FUNDAMENTOS PARA O ENSINO DE ASTRONOMIA

Semanas 2 e 3 [Aulas 5 a 12]

As ferramentas do astrônomo

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I. A natureza da luz

Qual informação física nós temos acesso ao olhar para o Universo?

A luz!

Fig. 1: Pilares de luz sobre o Alasca.

2016 February 8
Light Pillars over Alaska
Image Credit & Copyright: Allisha Libby

Explanation: What's happening behind those houses? Pictured here are not auroras but nearby light pillars, a nearby phenomenon that can appear as a distant one. In most places on Earth, a lucky viewer can see a Sun-pillar, a column of light appearing to extend up from the Sun caused by flat fluttering ice-crystals reflecting sunlight from the upper atmosphere. Usually these ice crystals evaporate before reaching the ground. During freezing temperatures, however, flat fluttering ice crystals may form near the ground in a form of light snow, sometimes known as a crystal fog. These ice crystals may then reflect ground lights in columns not unlike a Sun-pillar. The featured image was taken in Fort Wainwright near Fairbanks in central Alaska.

I. A natureza da luz

Luz como onda

Onda mecânica,
onda eletromagnética ou
onda gravitacional?

Onda mecânica → energia propagada por meio da vibração de corpos materiais;

Onda e-m → energia propagada por meio da vibração de campos eletromagnéticos;

Onda gravitacional → energia propagada por meio da vibração de campos gravitacionais;

2007 August 19
A Sonic Boom
Credit: Ensign John Gay, USS Constellation, US Navy

Fig. 2: Um estrôndo sônico

Explanation: Is this what a sonic boom looks like? When an airplane travels at a speed faster than sound, density waves of sound emitted by the plane cannot precede the plane, and so accumulate in a cone behind the plane. When this shock wave passes, a listener hears all at once the sound emitted over a longer period: a sonic boom. As a plane accelerates to just break the sound barrier, however, an unusual cloud might form. The origin of this cloud is still debated. A leading theory is that a drop in air pressure at the plane described by the Prandtl-Glauert Singularity occurs so that moist air condenses there to form water droplets. Above, an F/A-18 Hornet was photographed just as it broke the sound barrier. Large meteors and the space shuttle frequently produce audible sonic booms before they are slowed below sound speed by the Earth's atmosphere.

I. A natureza da luz

Exp. 1: Campo elétrico – lata, canudo, fio...

A luz é uma onda eletromagnética!

Velocidade de ondas eletromagnéticas no vácuo:
c = 300.000 km/s
$c = 3.10^8$ m/s

Aspectos cinemáticos das ondas:

Velocidade (c)
comprimento (λ)
frequência (ν)

