Lecture: Introduction to cosmic rays
WS 2019

Lecture program:

- Introduction: goals and typical units
- Historical remarks
- Primary cosmic ray spectrum and its composition
- Overview of measurements: direct and indirect
- Sources of cosmic radiation
- Acceleration and propagation of cosmic rays

Literature:

- H. V. Klapdor-Kleingrothaus and K. Zuber, *Particle Astrophysics*, IoP (2000)
- M. Kachelriess, *Lecture notes on high energy cosmic rays*, (2008) arXiv:0801.4376

Material for the lecture:

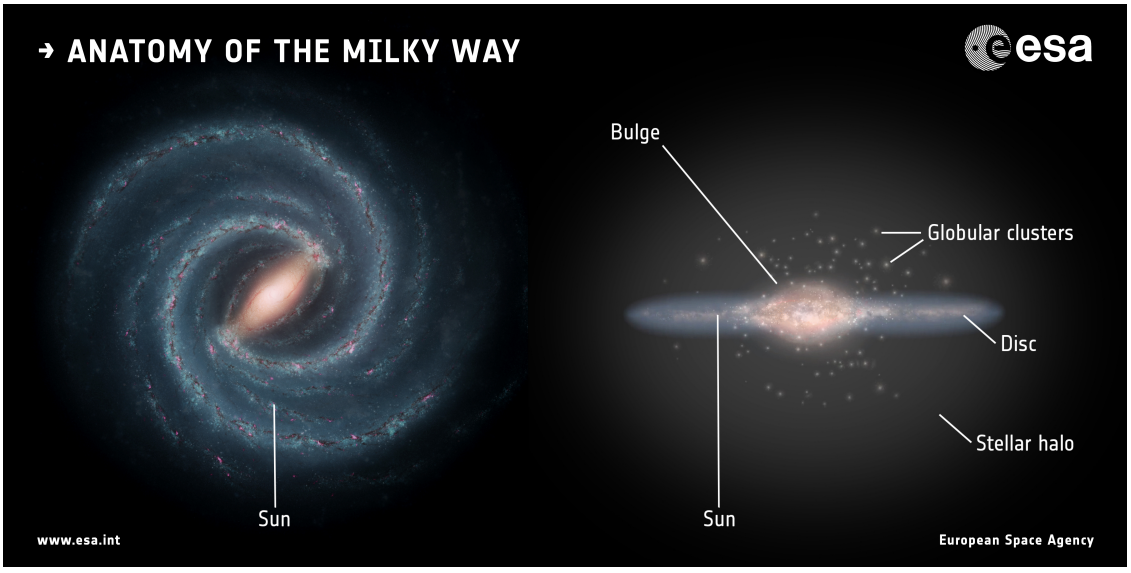

Figure 1: Anatomy of the Milky Way: an artist's impression of our Milky Way galaxy, a roughly 13 billon-year-old 'barred spiral galaxy' that is home to a few hundred billion stars. Figure from Left: NASA/JPL-Caltech; right: ESA; layout: ESA/ATG medialab.

