The Point about Conical Emissions of First Galaxies

Simulating Quasar Emissions During the Epoch of Reionisation

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Introduction

Simulations for the Epoch of Reionisation (EoR), typically assume that emissions of radiation are symmetrical in nature.
For this project we decided to investigate how the EoR would be affected if this was no longer the case, and instead photon emissions were only permitted in a given direction, resulting in conical shapes similar to what would be seen from quasar observations [1].
To do this we used an improved version of the ray-tracing code C^2-Ray [2].

Methodology

Each cell in the simulated grid was assigned a random unit vector $\hat{n}$, serving as central axis for the conical emissions. When calculating radiative emissions, cells that were not within an angle, α, between $\hat{n}$ and the vector from source to said cell, were ignored. For this case, $\alpha = 18°$
In order to take into account the missing photons that this method produced, the photon production of each source was increased by a factor P, the inverse of the faction the cone's solid angle was of a whole sphere.

$$P = \frac{2}{1 - cos(\alpha)}$$

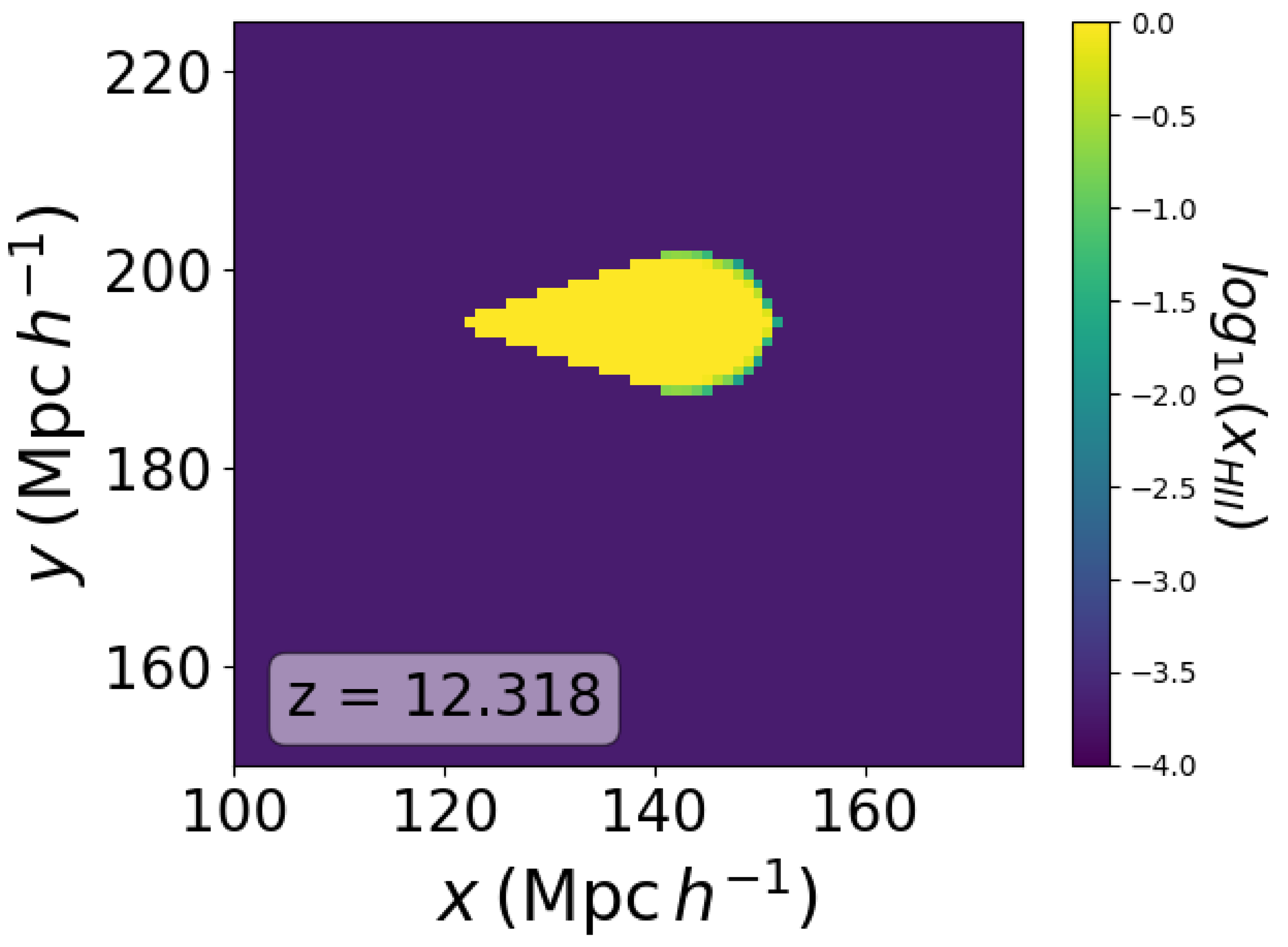

Figure 1: An example of space ionised by the conical emissions of a single radiative source. Here $\hat{n}$ was parallel to the x-axis.