$c = \lambda.\nu$

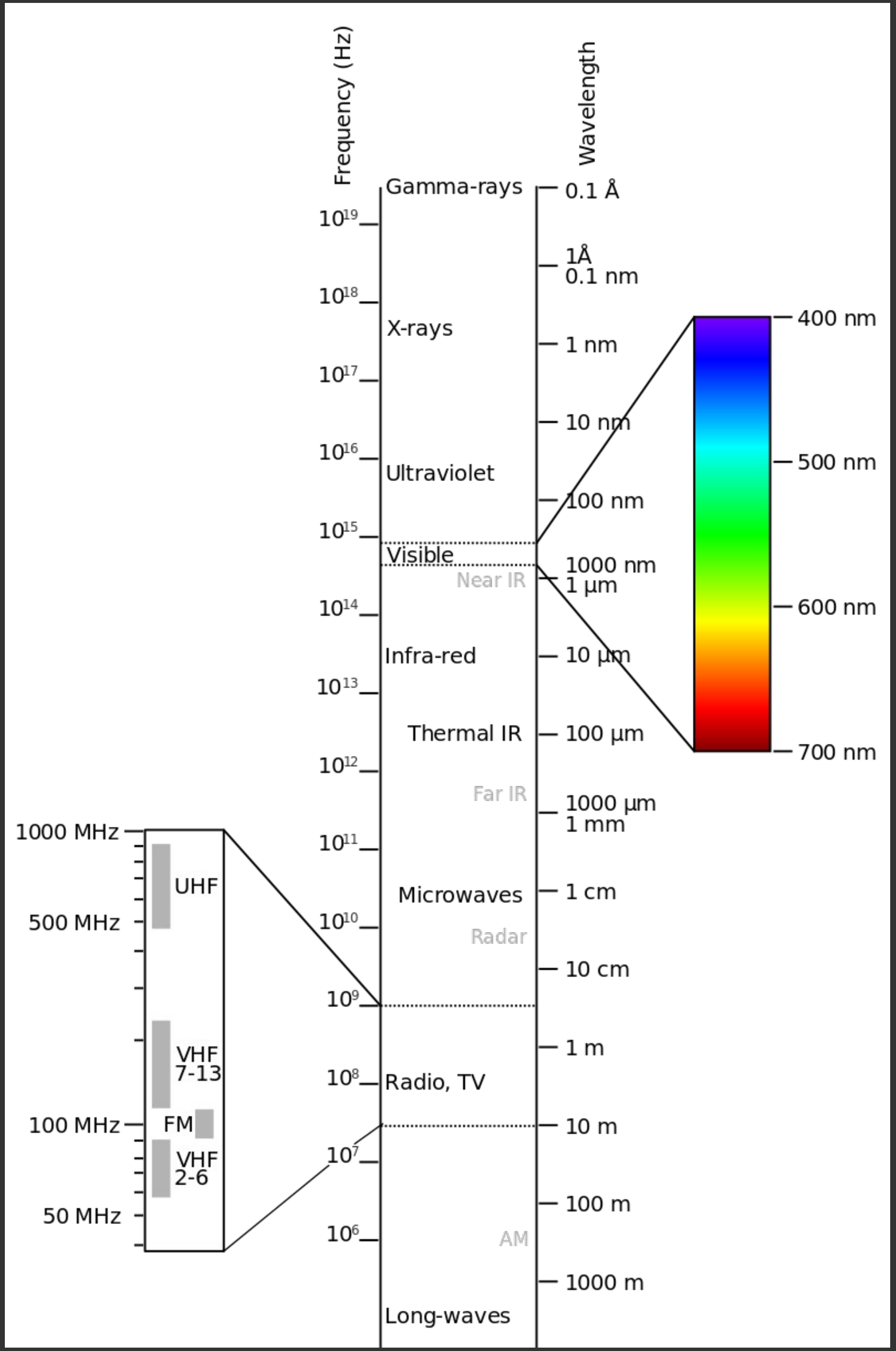


Fig. 3: faixas do espectro eletromagnético:
https://en.wikipedia.org/wiki/Electromagnetic_spectrum

I. A natureza da luz

A luz também é uma partícula!

Fóton

Energia (E)
Constante de Planck (h)
Frequência (ν)

$E = h.\nu$

$h = 6625.10^{-34}$ J

São pacotes individuais (discretos)
de energia! (Planck ~1900)

E como a luz, sendo onda ou partícula, interage com a atmosfera?

E como captar as ondas que são "filtradas" pela atmosfera?

