Astrophysics I - HS 2019

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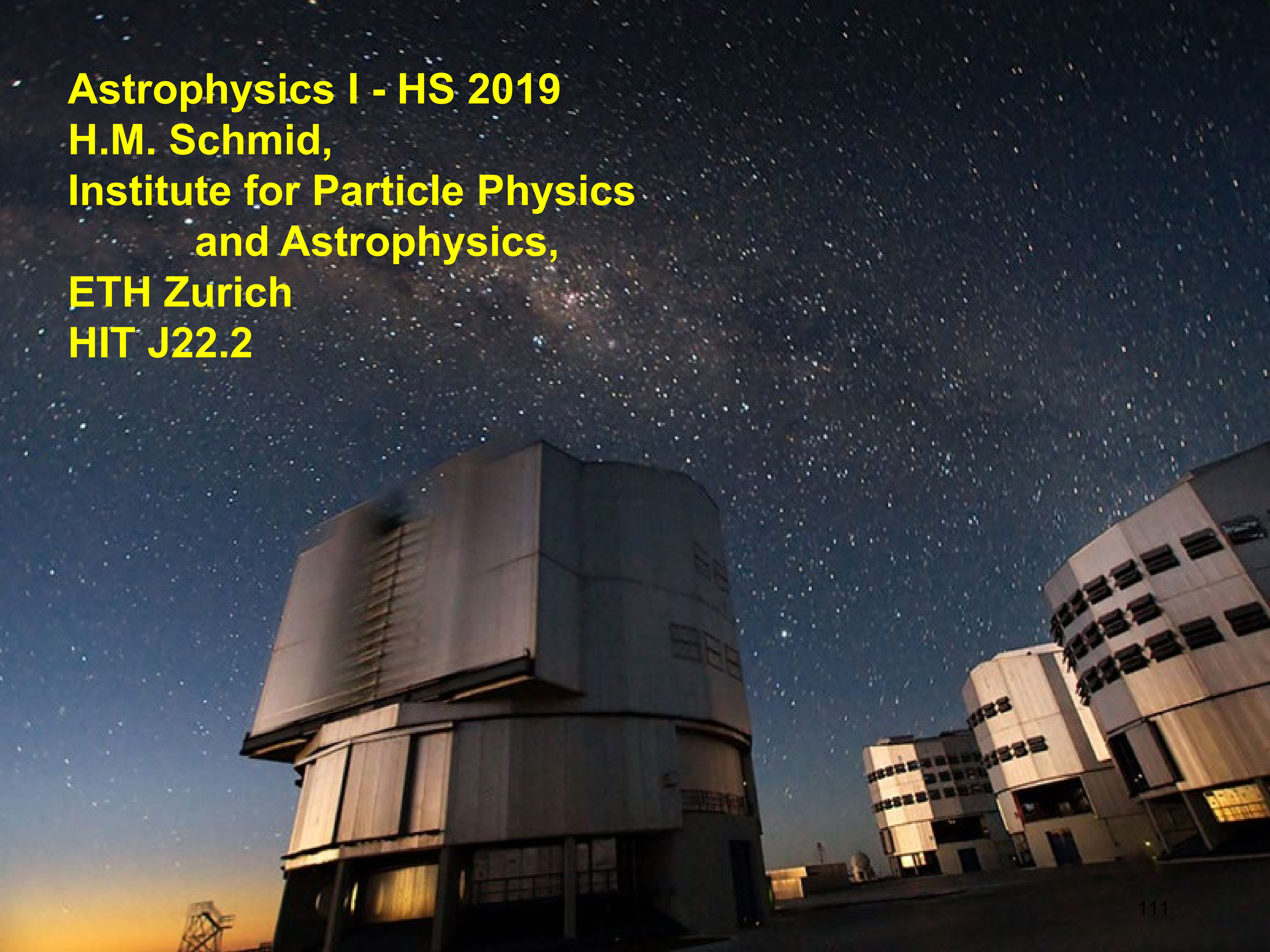
HIT J22.2



Astrophysics courses, D-Phys

1. Semester Bachelor

- Einführung in die Astronomie 2V (2 KE, not offered this year)

5. Semester Bachelor

- **Astrophysics I 3V + 2U (10 KE)**
- Astroweek (VP, Info event Sept. 28)
- Semesterprojects

6. Semester Bachelor

- Semesterprojects

1. Semester Master

- **Astrophysics I 3V + 2U (10 KE)**
- elective courses in Astrophysik
- Semesterprojects

2. Semester Master

- **Astrophysics II 3V + 2U (10 KE)**
- **Astrophysics III 3V + 2U (10 KE)**
- elective courses in Astrophysik
- Semesterprojects

3. Semester Master

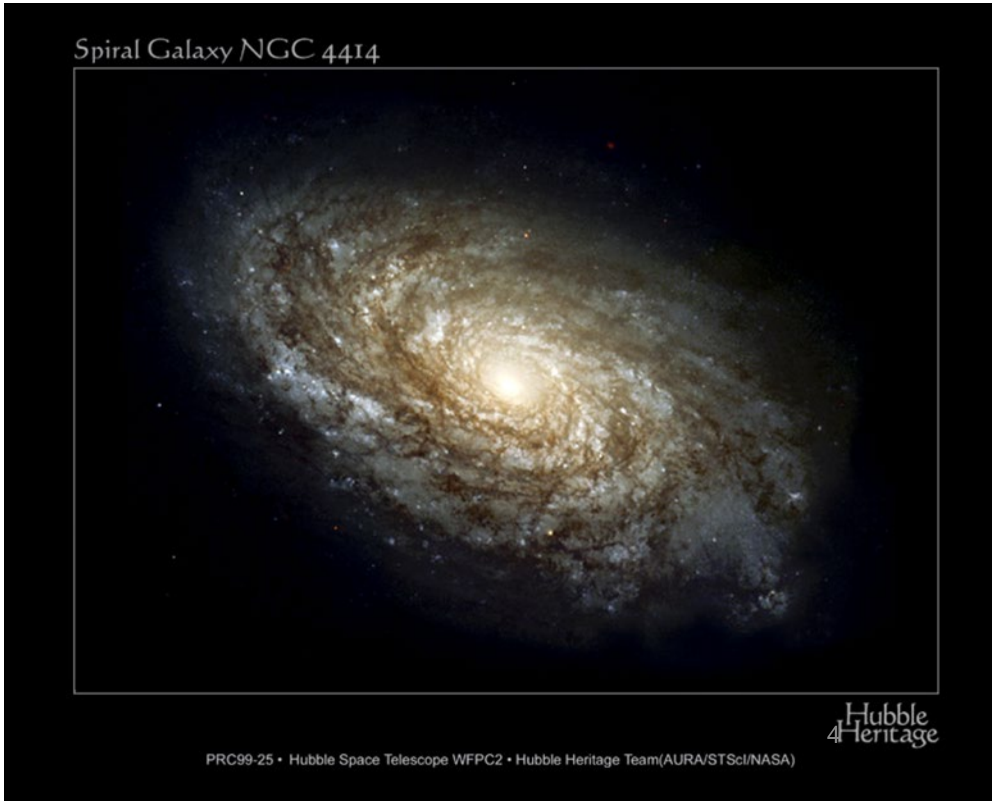
- **Master Thesis**

Topics of Astrophysics I lecture

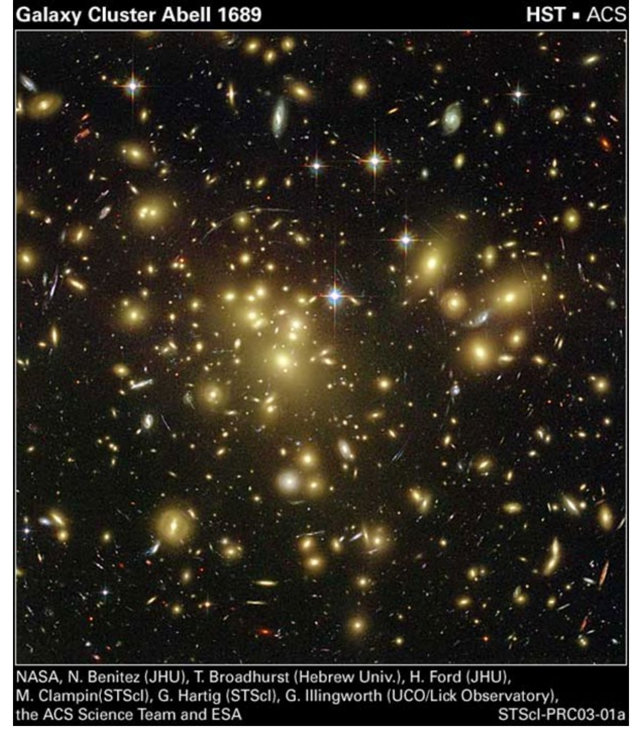
- Introduction
  - units
  - coordinates
  - observations
- Radiative Transfer
- Stellar Astrophysics
  - stellar models
  - nuclear processes
  - evolution

- Milky Way Galaxy
  - components
  - stellar populations
  - interstellar gas
  - stellar dynamics

