Notes on Observational Astronomy

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Our textbook is Obeservational Astronomy (Birney)

1. Locating

1.1. Coordinates

Hour angle the angle between the meridian and the object

1.2. Perform real observations

- Site' s info (**latitude**)
- Target' s info (**RA, DEC**)
- When to observe your star (**hour angle**)

1.3. Correction

precession

proper motion an example of correcting proper motion

```
from astropy import units as u
from astropy.coordinates import Angle

year = 2023
# See https://simbad.harvard.edu/simbad/sim-basic?Ident=55+cnc
pm_ra = -485.681e-3
pm_dec = -233.517e-3
ra = 3600 * 8 + 52 * 60 + 35.8111044043
ra *= 15
dec = 3600 * 28 + 19 * 60 + 50.954994470

dra = (year - 2000) * pm_ra
ddec = (year - 2000) * pm_dec

dec = Angle((dec + ddec) / 3600, unit=u.deg)
ra = Angle((ra + dra) / 3600, unit=u.deg)
print(
    "55 Cnc",
    ra.to_string(unit=u.hour),
    dec.to_string(unit=u.deg),
    "Year",
    year,
    "proper motion corrected",
)
```

2. Light

2.1. Convention

Regoin of spectrum	Units
gamma rays	MeV, GeV
x-ray	KeV
Ultraviolet	Å
infrared(near-IR, IR, far-IR)	µm
microwave	mm
radio	cm, m, MHz, GHz

Table 1: The language of light

2.2. Magnitude

pogson equation relationship between magnitude and flux (apparent brightness)

$$m_1 - m_2 = -2.5 \log\left(\frac{F_1}{F_2}\right)$$

$$m = -2.5 \log(F) + C \tag{1}$$

$$\Delta m = -1.086 \frac{\Delta F}{F} \approx -\frac{\Delta F}{F} \tag{2}$$

monochromatic version of Pogson equation applying to a range of wavelengths

$$m_\lambda = -2.5 \log(F_\lambda) + C_\lambda \tag{3}$$

bolometeric magnitude all the electromagnetic radiation is included

bolometeric correction difference between the bolometeric magnitude and the magnitude in some passband

$$\mathrm{BC}_{\mathrm{band}} = m_{\mathrm{bol}} - m_{\mathrm{band}} \tag{4}$$

absolute magnitude the apparent magnitude of an object if it were 10 parsecs away

distance modulus the difference between the apparent and absolute magnitude

$$m - M = 5 \log\left(\frac{d}{10}\right) = 5 \log(d) - 5 \tag{5}$$

apparent distance modulus A_λ is the absorption in magnitudes at wavelength λ or in a passband

$$(m - M)_\lambda = (m - M)_0 + A_\lambda \tag{6}$$

absolute bolometeric magnitude the luminosity of a source in terms of Sun's luminosity

$$M_{\mathrm{bol}} = 4.74 - 2.5 \log\left(\frac{L}{L_{\mathrm{sun}}}\right) \qquad (7)$$

surface brightness the total magnitude corresponding to the average flux in one arcsec^2

$$\mu = m + 2.5 \log(\Omega) \qquad (8)$$

where m is the magnitude and Ω is the solid angle of the source in units of arcsec^2.