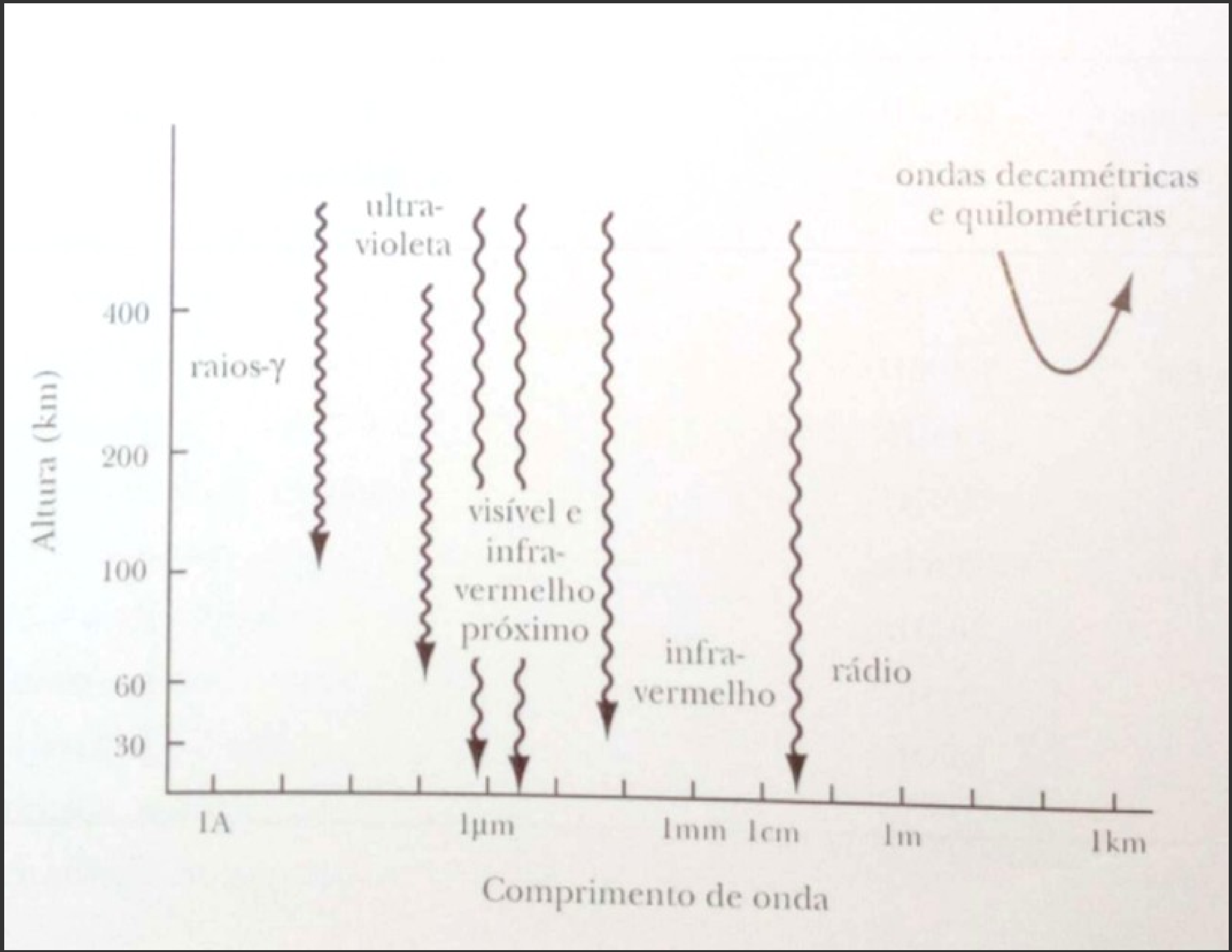


Fig. 4: Interação ondas-atmosfera (Fig. 2.2, p. 26).

II. Telescópios

Galileu e a luneta refratora (~1620)

Newton e o telescópio refletor (~1670)

Lentes (refração) e espelhos (reflexão)

Exp. 2: formação de imagens por refração e reflexão: lentes convergentes e divergentes, espelhos planos, côncavos e convexos.

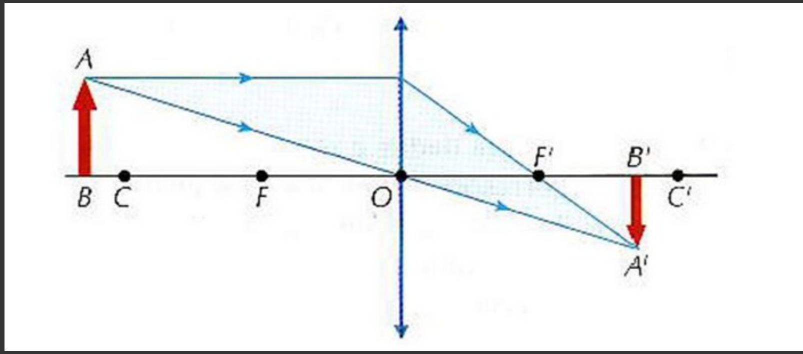


Fig. 5: Exemplo de lente convergente.
http://slideplayer.com.br/slide/1810385/

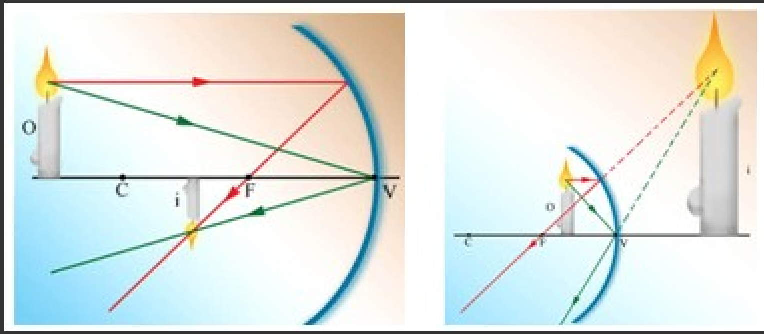


Fig. 6: Exemplo de espelhos côncavos.
http://www.passo-a-passo.com/mec/4.1.4/05_teoria.htm