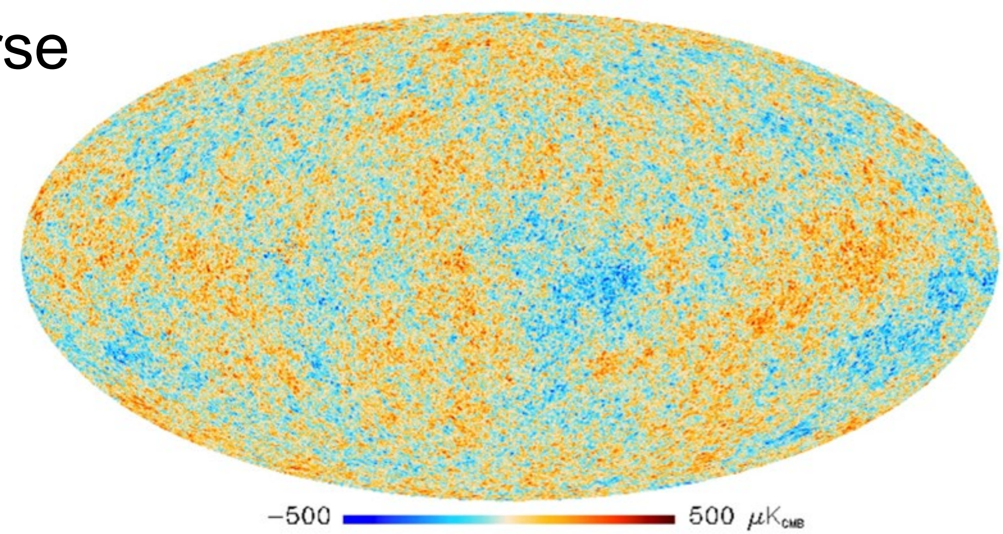
- Other galaxies
  - spirals and ellipticals
  - cluster of galaxies
  - active galaxies



- Space time dynamics
  - Hubble law
  - metric of the universe
  - content of the universe



- Thermal history of the universe
  - big bang
  - microwave background
  - structure formation



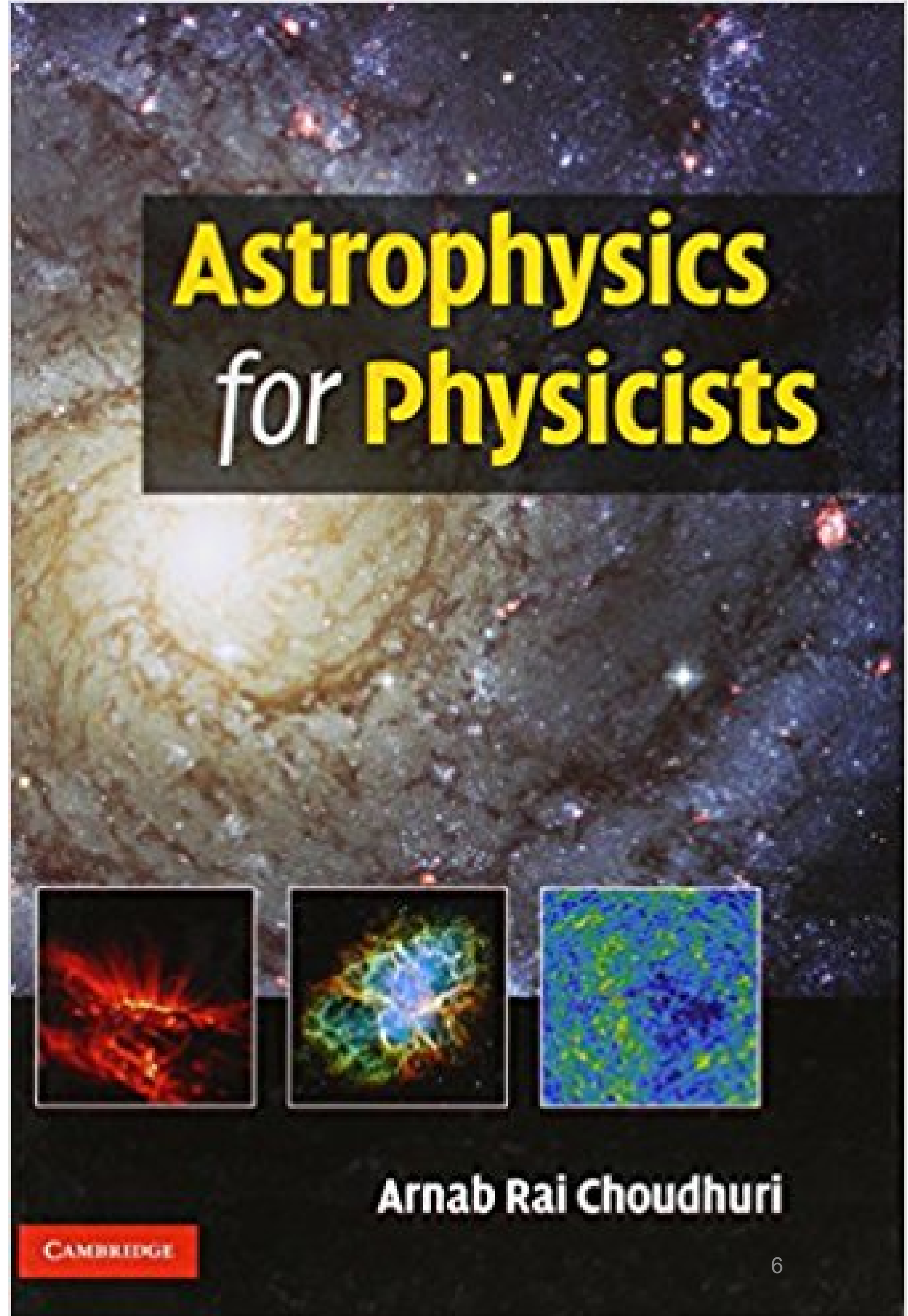
Lecture is based on book of
A.R. Choudhuri

``Astrophysics for Physicist''

Available as e-book in the ETH Library:

https://www.cambridge.org/core/books/astrophysics-for-physicists/9F6DBBDAAF177504899F5BB40B3BDE33

Individual chapters
available as pdf-files



“Plan” of the lecture

Tuesday: 12.45 – 14.30 HPV G4 (15 min break)
Wednesday: 12.45 – 13.30 HPV G5

Important parts:

- will be written on blackboard (and are in the lecture notes)
- or are shown as slides (will also be distributed)

Choudhuri's book is useful for this lecture

- many topics will be presented as in the book of Choudhuri
- the book gives also the corresponding context and additional information, which is not given in the lecture notes/slides
- Choudhuri's book includes also additional material, which is not treated in the lecture and which is not part of the exam
- some topics of the lecture are only given in the lecture notes. They are not given in Choudhuri, but will be part of the exam

- Exam: oral, 30 minutes, Englisch

Information

https://quanz-group.ethz.ch/education/lectures/astrophysics-I-hs2019.html

- Homepage: Institute for Particle Physics and Astrophysics, ETH Zurich
  Click: Education
  Click: Current lectures
  Click under Astrophysics I: Course Info
  Click left column: Astrophysics I / HS2018

- General information
- Link to the electronic textbook :
  Astrophysics for Physicists (Choudhuri)
- Table which all the lecture material
- pdf-versions of my notes and slides

Notes and slides are available

- if possible, before the lecture on the web
- a preview of the lecture content may also be obtained from the web page of last year (but there might be changes in the current lecture)

Teaching assistants

- Dr. Boehle, Anna — substitute lecturer
- Cugno, Gabriele
- Dr. Guidi, Greta
- Hunziker, Silvan — coordination
- Dr. Kacprzak, Tomasz — substitute lecturer
- Dr. Stolker, Tomas
- Tschudi, Christian

Exercise classes

- Thu 7.45 ?? am – 9.30 am HIT J 51 25 p.
- Thu 7.45 ?? am – 9.30 am HIT J 52 25 p.
- Fri 1.45 pm – 3.30 pm HIT F12 25 p.
- Fri 1.45 pm – 3.30 pm HIT K52 25 p.

first exercise classes start in the week of Sept. 23

Communication

- ask questions during the lecture!
  - Tuesday break
  - or after the lecture
- ask teaching assistants
- feedback:

  regular meeting with students team?

1 Introduction (Slides Astrophysics I)

- Basic quantities and definitions for Astrophysics (blackboard)
- Observational data for Astrophysics (slides)