color index the difference between the magnitudes of an object in two passbands

magnitude zeros a reference point for the magnitude scale

2.3. Filters

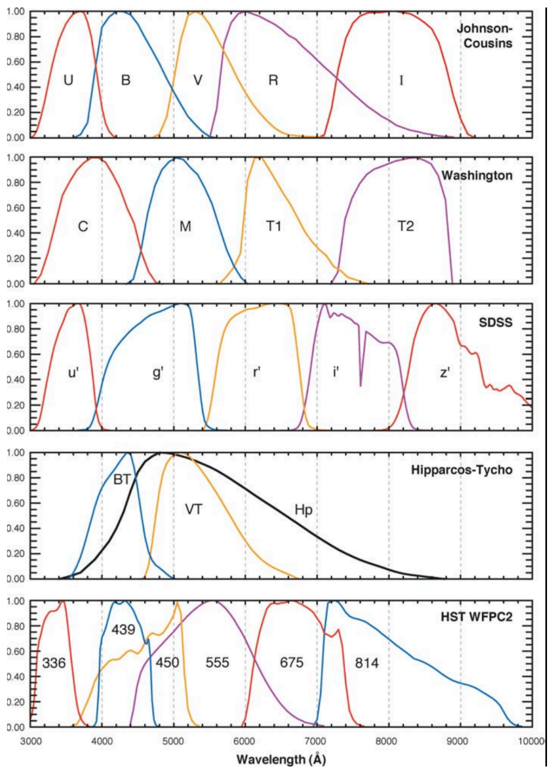


Figure 1: Photometric filters

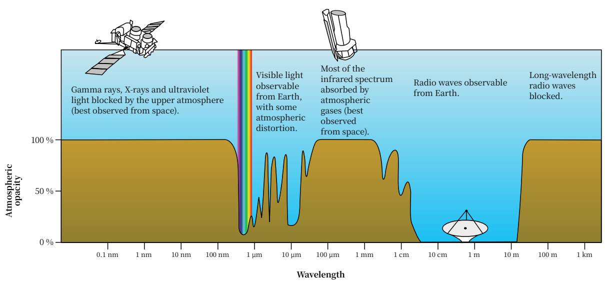


Figure 2: Atmospheric electromagnetic opacity

2.4. Flux

energy flux amount of light energy per unit in a given bandpass

$$F = \frac{E_{\mathrm{band}}}{\mathrm{d}A\,\mathrm{d}t} \text{ in unit of } \mathrm{W\,cm^{-2}} \qquad (9)$$

monochromatic flux energy flux in a single wavelength or frequency

$$F_\lambda = \frac{E_\lambda}{\mathrm{d}A\,\mathrm{d}t\,\mathrm{d}\lambda} \text{ in unit of } \mathrm{erg\,s^{-1}\,cm^{-2}\,Å^{-1}}$$

$$F_\nu = \frac{E_\nu}{\mathrm{d}A\,\mathrm{d}t\,\mathrm{d}\nu} \text{ in unit of } \mathrm{erg\,s^{-1}\,cm^{-2}\,Hz^{-1}}$$

$$\nu F_\nu = \lambda F_\lambda \qquad (10)$$

2.5. Blackbody

Wien's displacement law as the temperature increases, the peak of the blackbody spectrum shifts to shorter wavelengths

$$\lambda_{\mathrm{max}} = \frac{2900000}{T} \text{ in units of K and nm} \qquad (11)$$