II. Telescópios

Fig. 7:
Hubble
flutua livre

Refletor

2002 November 24
Hubble Floats Free
Credit: STS-82 Crew, STScI, NASA

Explanation: Why put observatories in space? Most telescopes are on the ground. On the ground, you can deploy a heavier telescope and fix it more easily. The trouble is that Earth-bound telescopes must look through the Earth's atmosphere. First, the Earth's atmosphere blocks out a broad range of the electromagnetic spectrum, allowing a narrow band of visible light to reach the surface. Telescopes which explore the Universe using light beyond the visible spectrum, such as those onboard the Chandra X-ray Observatory need to be carried above the absorbing atmosphere. Second, the Earth's atmosphere blurs the light it lets through. The blurring is caused by varying density and continual motion of air. By orbiting above the Earth's atmosphere, the Hubble Space Telescope, pictured above, can get clearer images. In fact, even though HST has a mirror 15 times smaller than large Earth-bound telescopes, it can still resolve finer details. A future large optical telescope in space is planned.

II. Telescópios

Telescópios atuais:

- Diâmetros cada vez maiores e geralmente refletores, para evitar distorções pela refração;

- Maiores refratores atuais: 1 m de diâmetro;

- Maiores refletores atuais: 10 m de diâmetro;

- Maiores radiotelescópios atuais: 300 m de diâmetro;

II. Telescópios

Telescópios Keck I, Keck II e Subaru no Hawaii. 10 m de diâmetro de espelho.

Fig. 8: Um ano de cosmologia escura.

2001 December 31
A Year of Dark Cosmology
Credit: W. M. Keck Observatory, Mauna Kea Observatory

Explanation: We live in the exciting time when humanity discovers the nature of our entire universe. During this year, in particular, however, the quest for cosmological understanding appears to have astronomers groping in the dark. Dark matter and dark energy are becoming accepted invisible components of our universe, much like oxygen and nitrogen have become established invisible components of Earth-bound air. In comprehending the nature and origin of the formerly invisible, however, we are only just exiting the cosmological dark age. Relatively unexplored concepts such as higher spatial dimensions, string theories of fundamental particles, quintessence, and new forms of inflation all vie for cornerstone roles in a more complete theory. As understanding invisible air has led to such useful inventions as the airplane and the oxygen mask, perhaps understanding dark matter and dark energy can lead to even more spectacular and useful inventions. Pictured above, three of the largest optical telescopes (Keck I, Keck II, and Subaru) prepare to peer into the dark and distant universe.