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A.1 Physical constants

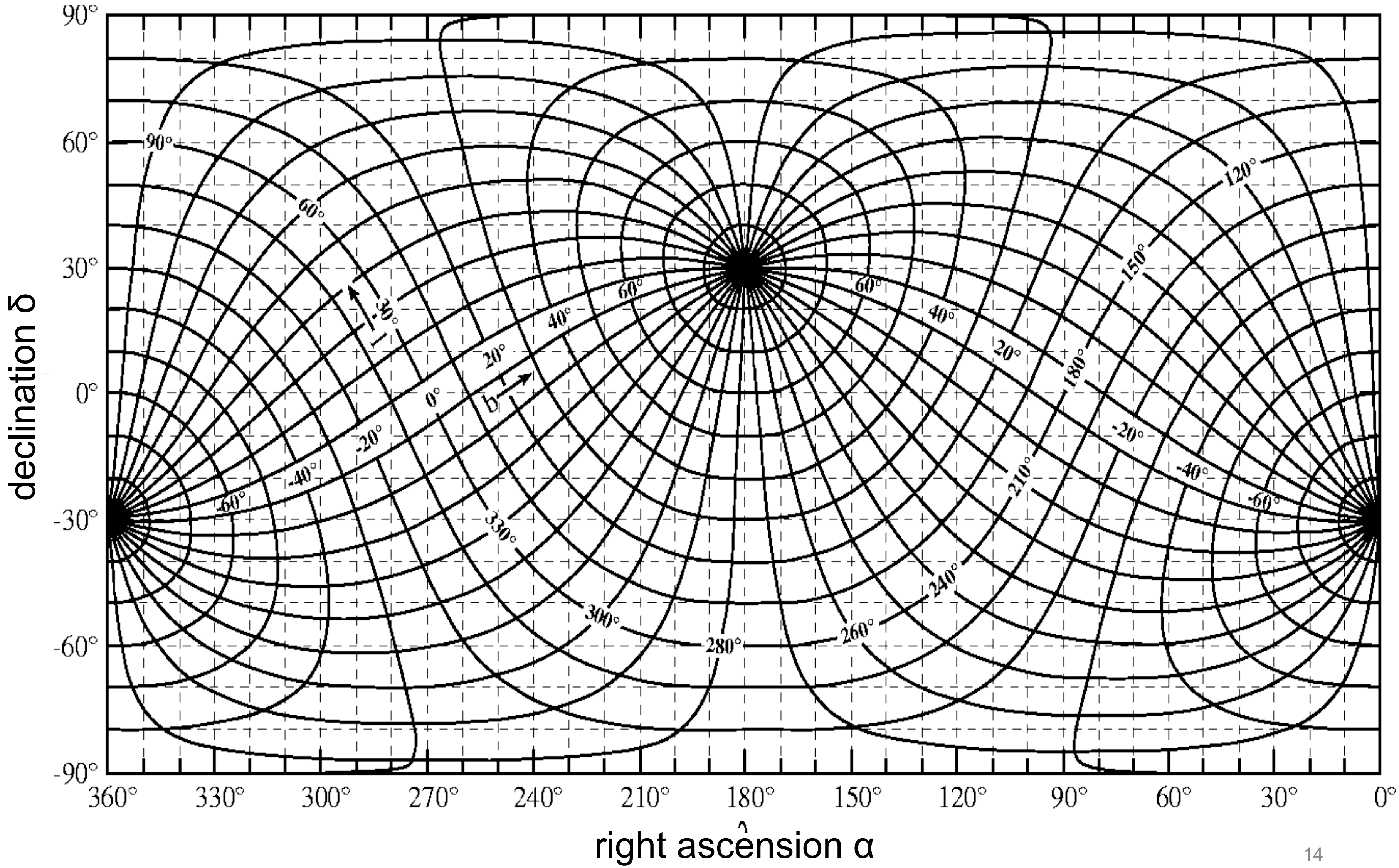
Speed of light	c	=	3.00×10^{8} m s^{-1}
Gravitational constant	G	=	6.67×10^{-11} m^3 kg^{-1} s^{-2}
Planck constant	h	=	6.63×10^{-34} J s
Boltzmann constant	κ_B	=	1.38×10^{-23} J K^{-1}
Permeability of free space	μ_0	=	1.26×10^{-6} H m^{-1}
Permittivity of free space	ϵ_0	=	8.85×10^{-12} F m^{-1}
Charge of electron	e	=	-1.60×10^{-19} C
Mass of electron	m_e	=	9.11×10^{-31} kg
Mass of hydrogen atom	m_H	=	1.67×10^{-27} kg
Stefan–Boltzmann constant	σ	=	5.67×10^{-8} W m^{-2} K^{-4}
Constant in Wien's law	$\lambda_m T$	=	2.90×10^{-3} m K
Standard atmospheric pressure		=	1.01×10^{5} N m^{-2}
1 electron volt	eV	=	1.60×10^{-19} J
1 angstrom	Å	=	10^{-10} m
1 calorie		=	4.19 J

A.2 Astronomical constants

1 astronomical unit	AU	=	1.50×10^{11} m
1 parsec	pc	=	3.09×10^{16} m
1 year	yr	=	3.16×10^{7} s
Mass of Sun	$M_\odot$	=	1.99×10^{30} kg
Radius of Sun	$R_\odot$	=	6.96×10^{8} m
Luminosity of Sun	$L_\odot$	=	3.84×10^{26} W
Mass of Earth	$M_\oplus$	=	5.98×10^{24} kg
Radius of Earth	$R_\oplus$	=	6.37×10^{6} m

from Choudhuri

Galactic coordinates l,b in an equatorial coordinate (α,δ) map



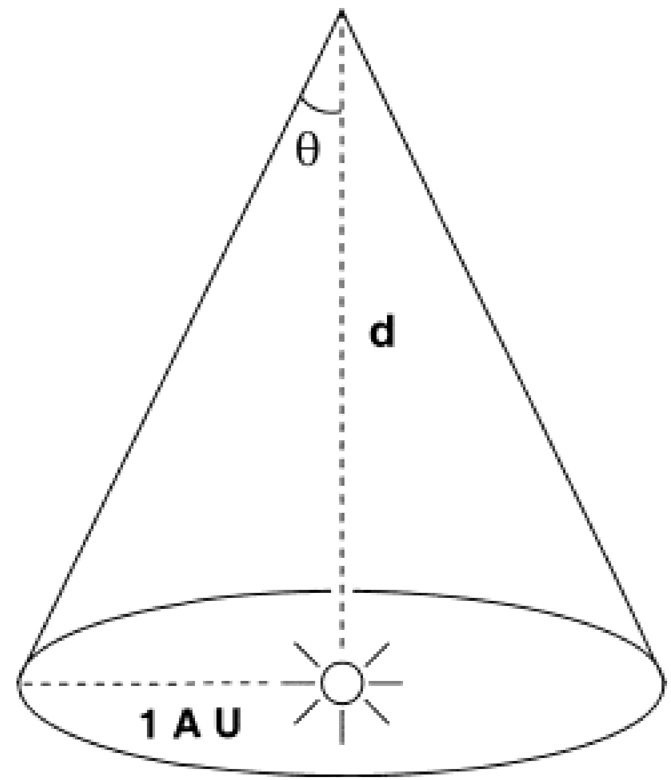
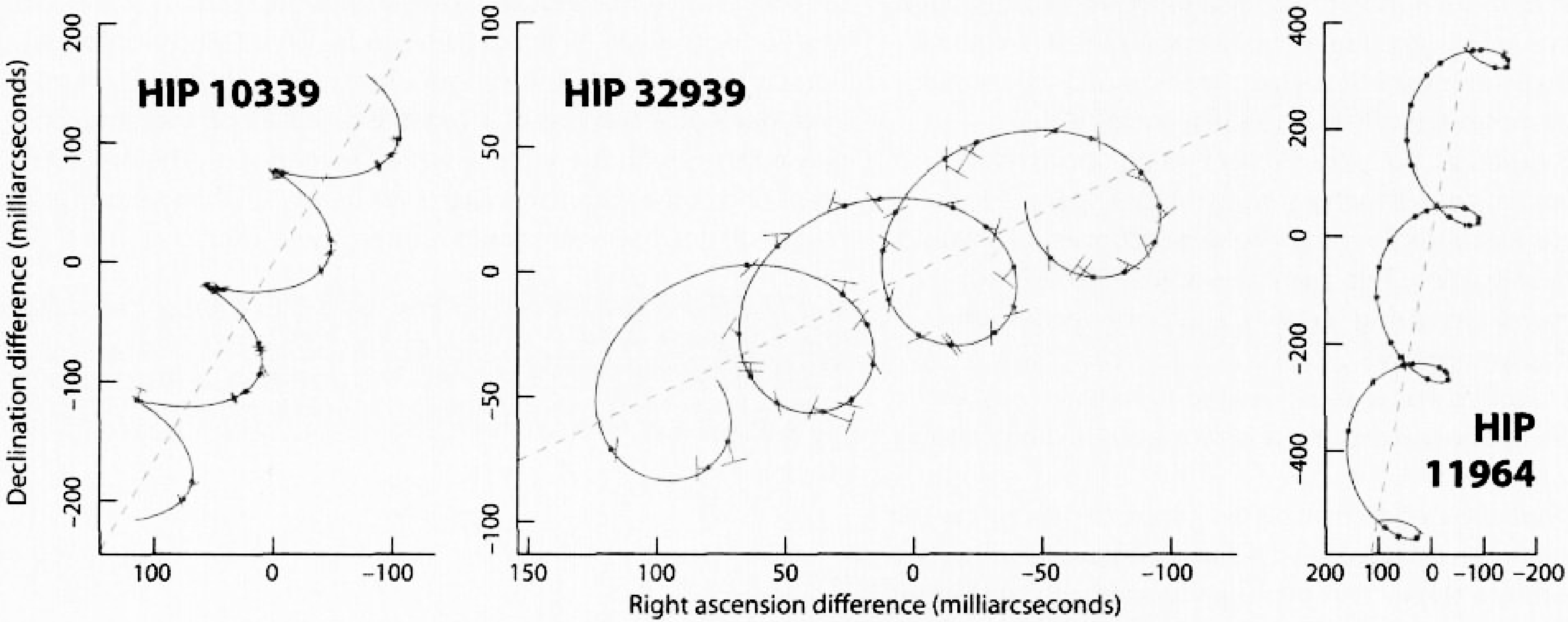


Fig. 1.1 Definition of parsec.

from Choudhuri

Proper motion and parallax of stars



The apparent paths of three stars across the sky during the three years of the Hipparcos mission. Each looping line shows the combination of parallax (an ellipse) and proper motion (a straight line) that best fits the data. The star's measured positions are shown by T-like intersections; these are often hidden under the dots, which mark their best-fit places on the line. Each curlicue in the 118,000-star database is different. From the Hipparcos Intermediate Data Web page.

