Radio Astronomy - Summary

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This summary is based on lecture slides and the NRAO Essential Radio Astronomy lectures: https://science.nrao.edu/opportunities/courses/era

1 multi-messenger astrophysics

Multi-messenger astrophysics: Research based on more than one source of astrophysical information. E.g. electromagnetic radiation, neutrino, gravitational wave or cosmic ray observations.

Example: merger of two neutron stars detected in gravitational waves + gamma rays + optical light

Multi-wavelength astrophysics: Research based on information in several wavelength regimes e.g. optical, radio, gamma rays, X-rays etc.

Example: We see different components and physical processes of galaxies in different wavelengths. The Sun looks different at different wavelengths → we see different depths in the Solar atmosphere or radiation from different processes.

One of the most common detector type in astronomy is CCD detectors. These detectors detect light as "particles", they only measure the intensity of light in a certain wavelength range.

1.1 Online data archives

There are many free online archives for astronomy data. Some examples:

- Skyview: https://skyview.gsfc.nasa.gov/current/cgi/query.pl
- Hubble legacy archive: https://hla.stsci.edu/
- Gaia telescope archive
- Dust Maps data
- etc.

Most of these archives are built to Virtual Observatory (VO) standards and are accessible trough various software tools, e.g. dedicated python libraries.

2 Radio Astronomy

- Wavelength range: 0.3 mm - 30 m
  - almost all types of astronomical sources
  - wide variety of radio telescopes and observing techniques
- interstellar dust grains are much smaller than radio wavelengths → dusty interstellar medium (ISM) is nearly transparent
- Low frequencies imply low photon energies $E = h\nu$.
- stimulated emission → maser emission
- Cold thermal emitters (e.g., the 2.73 K cosmic microwave background, or interstellar gas at temperatures below 100 K)
- synchrotron sources
- plasma effects (scattering, dispersion, Faraday rotation → tracing interstellar electron densities and magnetic field strengths.

Angular resolution limit: $\Theta = \lambda/D$. Because radio telescopes are able to detect both the intensity and the phase of the light ("wave" nature) it is relatively easy to combine telescopes trough interferometry. → Which results in the finest angular resolution in astronomy ($\sim \Theta = 0.00017$ arcsec).

2.1 Radiation Fundamentals

Basic definitions:

- specific intensity: wavelength dependent
- total intensity: specific intensity integrated over all wavelengths
- flux density: the specific intensity received by a detector of unit projected area (unresolved sources)
- spectral luminosity
- total power per unit bandwidth radiated by the source at frequency ν

Radiative transfer

- absorption and emission coefficients
- optical depth (optically thin $\tau << 1$, optically thick $\tau \sim 1$)
- Radiative transfer equation
- Kirchhoff law
- brightness temperature
- polarisation (elliptical polarisation, linear polarisation) - naturally measured with radio telescopes $\rightarrow$ information on magnetic fields
- Stokes parameters

Radio telescopes

- various shapes and types, e.g. horn antennas, dish antennas, stick antennas
- the response of a radio receiver is not the same as a CCD detector. The antennas have a radiation pattern called beams, which describe the direction dependent sensitivity pattern of the receiver.
- A radio receiver used to measure the average power of the noise coming from a radio telescope in a well-defined frequency range is called a radiometer.
- interferometers
- Earth rotation aperture synthesis