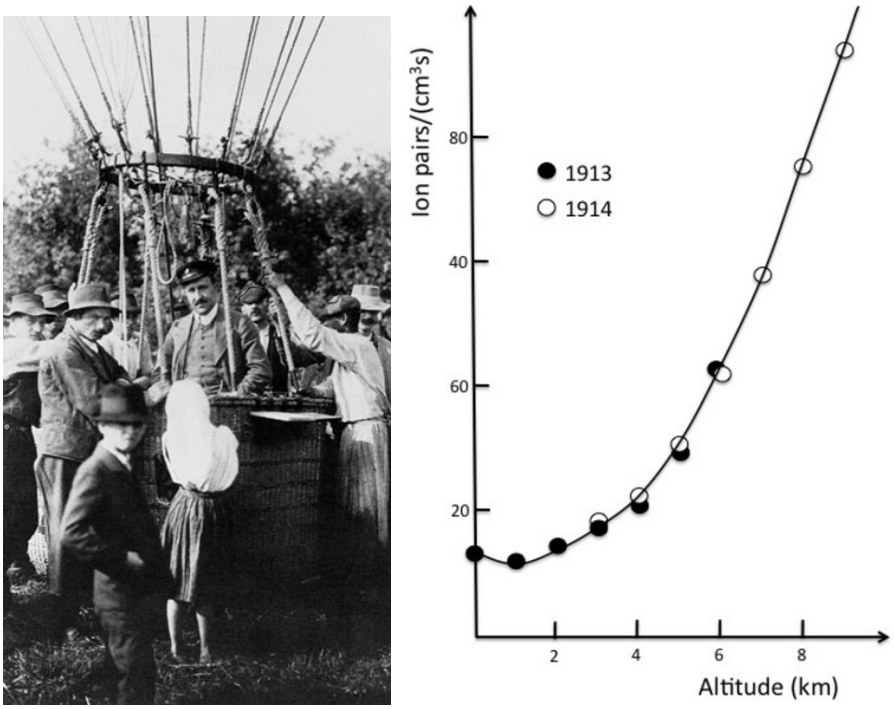

Figure 2: Victor Hess ascended with an open ballon (left figure) to 5 300 m in 1913 and measured the increase of ionizing radiation increases with altitude. The figure on the right includes data from another ballon flight in 1914 which reached 9 km. Figures from wikipedia.

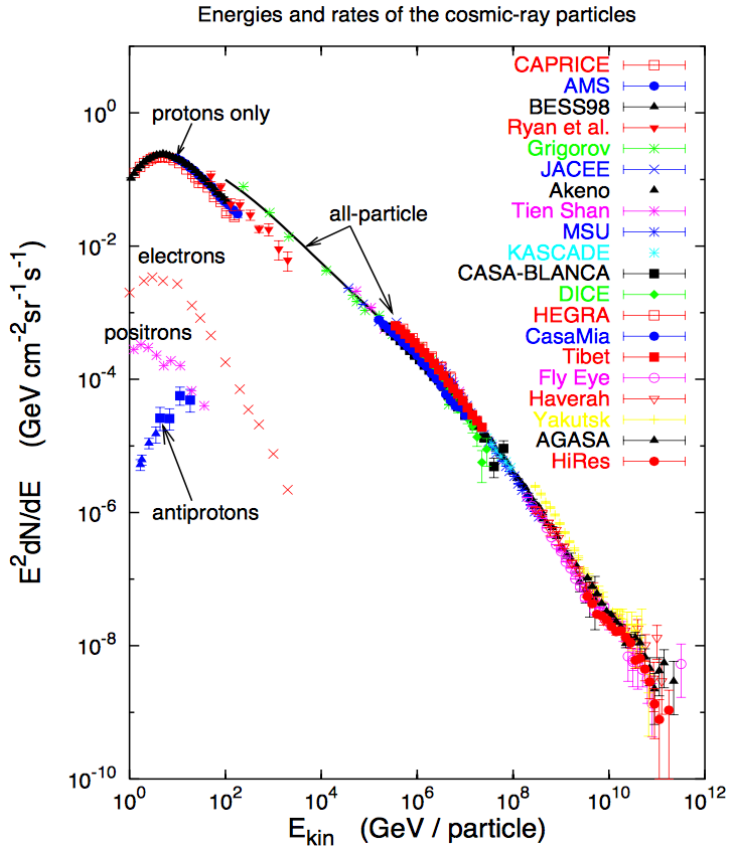

Figure 3: Compilation of cosmic ray measurements from several detectors. Figure from A.H. Hillas, arXiv:astro-ph/0607109.