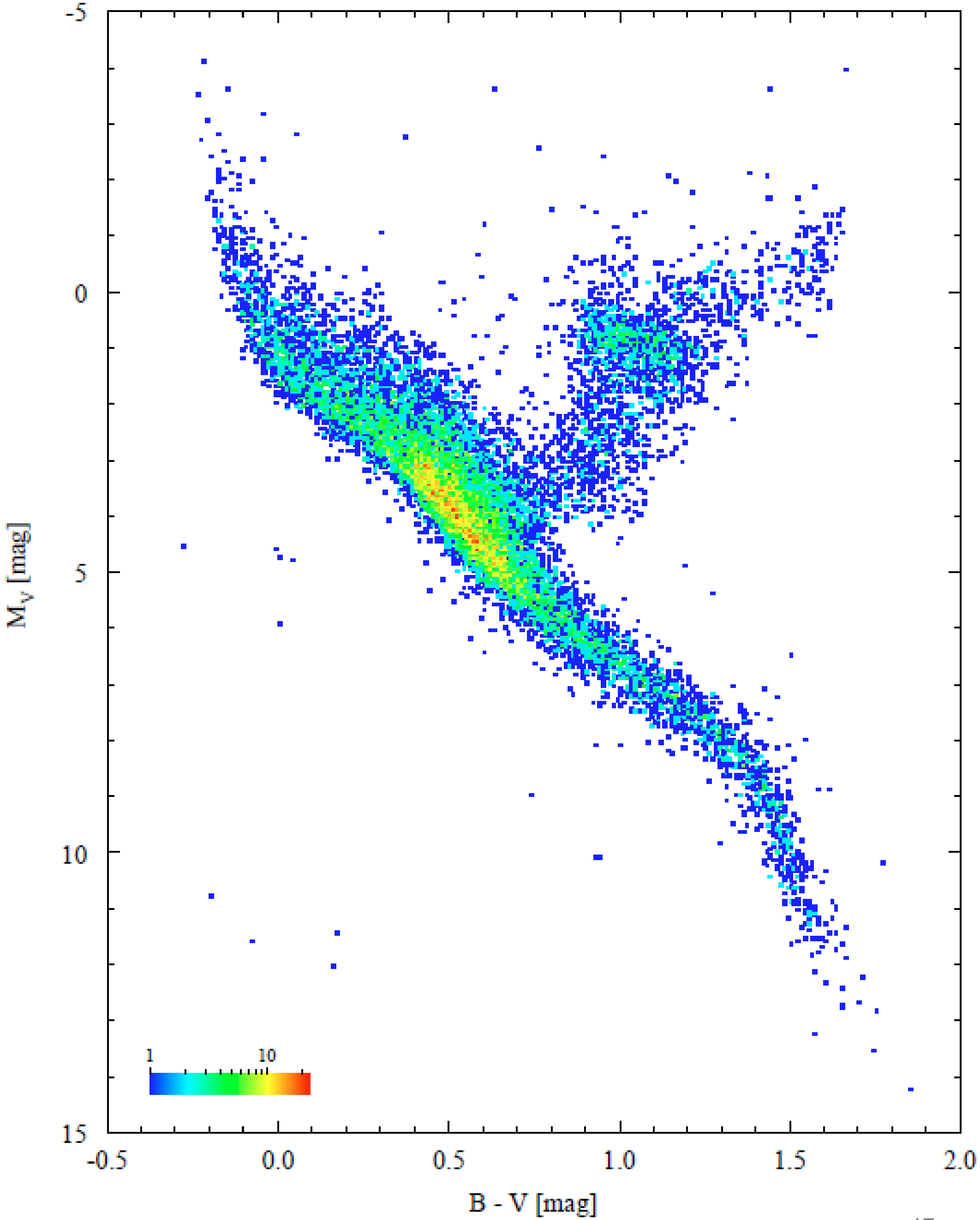
HR-Diagram from Hipparcos

HR-diagram (M_V, B-V) for 16631 single stars from the Hipparcos Satelite Catalogue
•nearby stars < 100 pc
•mostly bright < 8 mag

The stars were selected because their colors and distance and therefore M_V could be determined with high precision.

The colors give the number of stars per diagram cell

Source: http://www.rssd.esa.int/index.php?project=HIPPARCOS&page=HR_dia



Astronomical information:
a. Multi-wavelength electromagnetic radiation

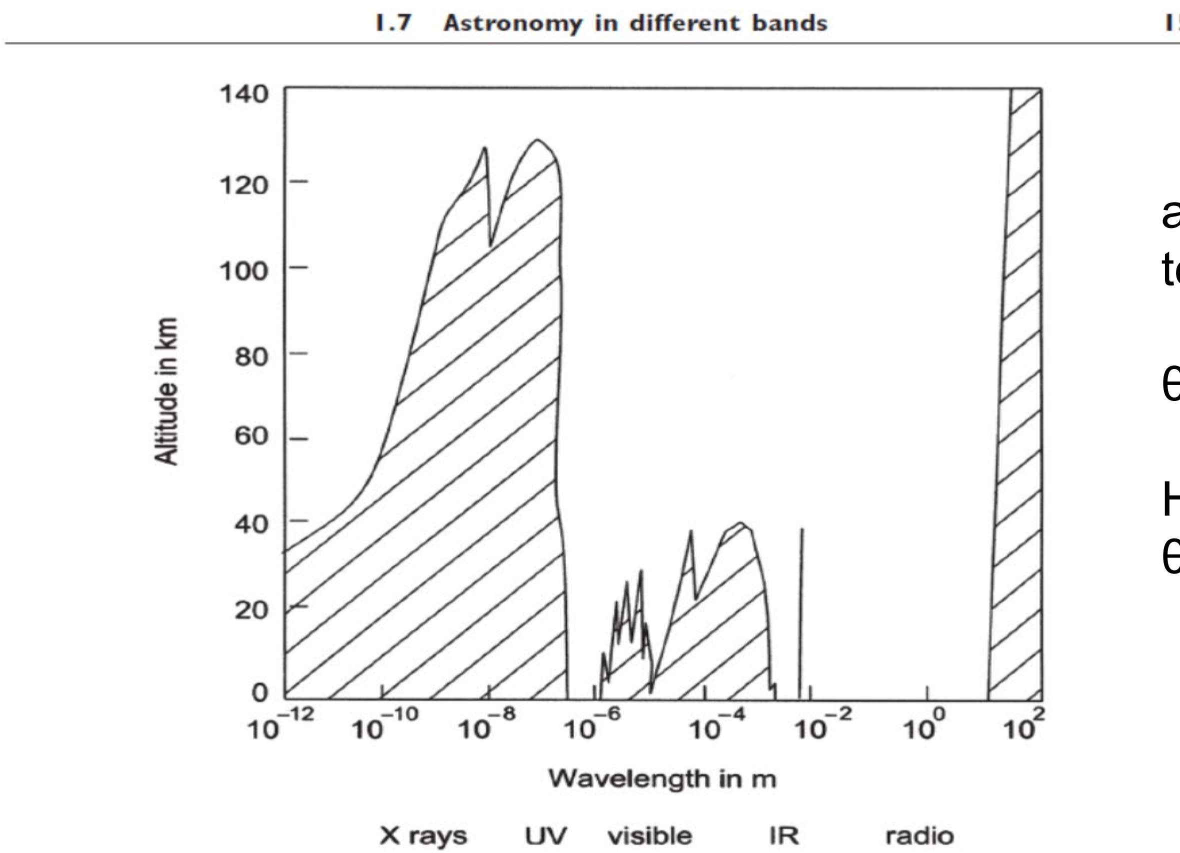


Fig. 1.3 The penetrating ability of electromagnetic wave through the Earth's atmosphere. The altitudes against different wavelengths indicate the heights above the sea level we have to climb to receive radiation of that wavelength from astronomical sources. Adapted from Shu (1982, p. 17).

angular resolution of telescopes (diffr. limit)

