **extinction coefficient**.
The optical depth ***increases*** if there are extinction events along ds.

- $\tau > 1$: the medium is *optically thick* – **opaque**
- $\tau < 1$: the medium is *optically thin* – **transparent**

Modelling the first light

Deterministic models vs. *Stochastic models*

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can be approached by drawing a random number $\mathcal{R} \in [0, 1]$, with the requirement

$$\mathcal{R} = \int_0^\tau e^{-\tau'} \mathrm{d}\tau' \tag{5}$$

inverting,

$$\tau(\mathcal{R}) = -\ln(1 - \mathcal{R}) \tag{6}$$

(Laursen 2010)

Polarisation

Polarisation

"A ray of ordinary light is symmetrical with respect to the direction of propagation. If, for example, this direction be vertical, there is nothing that can be said concerning the north and south sides of the ray that is not equally true concerning the east and west sides. In polarized light this symmetry is lost."

P. 137, John William Strutt, Lord Rayleigh (1902).

Polarisation

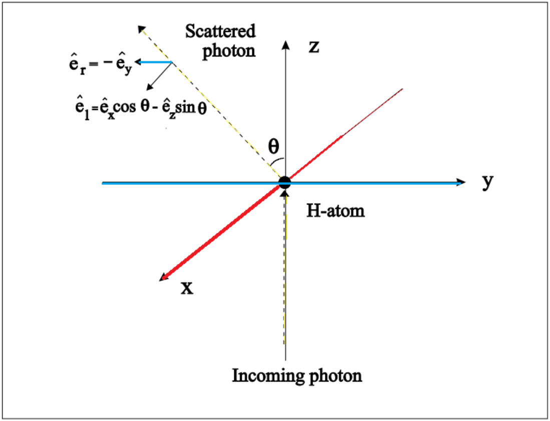

Fig. 4. The definition of the polarization vectors for the scattered light. The scattered beam is taken to lie in the xz-plane.

Figure: From Brasken & Kyrola (1998).

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Line centre:

$$p(\theta) = \frac{11}{12} + \frac{3}{12}\cos^2\theta, \qquad \Pi(\theta) = \frac{\sin^2\theta}{\frac{11}{3} + \cos^2\theta} \tag{7}$$

with: $p(\theta)$: *phase function*, giving scattering probability and $\Pi(\theta)$: *polarisation degree*.

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Wing:

$$p(\theta) = \frac{3}{4} + \frac{3}{4}\cos^2\theta, \qquad \Pi(\theta) = \frac{\sin^2\theta}{1 + \cos^2\theta} \tag{8}$$

From Dijkstra & Loeb (2008).

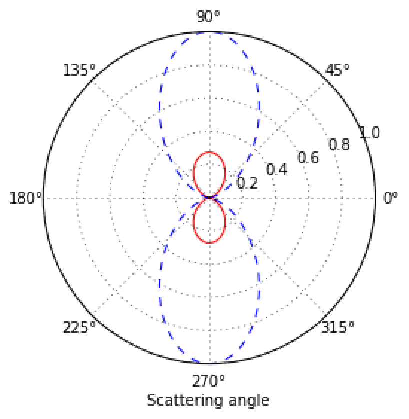

Figure: Polarisation degree $\Pi(\theta) = \frac{I_{\parallel} - I_{\perp}}{I_{\parallel} + I_{\perp}}$, here I_i are the components of the intensities following fig. (3). The red solid line is in the case where scattering occurs in the Lyα line centre, where as the dashed blue line is for wing scattering events.

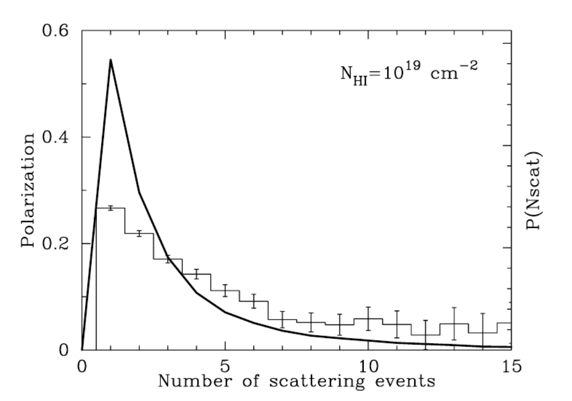

Figure: Histogram showing angle-averaged polarisation as function of scattering events. Line showing the *probability distribution* of the number of scatterings. Numerical model where one has single expanding thin shell of neutral hydrogen around the galaxy. From Dijkstra & Loeb (2008).

Brasken, M., & Kyrola, E. 1998, A&A, 332, 732

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