

## Units and cosmological calculations with Astropy

**Astropy** is a python-package specialised to do astronomy-related calculations. In the following you will use astropy to convert between different units and to carry out cosmological distance calculations.

### Units

With **import astropy.units as u** the unit-object from astropy can be loaded. A velocity can for example be specified via **v=300000 \* u.km / u.s**

- Use the units module to convert to the following units: 1) cm per second 2) kpc per gigayear, 3) lightyear per year.

With **import astropy.constants as const** you can import a number of physical constants. For example the gravitational constants can be obtained by typing **const.G**.

- Use astropy to calculate the value of the gravitational constant,  $G$ , in units of  $\text{kpc}^3 M_{\odot}^{-1} \text{Gyr}^{-2}$ .

In galaxy simulations a unit system based on kpc,  $\text{km s}^{-1}$  and  $10^{10} M_{\odot}$  is often used:

```
import astropy.units as u
length_unit = 1.0 * u.kpc
v_unit = 1.0 * u.km/u.s
Mass_unit = 1e10 * u.M_sun
```

We can derive a time unit as following:

```
time_unit = length_unit/v_unit
```

- Calculate the value of  $G$  in this unit system.

### Cosmological distance calculations

- Create a plot of the comoving distance, angular diameter distance, luminosity distance and lookback time as a function of redshift for the PLANCK18 cosmology.
- repeat for a WMAP 7 cosmology.

Hints: <http://docs.astropy.org/en/stable/cosmology/index.html> and also <http://docs.astropy.org/en/stable/index.html>