Slices of Ionised Space

We ran two simulations from $z = 22$ to $z = 6$, one using the standard spherical emissions and one using the new conical emissions. Our findings show significant differences in the morphology of the EoR, as seen in Figure 2.

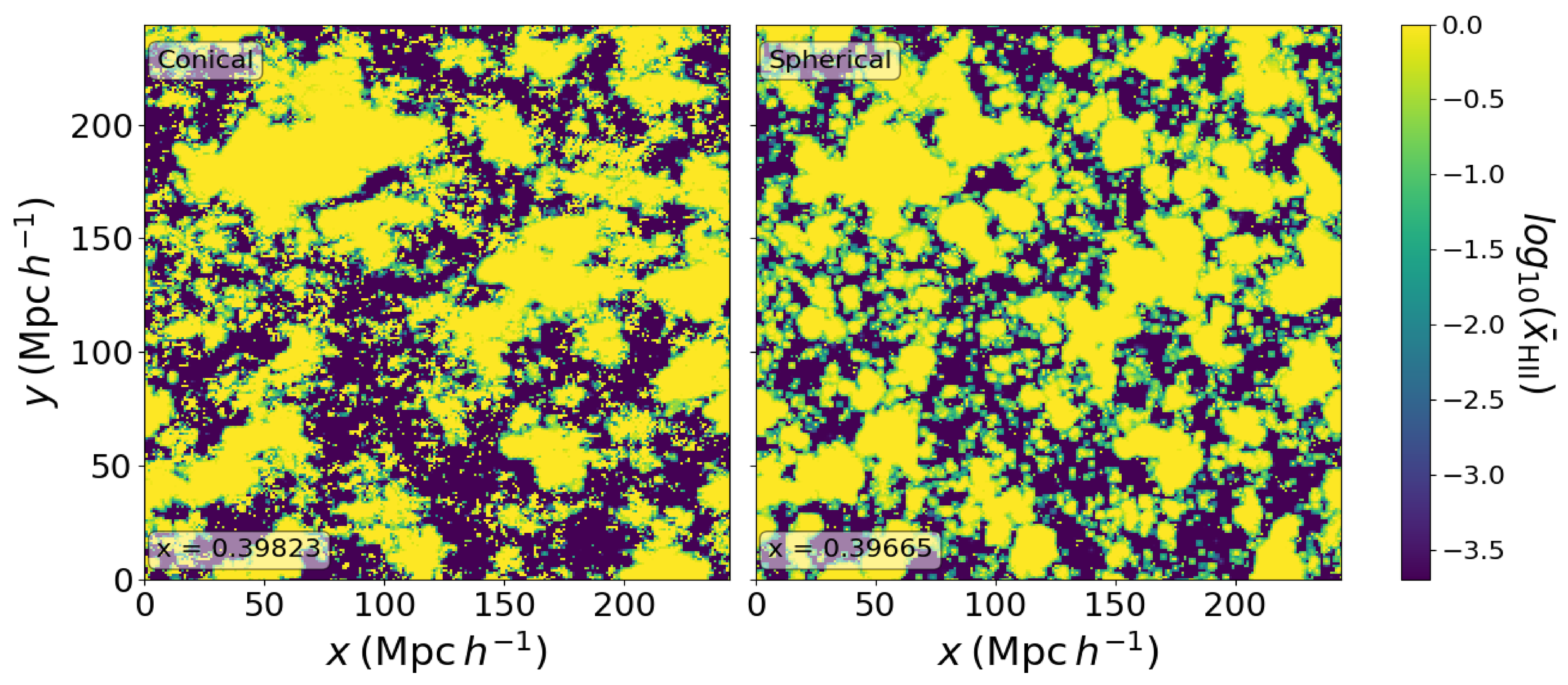

Figure 2: Two slices of the simulations, comparing the reionisation when 40% of cells in the simulation were ionised.