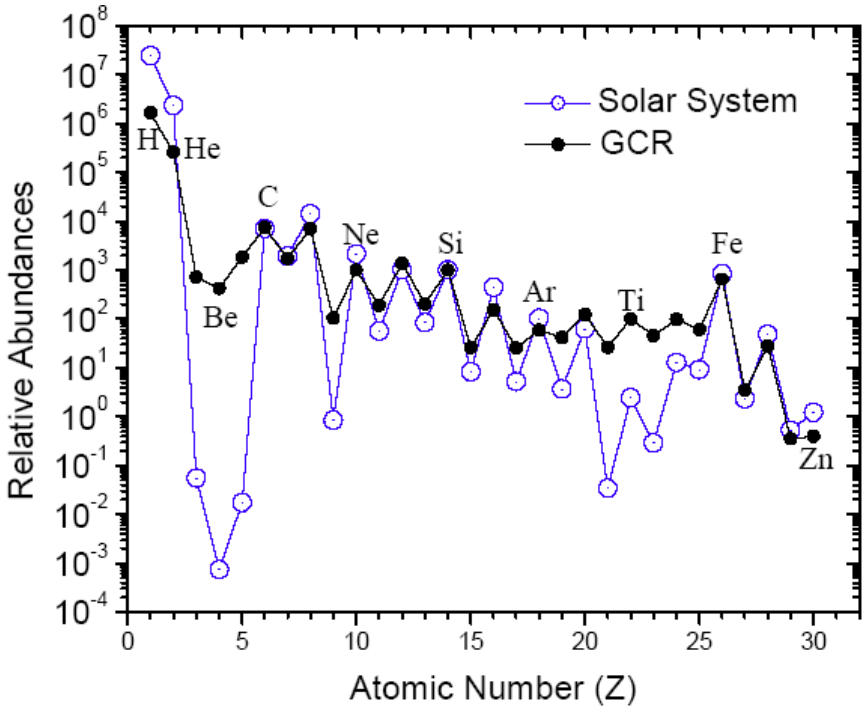

Figure 4: An overview of cosmic-ray elemental composition. Figure from `http://www.srl.caltech.edu/ACE/ACENews/ACENews83.html`