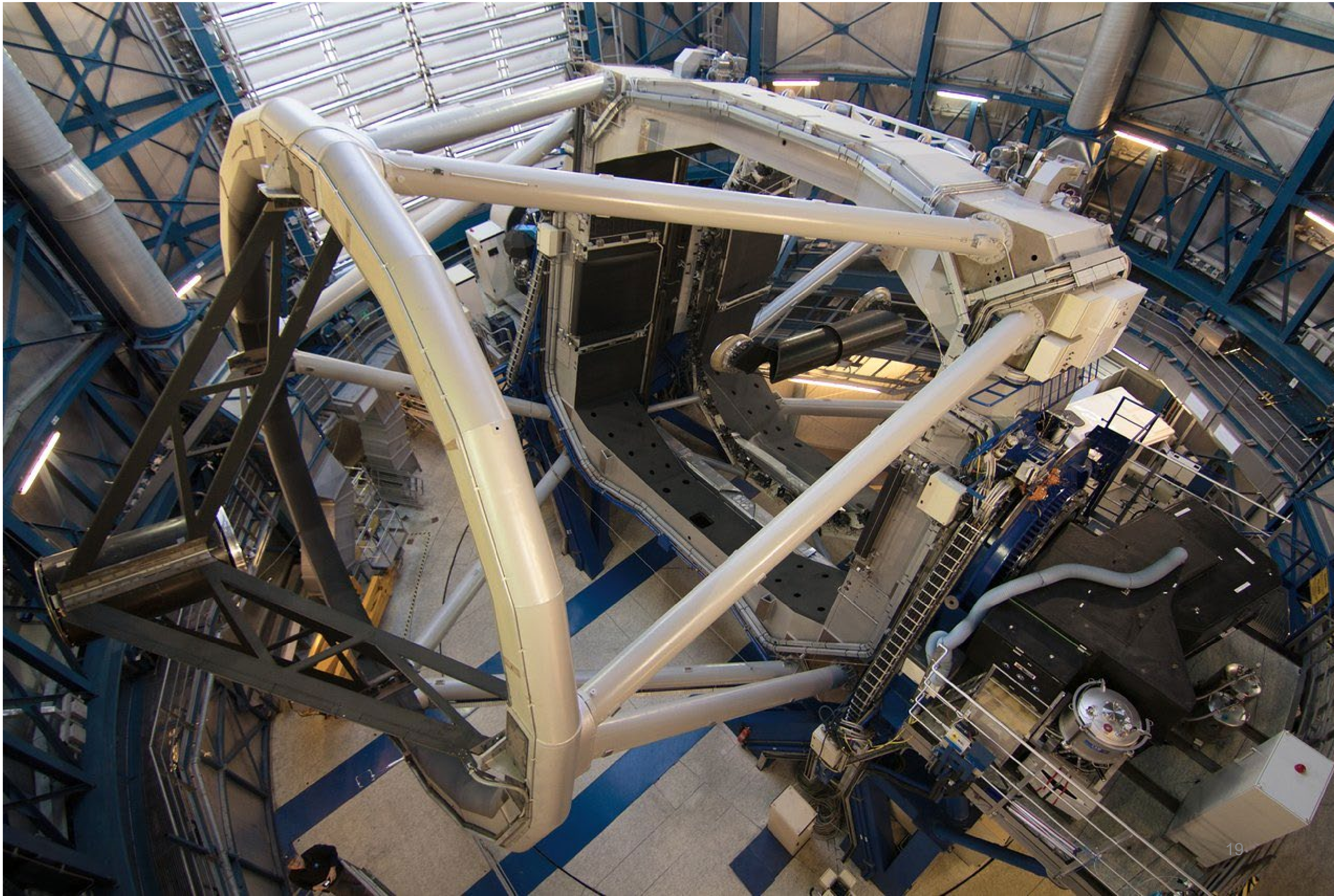
$\theta \approx \lambda/D$

HPP student telescope

$\theta = 0.5\mu m/0.5m = 10^{-6}$ rad

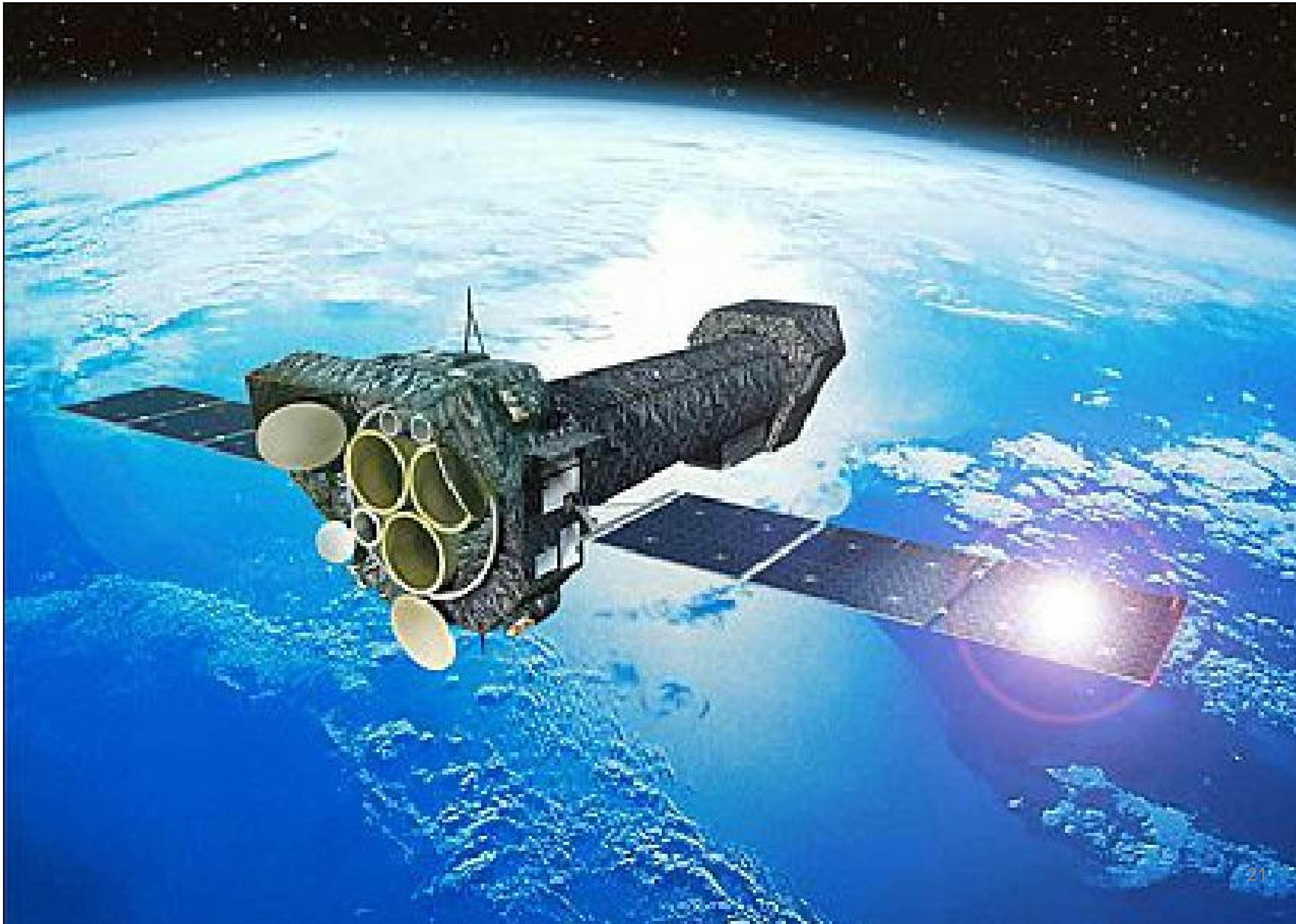
$= 0.206$ arcsec

e.g. VLT with SPHERE "Planet Finder"