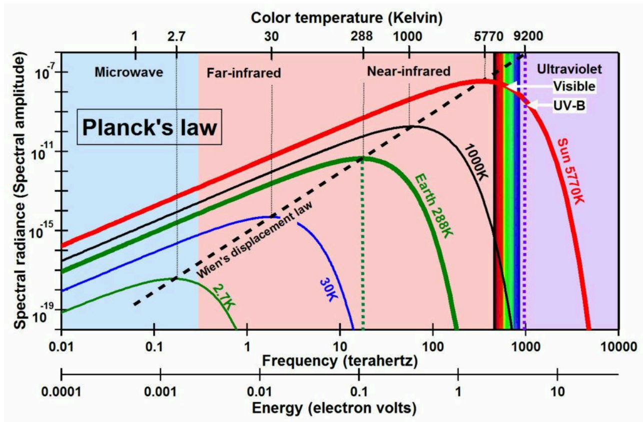


Figure 3: Blackbody radiation

3. Stars

OBAFGKM the spectral classification in descending effective temperature

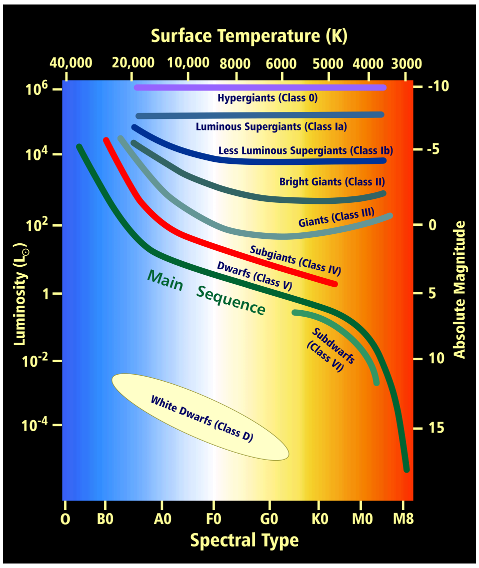
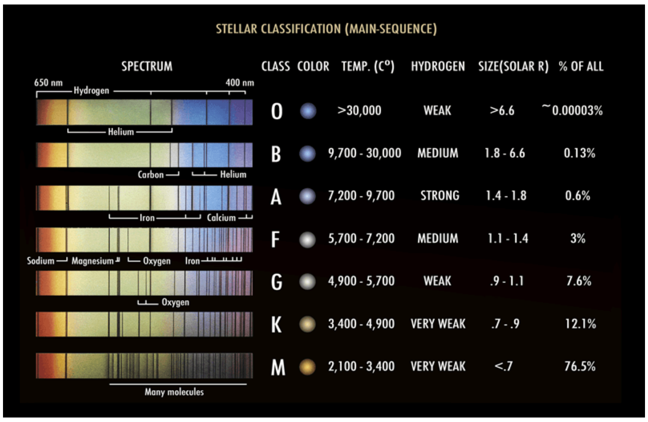


Figure 4: Stellar classification



STELLAR CLASSIFICATION (MAIN-SEQUENCE)

SPECTRUM	CLASS	COLOR	TEMP. (C°)	HYDROGEN	SIZE(SOLAR R)	% OF ALL
650 nm, Hydrogen, 400 nm, Helium	O		>30,000	WEAK	>6.6	~0.00003%
Carbon, Helium	B		9,700 - 30,000	MEDIUM	1.8 - 6.6	0.13%
Iron, Calcium	A		7,200 - 9,700	STRONG	1.4 - 1.8	0.6%
Sodium, Magnesium, Oxygen, Iron	F		5,700 - 7,200	MEDIUM	1.1 - 1.4	3%
Oxygen	G		4,900 - 5,700	WEAK	.9 - 1.1	7.6%
	K		3,400 - 4,900	VERY WEAK	.7 - .9	12.1%
Many molecules	M		2,100 - 3,400	VERY WEAK	<.7	76.5%

Figure 5: Stellar spectrum

4. Observations

4.1. Distance

parallax the apparent shift in the position of a nearby star relative to the background

$$d = \frac{1}{p} \tag{12}$$

p is measured in arcsec and d in pc.