II. Telescópios

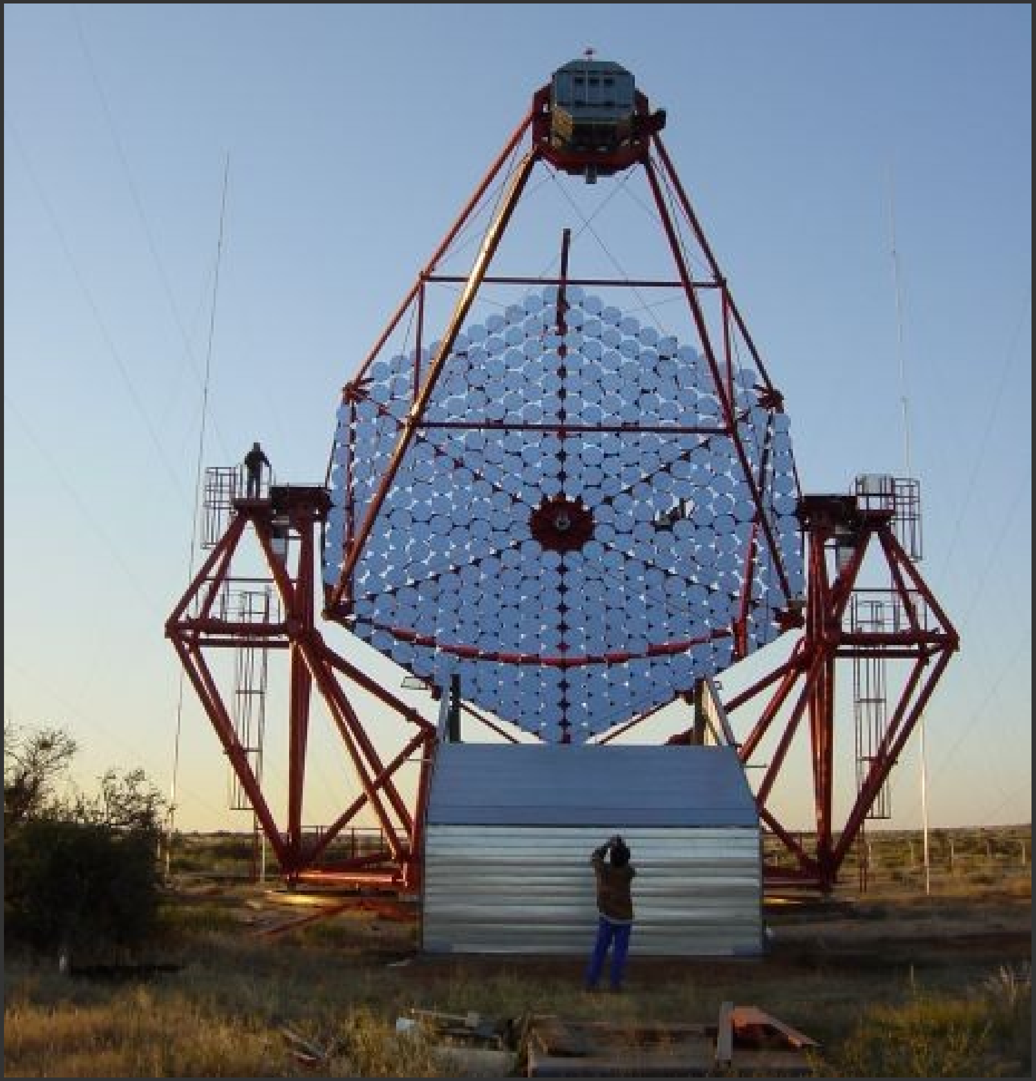
Fig. 9: Radiotelescópio Arecibo: o maior (Porto Rico).

November 29, 1998
Arecibo: The Largest Telescope
Credit: National Astronomy and Ionosphere Center, Cornell U., NSF

Explanation: The Arecibo radio telescope is currently the largest single-dish telescope in the world. First opening in 1963, this 305 meter (1000 foot) radio telescope resides in a natural valley of Puerto Rico. The Arecibo telescope has been used for many astronomical research projects, including searches and studies of pulsars, and mapping atomic and molecular gas in the Galaxy and the universe. As the Arecibo dish can also be used to send radio waves, it has bounced and recorded radiation off of planets in our Solar System, and has even broadcast messages to areas of the Galaxy that might contain intelligent extra-terrestrial life. Any person in the world may use the telescope, providing their proposal is selected by a review committee.

II. Telescópios

Fig. 10: HESS: telescópio de raios gama



2002 September 6
HESS Gamma-Ray Telescope
Credit: The HESS Collaboration

Explanation: Most ground-based telescopes with lenses and mirrors are hindered by the Earth's nurturing, protective atmosphere that blurs images and scatters and absorbs light. But this telescope was designed to detect extreme gamma rays - photons with over 100 billion times the energy of visible light - and actually requires the atmosphere to operate. As the gamma rays impact the upper atmosphere they produce air showers of high-energy particles. Adorned with 382 separate mirrors each 60 centimeters in diameter and equipped with a fast camera, the telescope records in detail the brief flashes of optical light, called Cherenkov light, created by the air shower particles. The telescope pictured here was inaugurated this week and is intended to operate as part of the High Energy Stereoscopic System (HESS) array under construction in Namibia. The initial phase of HESS will consist of four telescopes working in concert to provide multiple stereoscopic views of the air showers, relating them to the energies and directions of the incoming cosmic gamma rays.