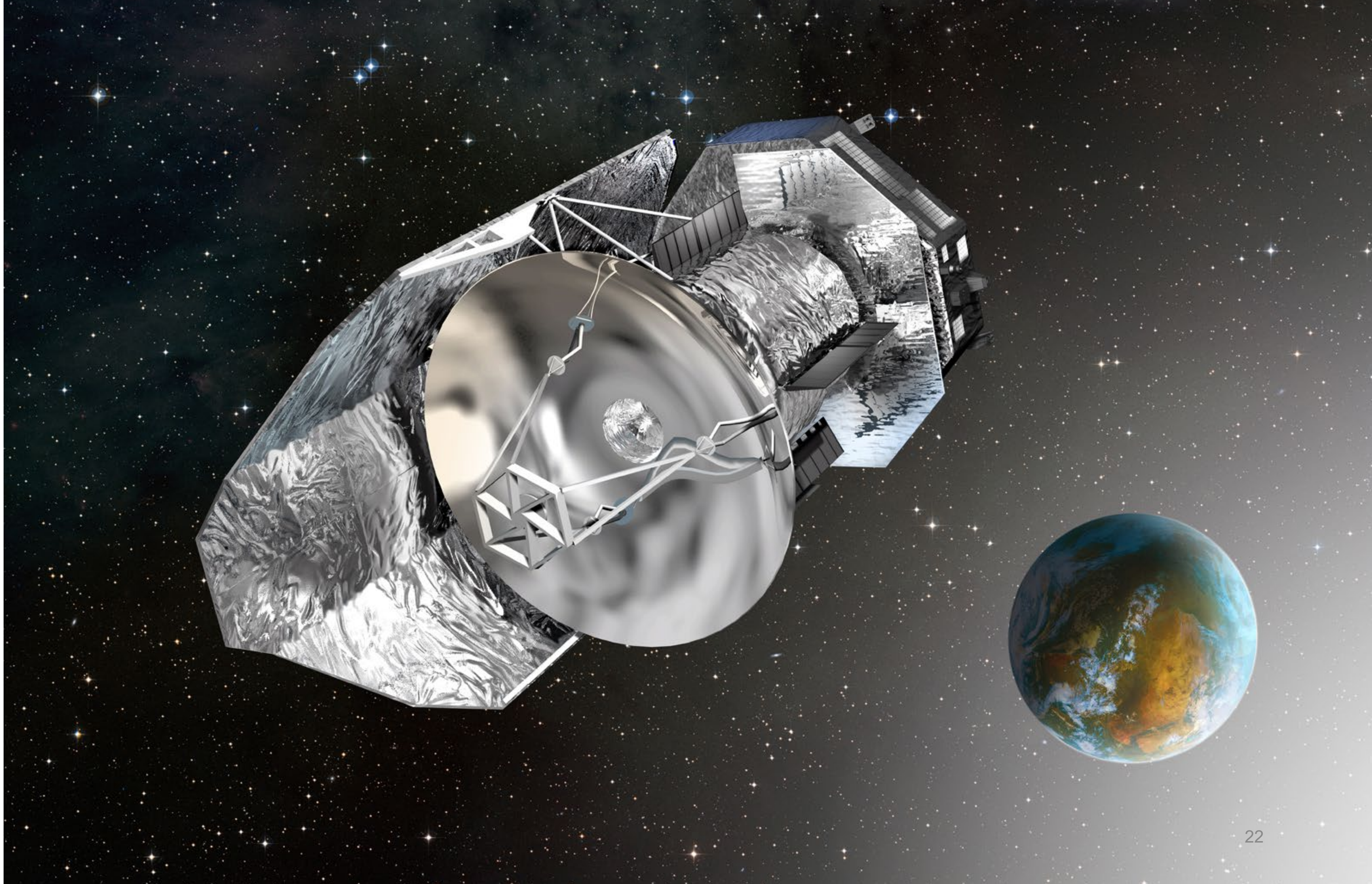


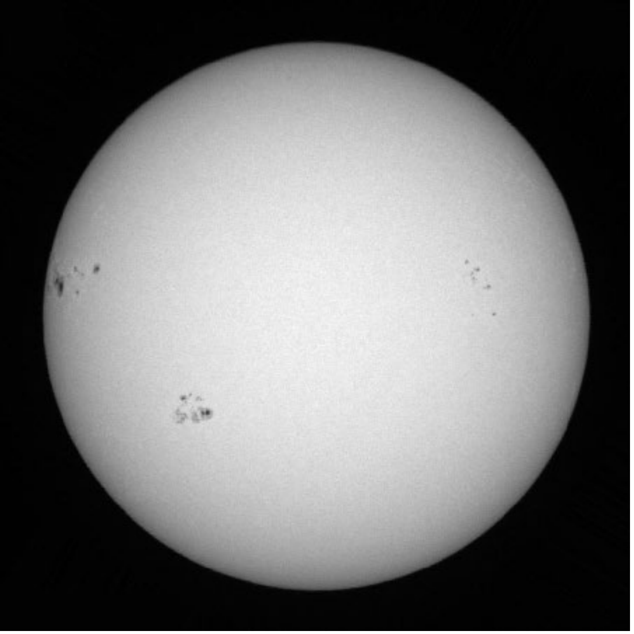
e.g. ALMA: 66 Antennas for mm/sub-mm range