What is of interest here is the sharp difference in the number of partially ionised cells between simulations, which will likely have a noticeable impact on the emitted 21-cm photons. In the spherical case there are more then twice as many cells with ionisation fractions between 0.1 and 0.9, than in the spherical case

Measuring the Volume of Ionised Space

Looking into the bubble sizes with the Friends of Friends [3], and Mean Free Path [4] methods respectively, it can be seen that the conical method produces larger ionised bubbles while the spherical method produces a greater number of smaller bubbles.

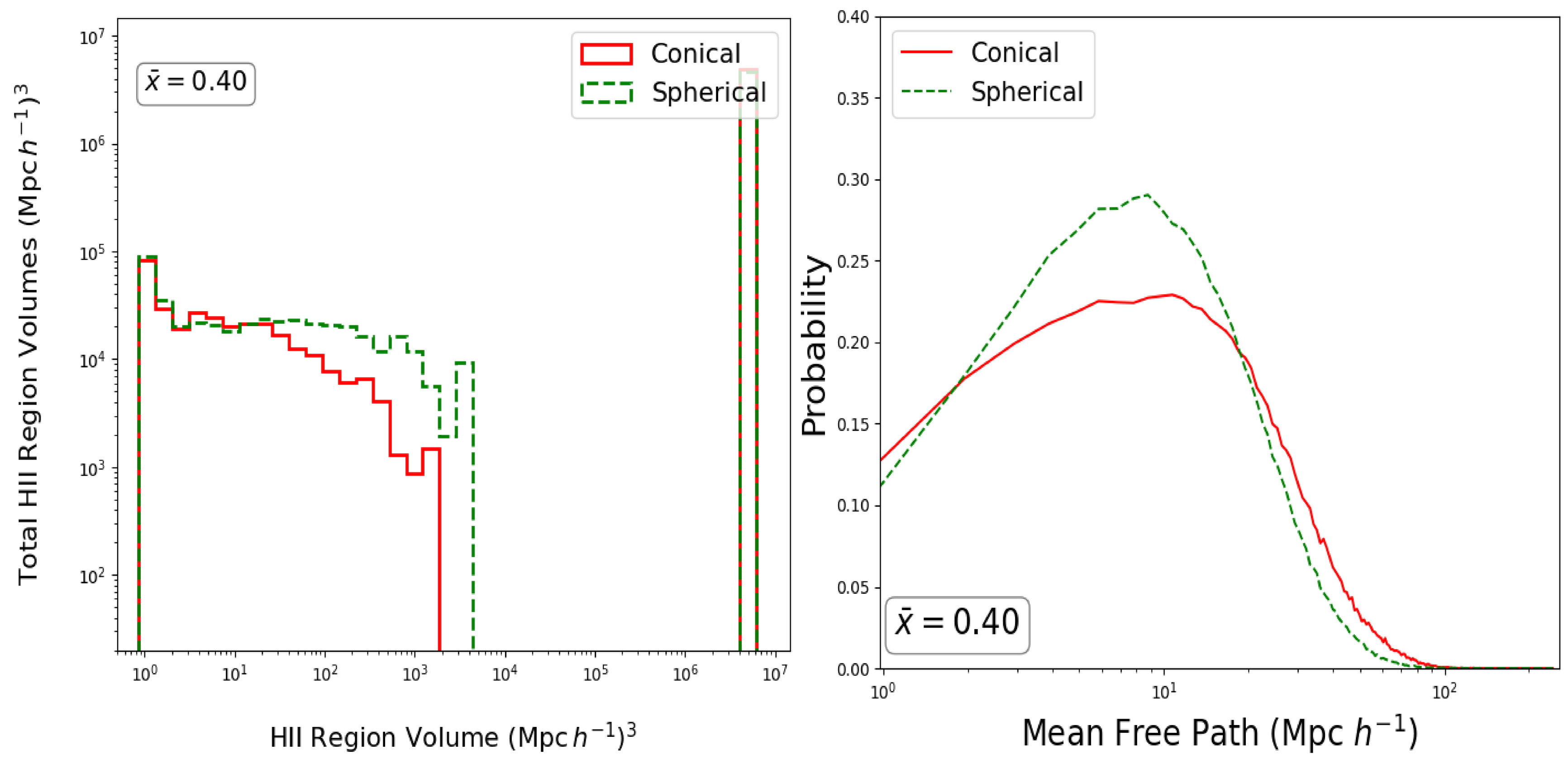

Figure 3: The sizes of ionisation bubbles produced by the FOF and MFP bubbles, while at 40% ionised.

The reason for this difference in bubble size is likely due to the amount a cell has to be ionised in order to be considered ionised by the code. Since there are more partially ionised cells in the spherical case there is a greater probability for bubbles to be split by said neutral space.