$$1\text{pc} = 3.2615637769\text{ly} \tag{13}$$

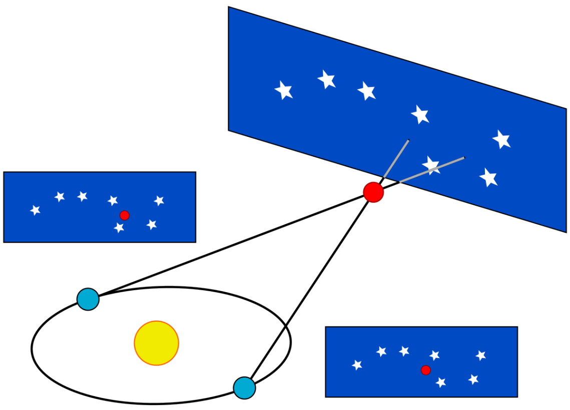


Figure 6: Parallax

4.2. Size

$$L = \mathcal{F} 4\pi r^2 \tag{14}$$

$$L = 4\pi R^2 \sigma T_{\text{eff}}^4 \tag{15}$$

4.3. Mass

Virial theorem

$$2K + V = 0$$

$$2\sum_i \frac{1}{2} m_i v_i^2 - \sum \frac{G m_i m_j}{r_{ij}} = 0$$

$$\frac{GM}{R} = \sigma^2 \tag{16}$$

4.4. Age

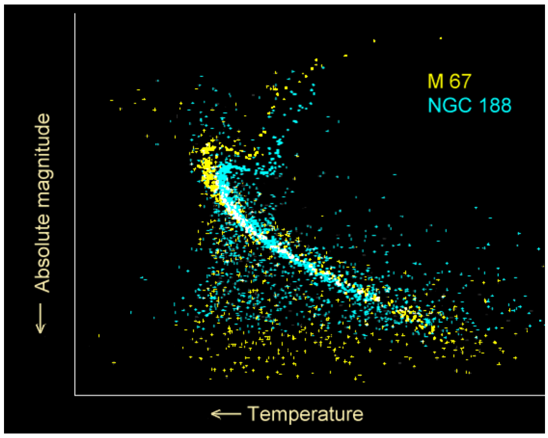


Figure 7: Comparing ages of clusters

5. Telescope

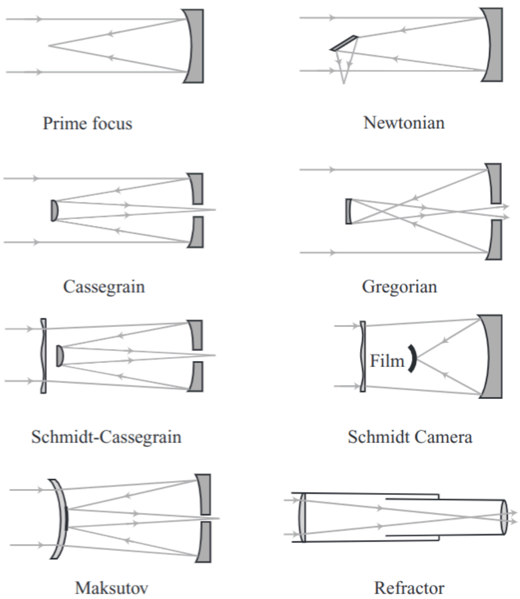


Figure 8: Types of telescopes

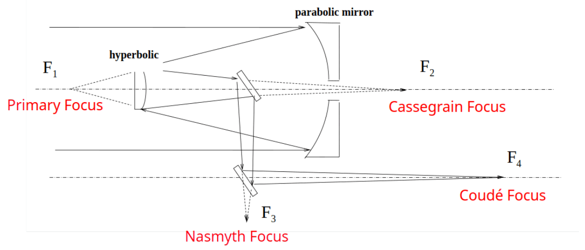


Figure 9: Types of focus

5.1. Parameters

mount how the telescope is supported and pointed

- equatorial mount
  - German
  - English yoke
  - English cross-axis
  - Fork
- alt-az mount

image formation 2 beams of light separated by an angular distance are focused to 2 points

$$S = F\tan(\theta) \approx F\theta \tag{17}$$

plate scale angular size of the object per unit length on the plate

$$P_s = \frac{\theta}{S} = \frac{1}{F} \tag{18}$$

image scale how much of the sky in arcsec each and every pixel can see

$$\frac{206.2648 \times \text{pixel size}_{\text{in µm}}}{F_{\text{in mm}}} \tag{19}$$

see also to explain image scale.