e.g. XMM-Newton satellite

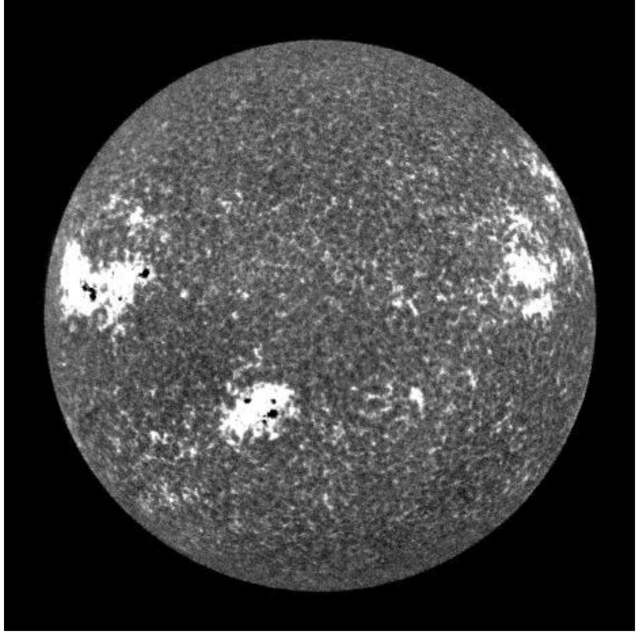


e.g. Herschel-Satellite

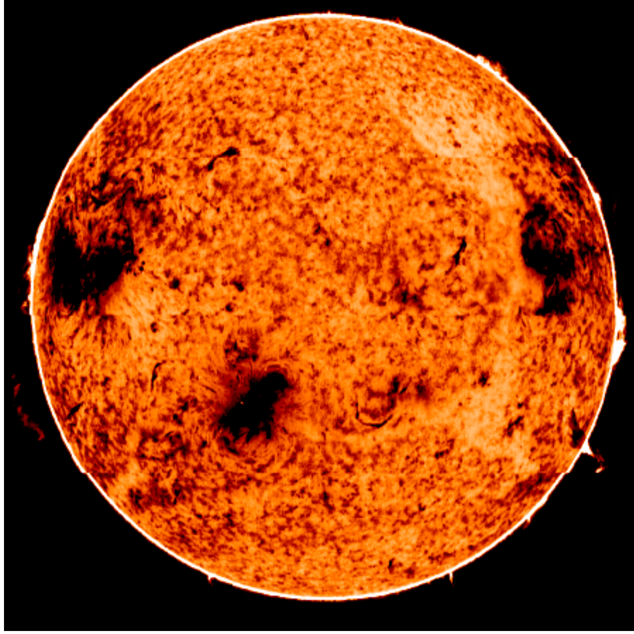




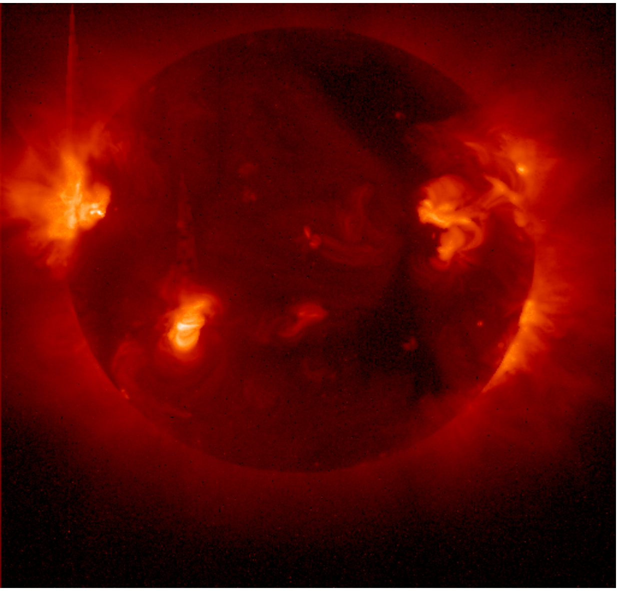
white light



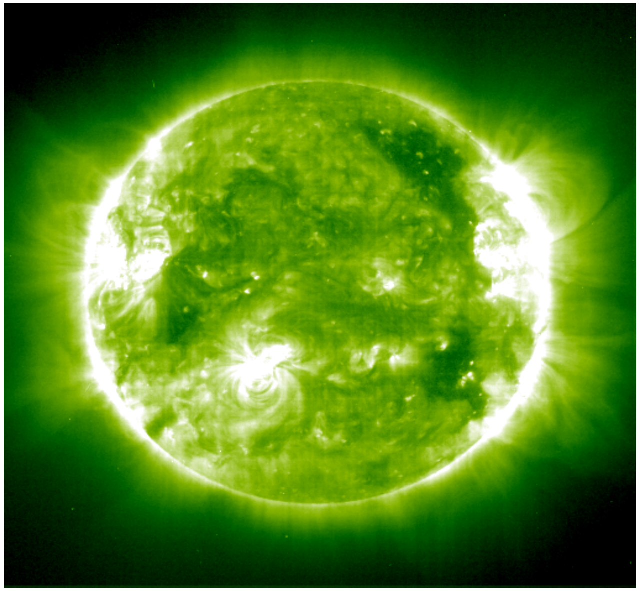
Ca II K line



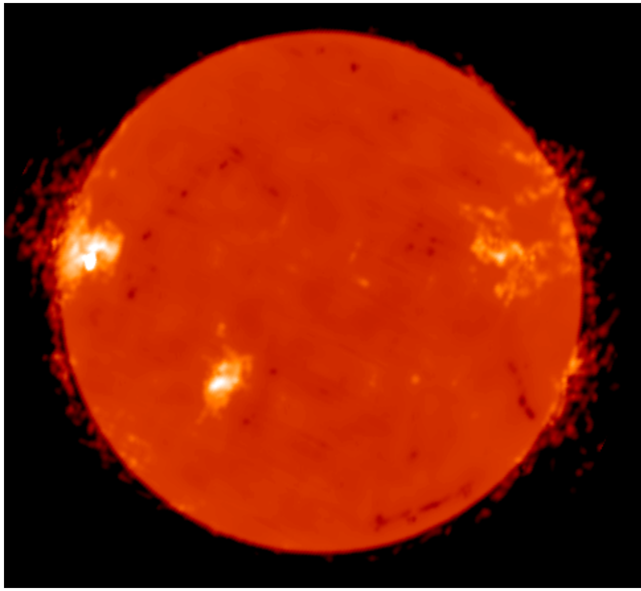
near-IR 1.08μm



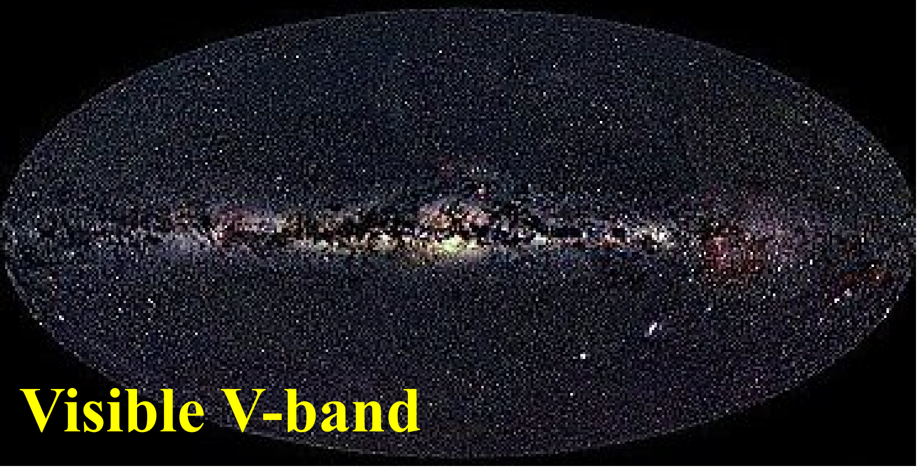
X-rays ~1keV

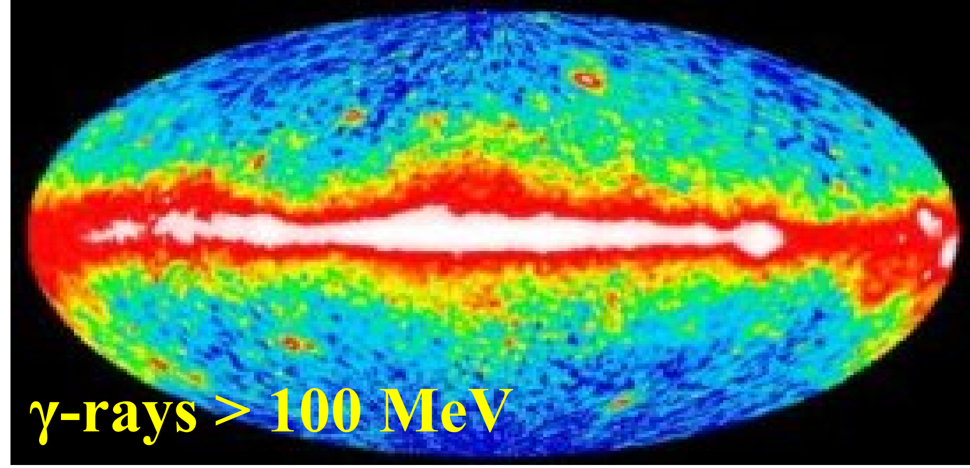


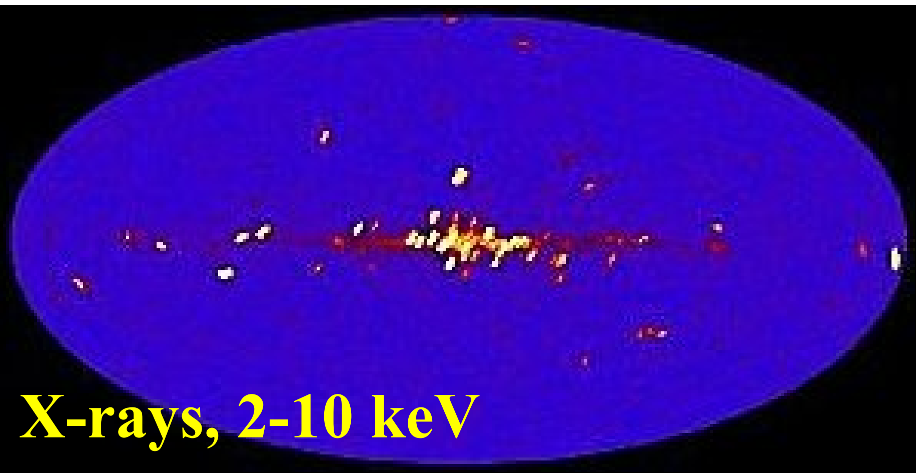
EUV 19.5 nm

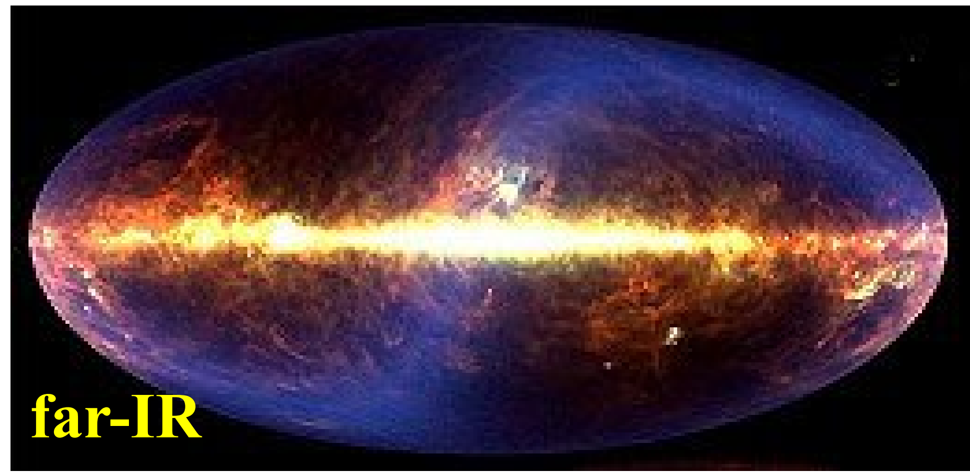


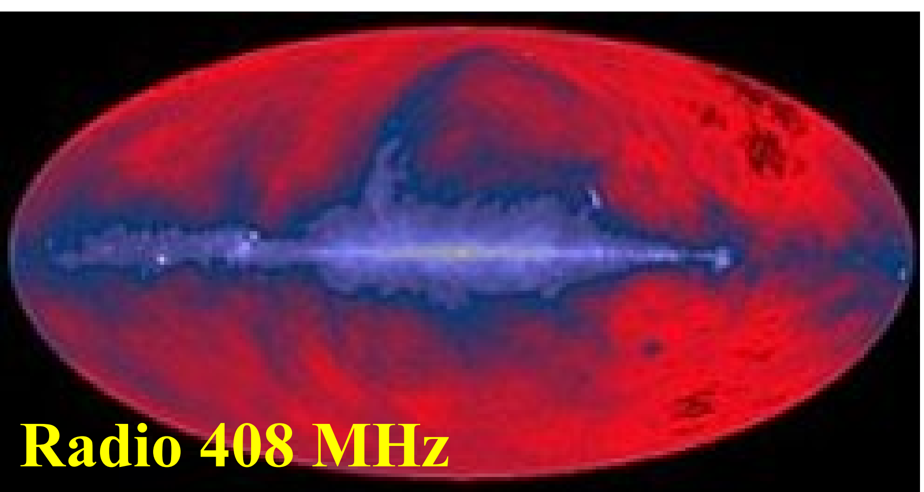
radio 17GHz


Visible V-band