III. Imagens e fotometria

Detectores de imagens:

- Olho
- Filme fotográfico
- CCD
- …

Olho:
- Duas lentes (córnea e cristalino)
- Um sensor (retina) com milhares de nervos captadores de luz.

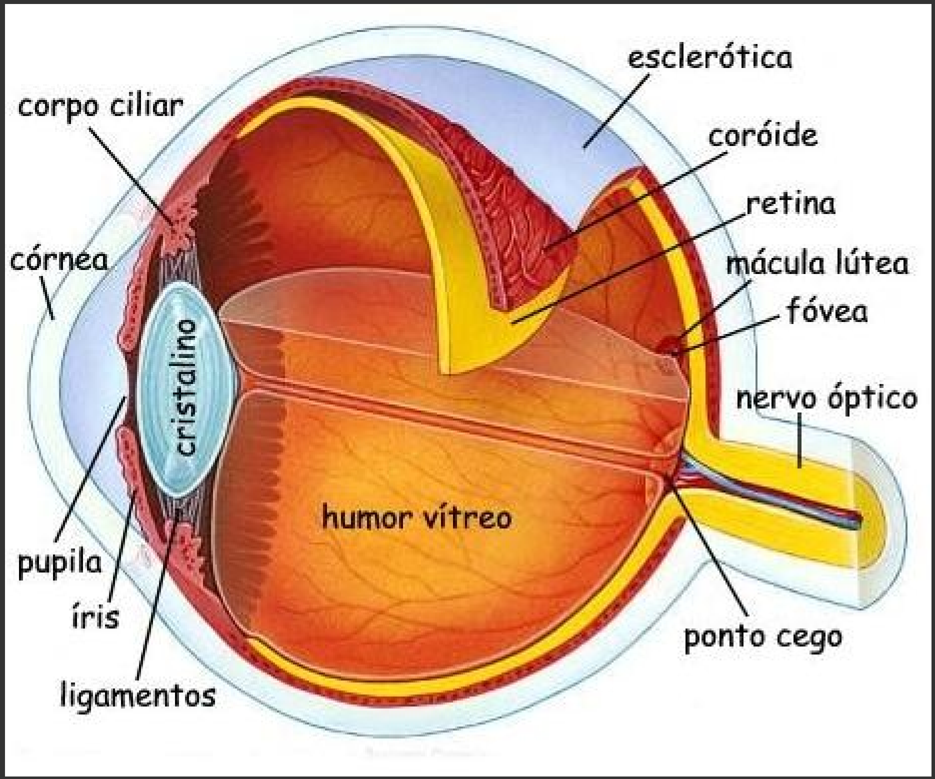


Fig. 11: Representação do olho humano.
https://olhohumano.wordpress.com/

III. Imagens e fotometria

Estrelas e magnitude

De Hiparco - Grécia (~150 a.C.) a Pogson - Inglaterra/Índia (~1850).

Mais brilhantes: magnitude 1
Menos brilhantes visíveis: magnitude 6

De 1 para 6 de magnitude temos 100 vezes menos brilho, assim definido na Relação de Pogson:

$$(m-m_0) = (-5/2).\log(F_0-F)$$

m: magnitude aparente (de -27 a +25) vista da Terra;
F: brilho aparente (em W/m^2, por exemplo).

Comentário: Madras catalogue (Índia - Pogson) com 11015 estrelas.

III. Imagens e fotometria

Fig. 12: De alfa a ômega em Creta

2016 June 29
From Alpha to Omega in Crete
Image Credit & Copyright: Johannes Schedler (Panther Observatory)

Explanation: This beautiful telephoto composition spans light-years in a natural night skyscape from the island of Crete. Looking south, exposures both track the stars and record a fixed foreground in three merged panels that cover a 10x12 degree wide field of view. The May 15 waxing gibbous moonlight illuminates the church and mountainous terrain. A mere 18 thousand light-years away, huge globular star cluster Omega Centauri (NGC 5139) shining above gives a good visual impression of its appearance in binoculars on that starry night. Active galaxy Centaurus A (NGC 5128) is near the top of the frame, some 11 million light-years distant. Also found toward the expansive southern constellation Centaurus and about the size of our own Milky Way is edge on spiral galaxy NGC 4945. About 13 million light-years distant it's only a little farther along, and just above the horizon at the right.