limiting magnitude the magnitude of the faintest star an average observer is likely to see through the telescope

$$M_L \approx 2.7 + 5\log(d) \tag{20}$$

where d is the objective lens diameter in millimeter

focal ratio

$$R = \frac{F}{D} \text{ as } E \propto \frac{D^2}{F^2} \tag{21}$$

field of view

$$\text{fov} = 2\arctan\left(\frac{w}{2f}\right)$$
$$\text{where } w \text{ is the sensor width} \tag{22}$$

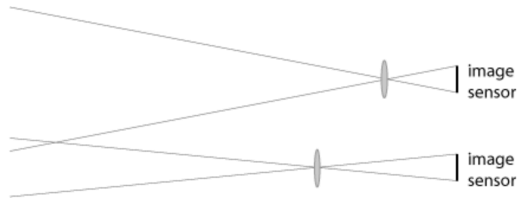


Figure 10: Field of view

5.2. Resolution

Ariy disk The circular aperture has a diffraction pattern described by the Bessel function, whose first zero is at 1.22

$$\sin\theta = 1.22\frac{\lambda}{d} \tag{23}$$

Seeing the degradation of the image of an astronomical object due to turbulence in the atmosphere of Earth that may become visible as blurring, twinkling or variable distortion. The strength of seeing is often characterized by the angular diameter (FWHM) of the long-exposure image of a star (seeing disk) in unit of arcsec.

6. CCD

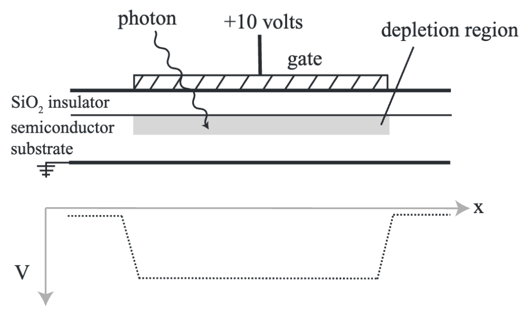


Figure 11: Single pixel of CCD

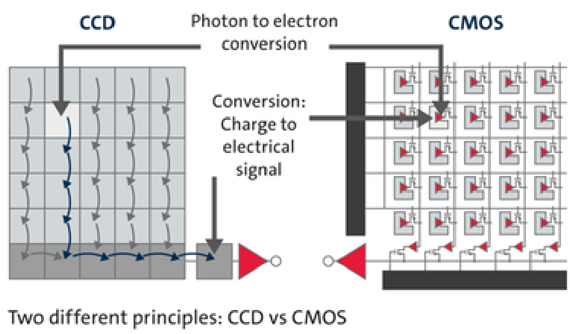
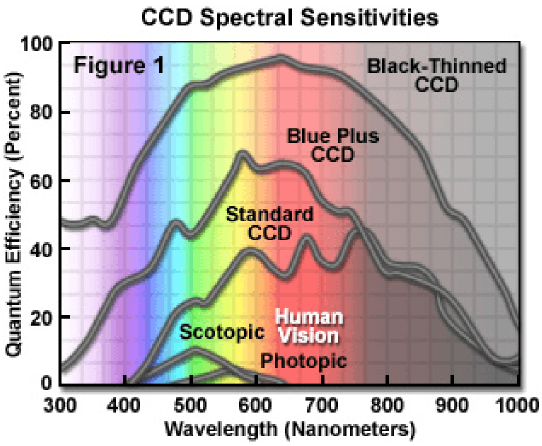


Figure 12: Image formation: CCD vs CMOS

Quantum Efficiency the fraction of photons that are converted into electrons



ADU [What is ADU]

6.1. Image reduction

$$\text{reduced} = \frac{\text{science} - \text{dark} - \text{bias}}{(\text{flat} - \text{dark} - \text{bias})_{\text{normailzed}}} \tag{24}$$