γ-rays > 100 MeV

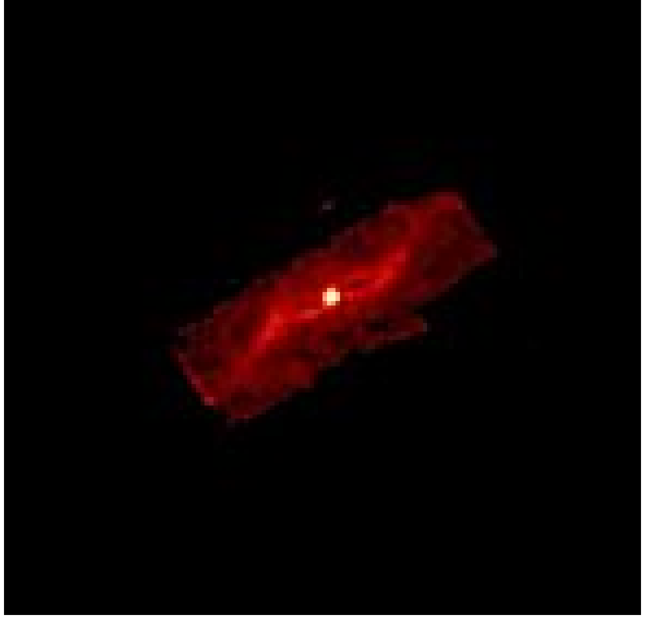

X-rays, 2-10 keV


far-IR

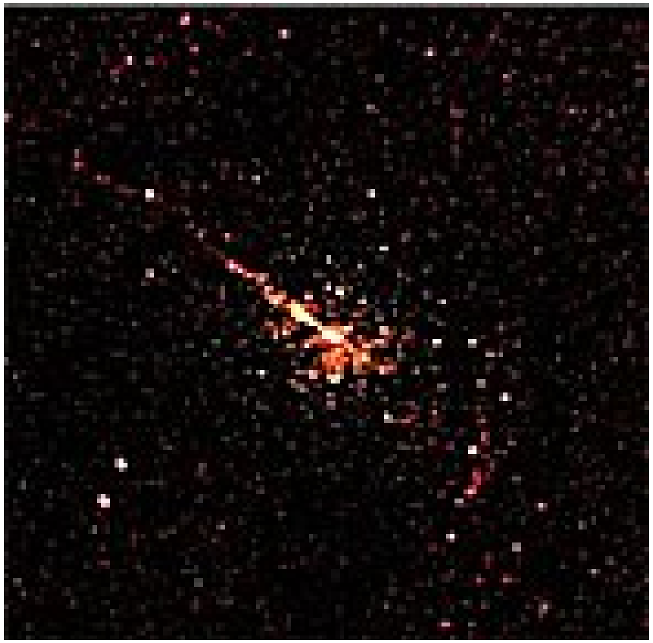

Radio 408 MHz


HI 1420 MHz

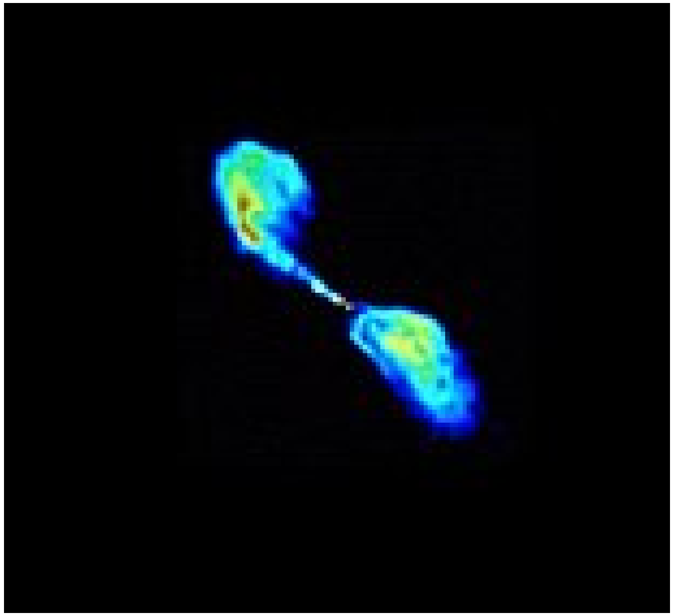
visible



mid-IR 7μm



X-ray



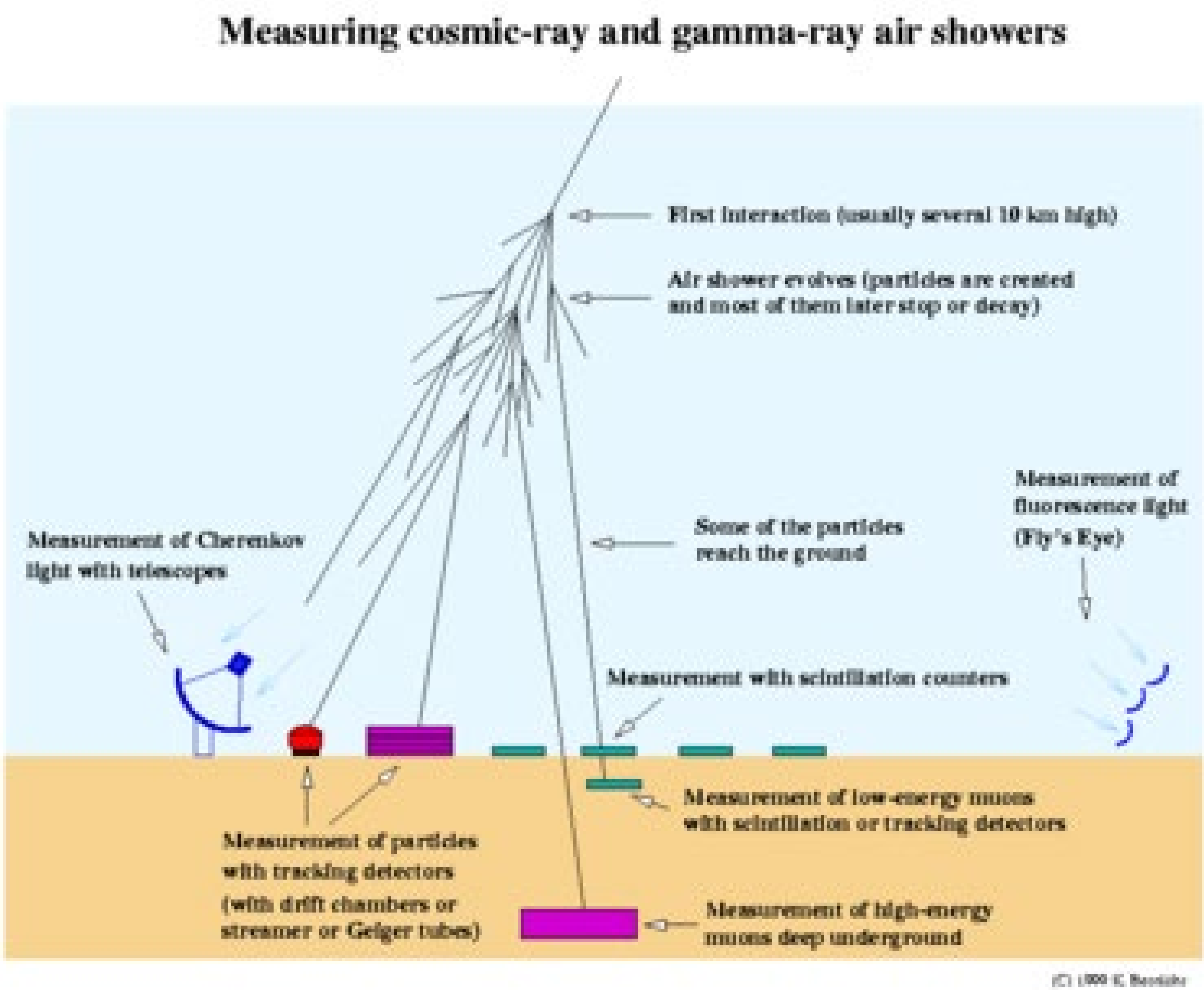
radio 4.9 GHz

b: Meteorites

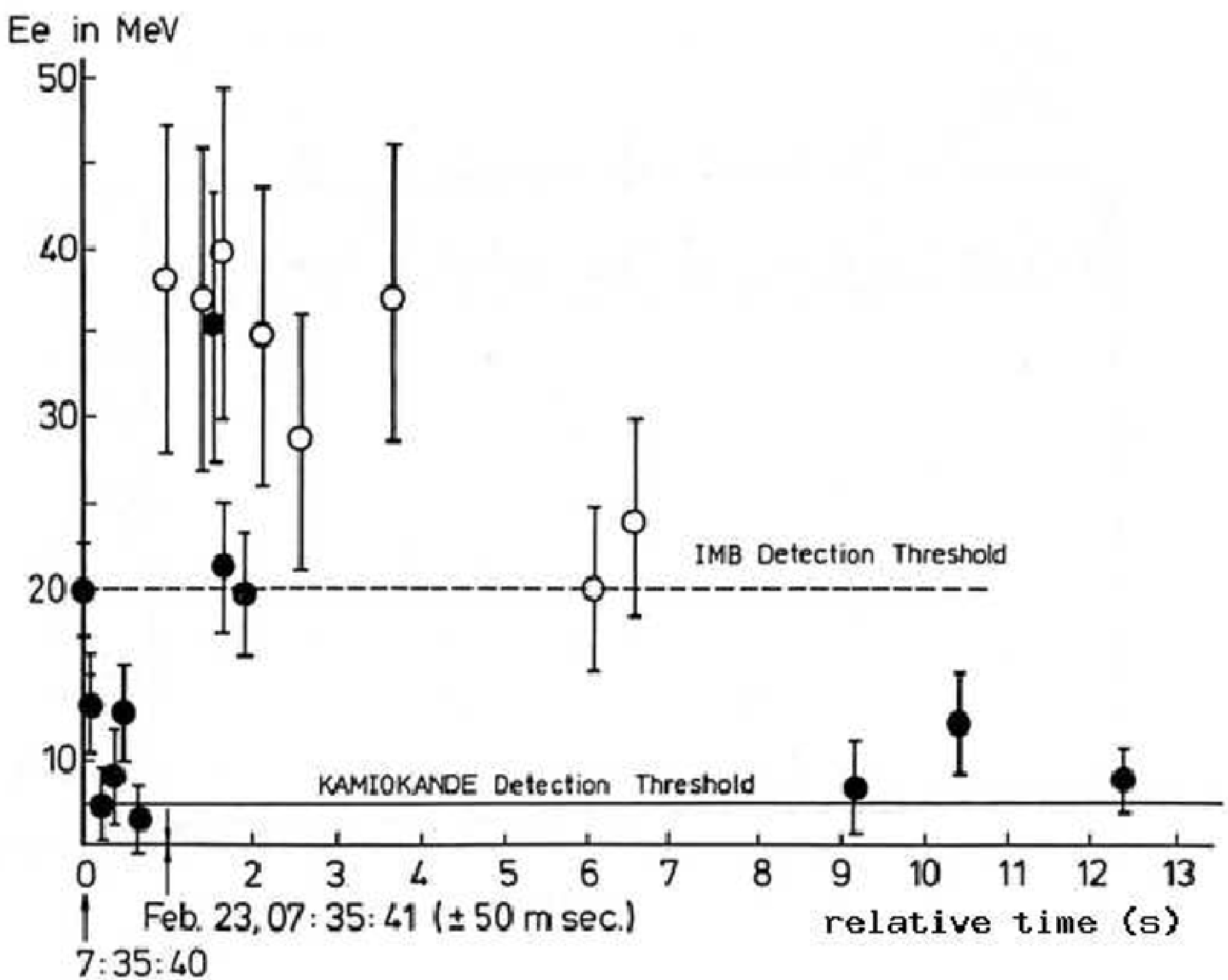
e.g. presolar isotope ratios

e.g. evolution of solid bodies in solar system

c: Cosmic rays:
relativistic particles from space



d: Neutrinos from SN1987a



e: Gravitational waves from GW150914

from merging black holes at z=500 Mpc