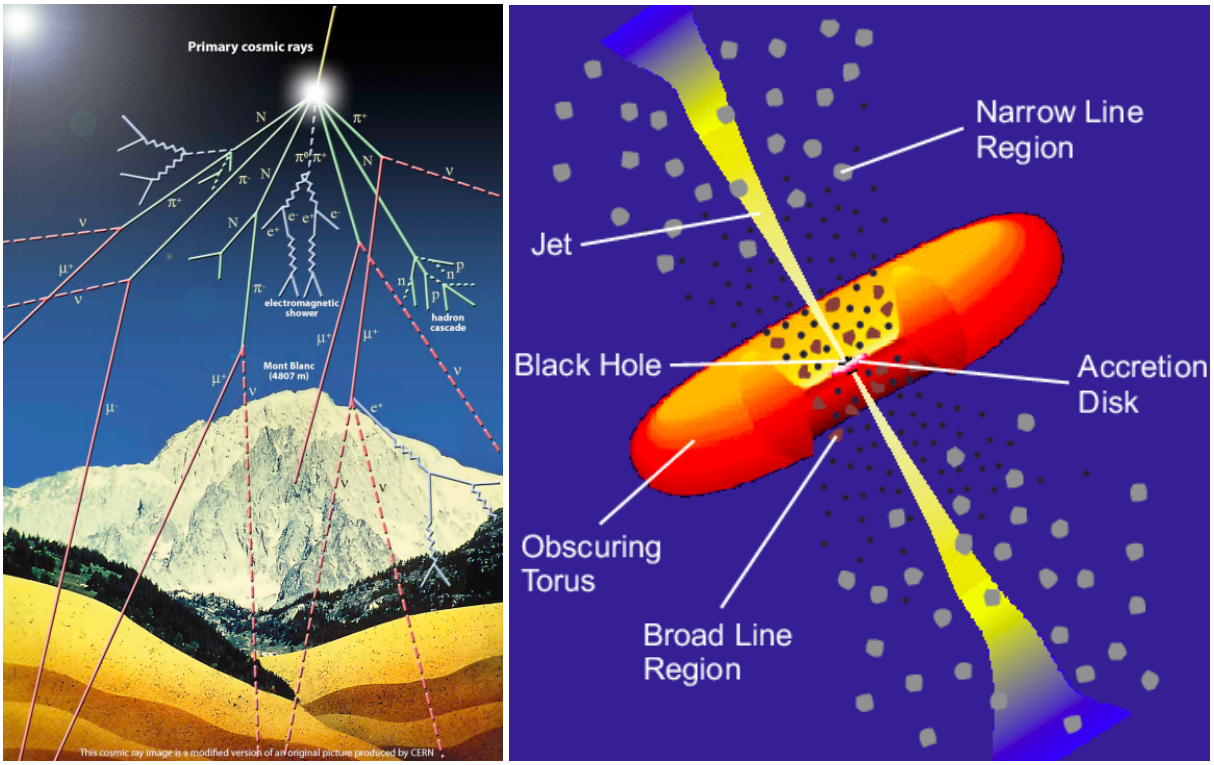

Figure 5: (Left) Scheme of a cosmic ray shower. (Right) Picture of an active galactic nucleus (AGN) after Urry and Padovani (1995).

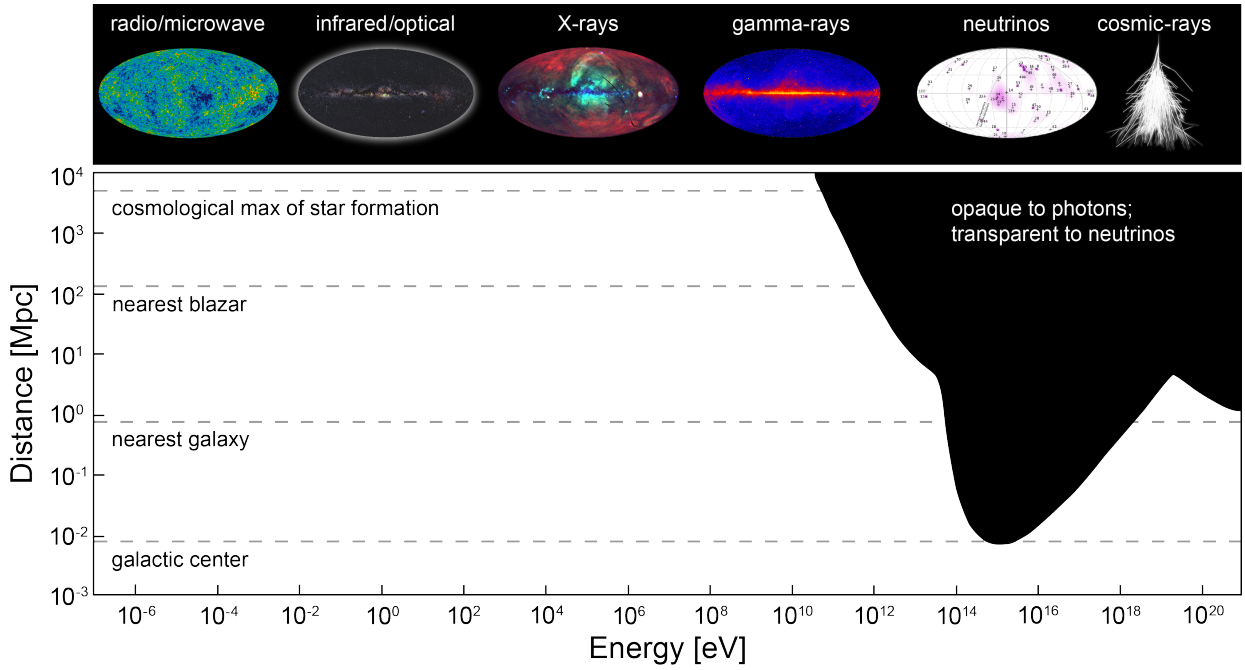

Figure 6: Energy and wavelength spectra vs distance of the visible universe. About a fifth of the universe cannot be explored using photon-based telescopes. Figure from the Ice Cube homepage.