6.2. Noise

SNR signal to noise ratio

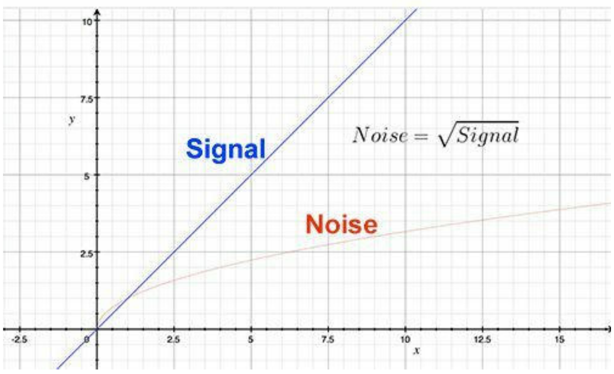


Figure 14: Long exposure to boost SNR

CCD equation

$$S_{\text{net}} = (S + B) - B_{\text{estimated}} - D \tag{25}$$

$$B_{\text{estimated}} = \frac{n_s}{n_B} B_{\text{total}} \tag{26}$$

$$\sigma_B = \frac{n_s^2}{n_B^2} B_{\text{total}} \tag{27}$$

$$\text{SNR} = \frac{S_{\text{net}}}{\sqrt{S_{\text{total}} + \sigma_B^2 + N_d + n_s N_r^2}} \tag{28}$$

I	photon flux	photons per second

Howell, Koehn, Bowell, Hoffan equation

7. Spectroscopy

[Redshift]

$$z = \frac{\lambda_{\text{obs}} - \lambda_{\text{emit}}}{\lambda_{\text{emit}}} \tag{29}$$

8. Concepts and their translations

中文术语参考自[天文学名词]

ABBR.	Concepts	术语
	barycenter	质心
	heliocentric	日心
	azimuth axis	方位轴
	sidereal time	恒星时
LST	local sidereal time	本地恒星时
GST	greenwich sidereal time	格林威治恒星时
	epoch	历元,时期
RA	right ascension	赤经
DEC	declination	赤纬
	zenith	天顶
ICRS	international celestial reference system	国际天球参考系
	meridian	子午圈
HA	hour angle	时角
	proper motion	自行
	color index	色指数
	photometry	光度学
	apparent brightness	视亮度
	bandpass	带通
SED	spectral energy distribution	光谱能量分布
	atmospheric extinction	大气消光
	limiting magnitude	极限星等
	aberration	像差
	field of view	视场
	prime focus	主焦点
	cassegrain foucs	卡赛格林焦点
	nasmyth focus	内氏焦点
	coude focus	折轴焦点
	exit pupil	出射光瞳
	achromatic lens	消色差透镜
coma	comatic aberration	彗差
	spherical aberration	球差
	vignetting	渐晕
	plate scale	底片比例尺
	focal ratio	焦比

ABBR.	Concepts	术语
	seeing	视宁度
	kinetic temperature	运动温度
	color temperature	色温度
	excitation temperature	激发温度
	ionization temperature	电离温度
	distance ladder	距离阶梯
	trigonometric parallax	三角视差
	secular parallax	长期视差
	statistical parallax	统计视差
	peculiar motion	本动速度
	standard candle	标准烛光
	cepheid variable	造父变星
CCD	charge coupled device	电荷耦合器件
	full well capacity	势阱容量
	front illumination	前照式
	back illumination	后照式
	thermal detector	热探测器
	chopping	斩波法
	flat	平场
	twilight sky flat	晨昏天光平场
	dome flat	圆顶平场
CV	cataclysmic variable	激变变星
	roche lobe	洛希瓣
TDE	tidal disruption event	潮汐瓦解事件
	accretion disc	吸积盘
	differential photometry	较差测光
	photoelectric photometer	光电光度计
	photometric night	测光夜
	instrumental magnitude	仪器星等
	aperture photometry	孔径测光
	spectral calibration lamp	光谱定标灯
	telluric line	大气谱线
	column density	柱密度