Power Spectra

In order to determine if there would be a significant difference between potential observations of telescopes such as SKA, we also calculated the spherically averaged power spectra.

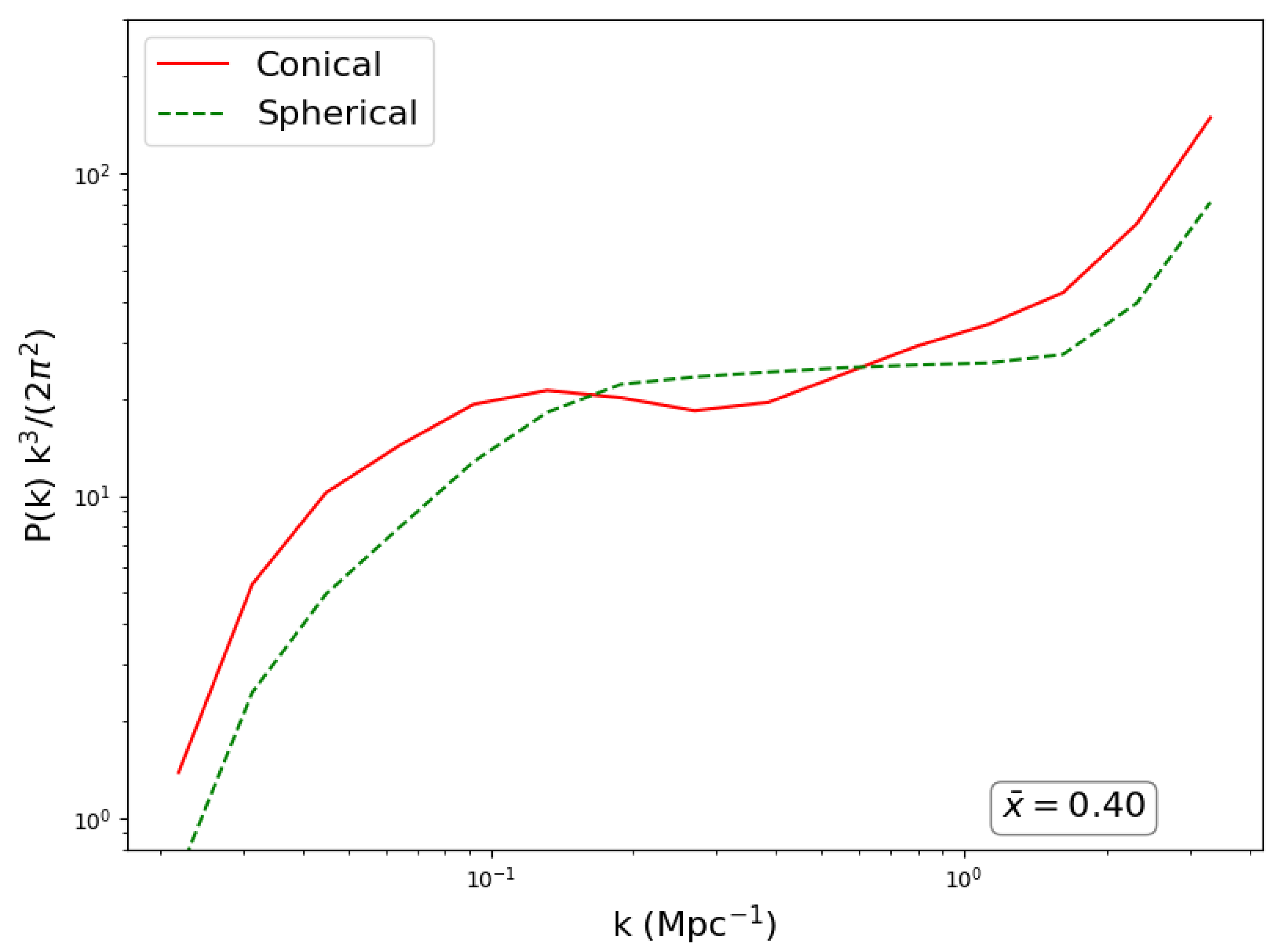

Figure 4: The spherically averaged power spectra at 40% ionised. Notice the significant differences, especially around k = 0.2.

This difference is interesting for low-k observations and upper limits, as it shows a clear difference between the two cases, something that should certainly be looked into further.

References and Acknowledgements

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(2) G. Mellema, I. T. Iliev et al., 2006, **11**, 374–395.
(3) I. T. Iliev, G. Mellema et al., 2006, **369**, 1625–1638.
(4) A. Mesinger and S. Furlanetto, 2007, **669**, 663–675.

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