Intensity Mapping Working Group

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Abstract:
Radio telescopes such as MeerKAT, and in the future the Square Kilometre Array (SKA), can map the distribution of cosmic neutral hydrogen via its 21cm line emission exploiting a relative novel technique called Intensity Mapping. Such measurements could unveil the underlying large scale structure of the Universe and contribute in a fundamental way to our understading of dark matter and dark energy. In this Working Group we will construct step-by-step a mock 21cm observation, analyzing all the different components. We will see that the key challenge to fully exploit 21cm Intensity Mapping is the subtraction of bright foregrounds (such as the synchrotron emission of our Galaxy in the same frequency range). We will then try to apply some of the latest techniques to "clean" the observed data cube from the foreground contamination in order to obtain a good estimation of the pristine cosmic signal.

Acknowledgments:
The project proposed for this WG revolves around (although with some necessary simplifications) the work of the members of the SKA IM Fous Group. In particular, I would like to thank Laura Wolz, Isabella Carucci, Siymabonga Matshawule, Melis Irfan and Alkistis Pourtsidou.

Requirements:
We will run `jupyter` notebooks (https://jupyter.org/) that import the following packages:

```
import numpy as np
import healpy as hp
from astropy.io import fits
import scipy.ndimage as ndimage
from sklearn.decomposition import FastICA
from numpy import linalg as LA
import matplotlib.pyplot as plt
from mpl_toolkits.axes_grid1 import make_axes_locatable
```

Although running the notebooks on your laptop and print/plot stuff on your own it is useful, we will mostly try to understand the ideas behind the code. Having `jupyter` and the necessary packages ready it is thus not mandatory (but highly recommended).
In case, please also download the content of the `input` folder you find at this link: https://github.com/spinemart/Tonale2021

The code is simple but to avoid problems better to have the version of the packages listed below available (in a conda enviroment if you need different versions for your work).

```
np.__version__
```
```
'1.18.5'
```
```
hp.__version__
```
```
'1.14.0'
```
```
scipy.__version__
```
```
'1.5.0'
```
```
matplotlib.__version__
```
```
'3.2.2'
```

Description of the project

In this project we will construct a mock 21 cm observation and discuss how to extract the pristine 21 cm signal. It is divided in 3 steps, associated to 3 notebooks available at https://github.com/spinemart/Tonale2021.

1. We will start discussing the relevant foregrounds for our frequency range of interest and simulate a foreground data-cube. We will also discuss and add to the data cube the simulated 21cm signal.
2. We will then discuss the effect of the telescope and implement it. We will also discuss the telescope thermal noise. Once added the effect of the telescope on our simulated sky-cube, we will have ready a toy mock 21cm observation.
3. Given our mock observation, we will then test the "blind" foreground cleaning approach of PCA and FastICA.

Useful papers:
Some works (among others) on data/simulations for 21cm IM: simulations Wolz et al. (2014); Alonso et al. (2014, 2015); Wolz et al. (2017); Carucci et al. (2020); Matshawule et al. (2021); Cunnington et al. (2021); Spinelli et al. (2022).

References

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Wolz, L., Abdalla, F., Blake, C., et al. 2014, MNRAS, 441, 3271

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