III. Imagens e fotometria

Olho x telescópios

Pupila: 7 mm de abertura no escuro;

Lente com 70 mm: 100 vezes mais luz captada do que o olho → 100 vezes mais fótons captados e estrelas com magnitudes 5 vezes maior (100 vezes menos brilhantes).

CCD (charge coupled device): captação via pixels com sensores de luz por acumulação de carga elétrica (efeito fotoelétrico).

Visível, rádio, UV, IV...

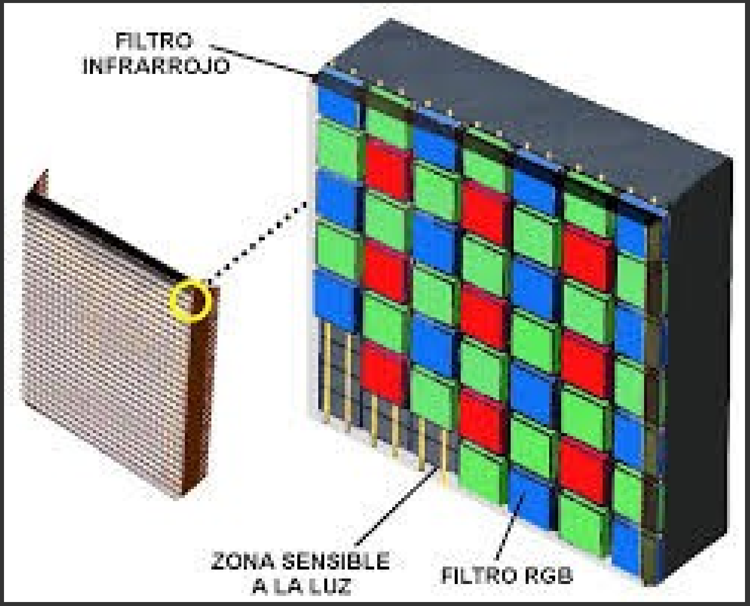


Fig. 13: CCD.
http://wwwuser.cnb.csic.es/~fotonica/Photonic_en/Review/ccd1.htm

IV. Espectroscopia

Espectrógrafo e Espectroscópio

Espectros contínuos: emissão de ondas e-m dependentes da temperatura;
Ex.: corpo humano, metais quentes...

Espectros discretos: gás excitado, alta ou baixa densidade
linhas de emissão ou absorção (Leis de Kirchoff / ~1860)

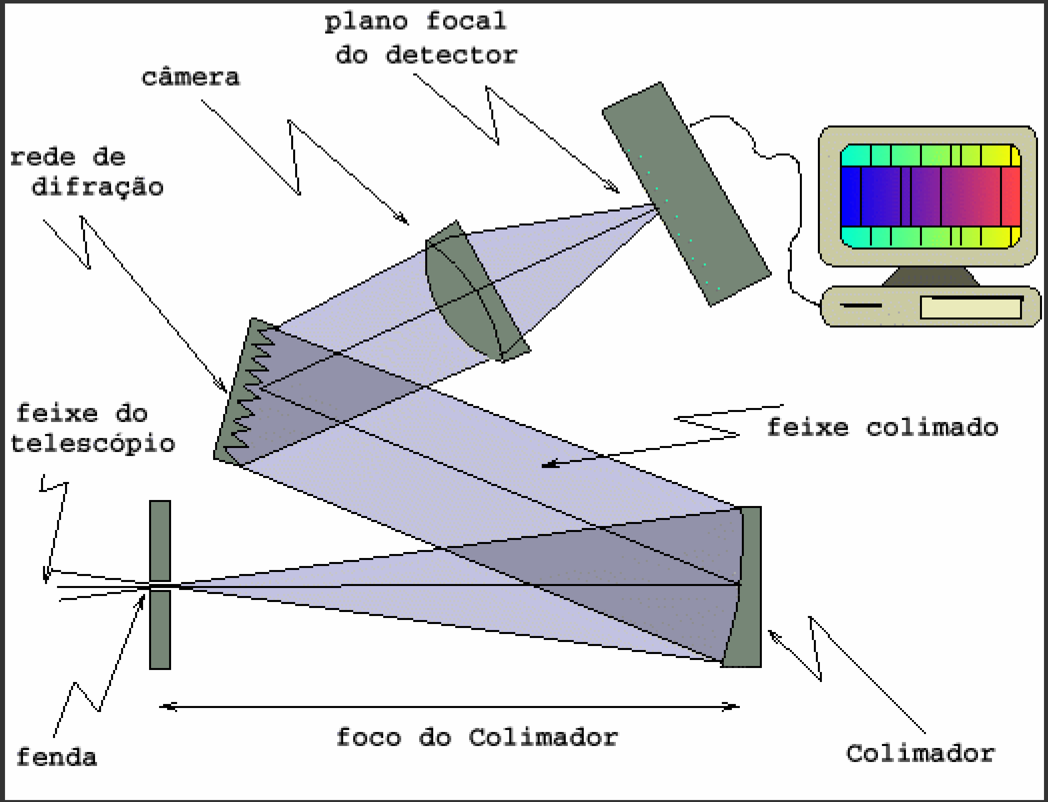


Fig. 14: Espectrógrafo.
http://www.astro.iag.usp.br/~ronaldo/intrcosm/Glossario/Espectrografo.html

IV. Espectroscopia

Efeito Döppler (~1842) e Döppler-Fizeau (~1848).
Quanto mais distante a galáxia ou quasar, maior o deslocamento para o vermelho;

Expansão do Universo.

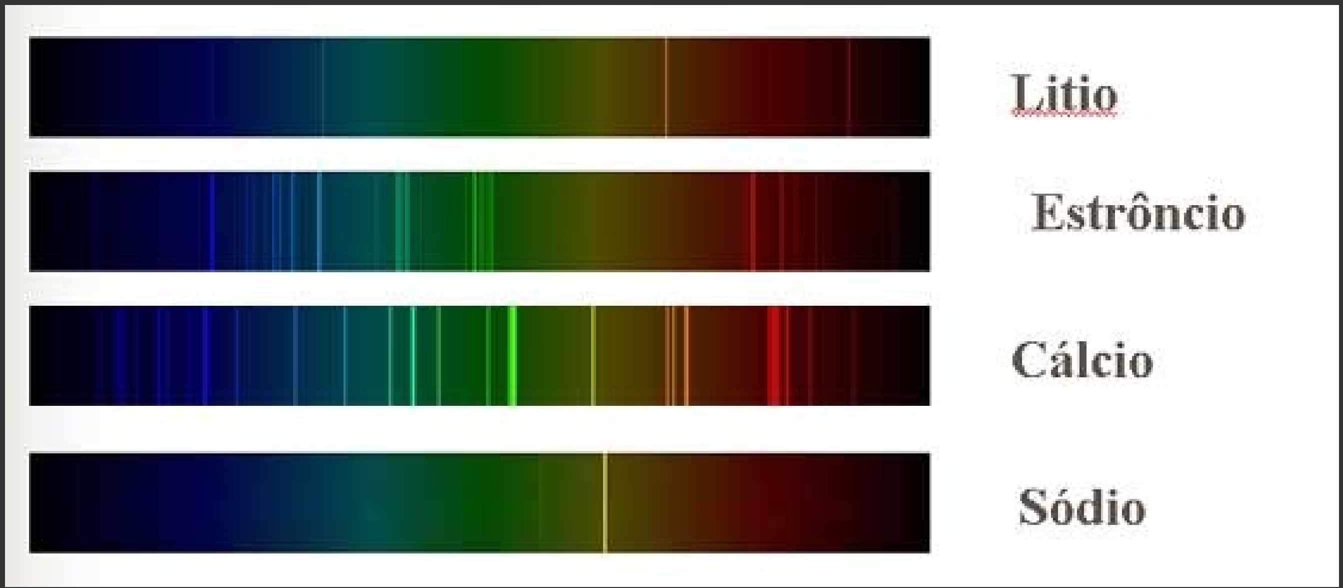


Fig. 15: faixas espectrais.
http://www.quimlab.com.br/cursos.htm

VIII. Atividade

Durante a aula:

- Oficina de construção de um espectroscópio.

- Reconhecimento e utilização de um telescópio refrator.

Após a aula:

- Baixar, instalar o programa Stellarium (para Desktop/Notebook) e começar a explorar.