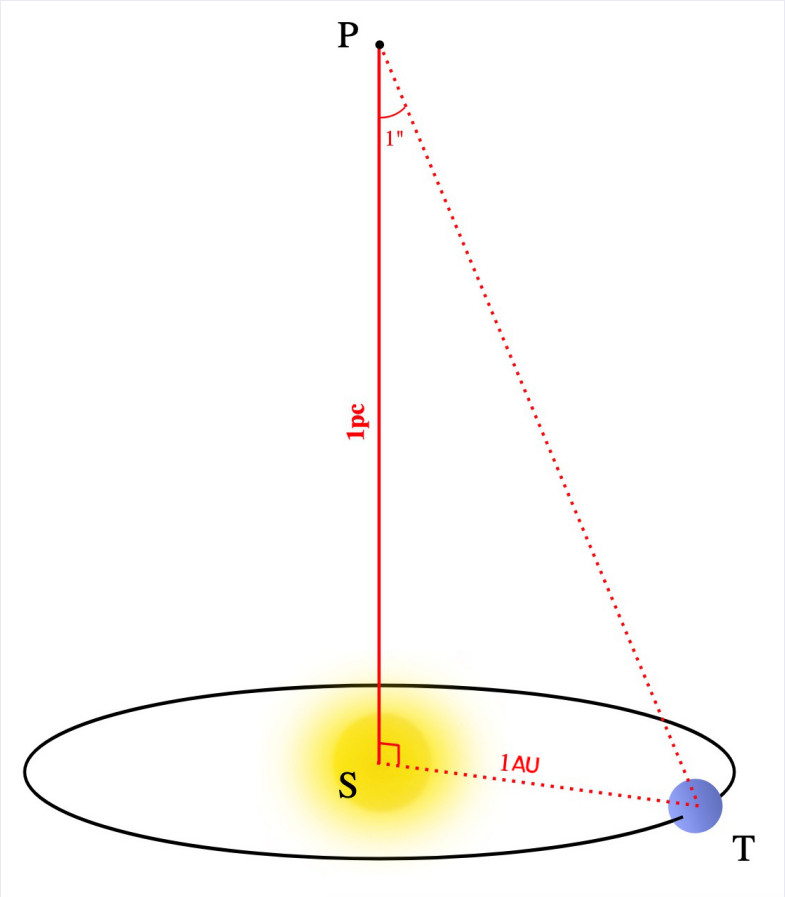
Astronomia Pozagalaktyczna: Skala (drabina) odległości

Szymon Kozłowski

Uniwersytet Warszawski

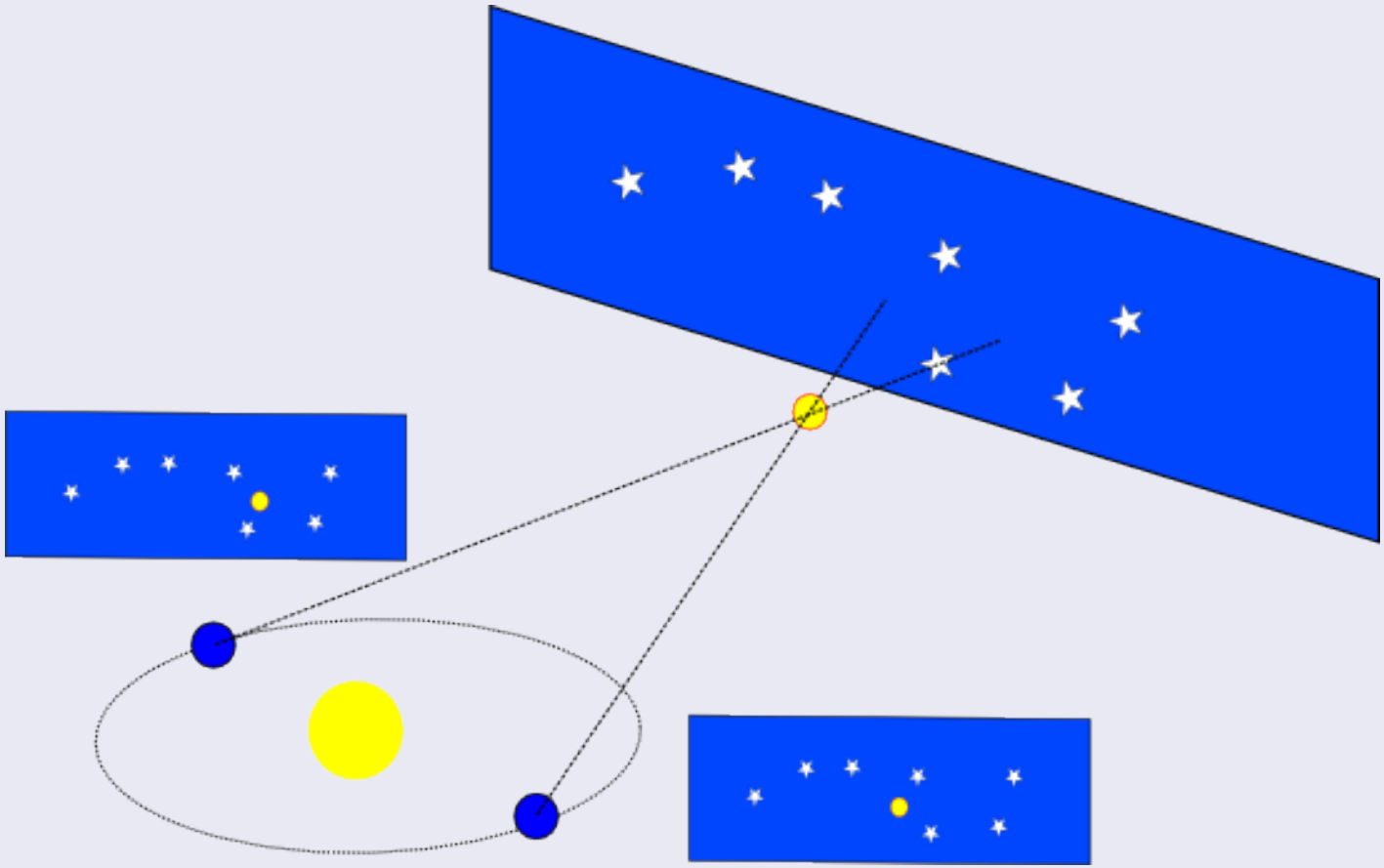
2023

Parsek



1 pc – to odległość z jakiej promień orbity Ziemi (1 AU) ma na niebie rozmiar 1".

Paralaksa

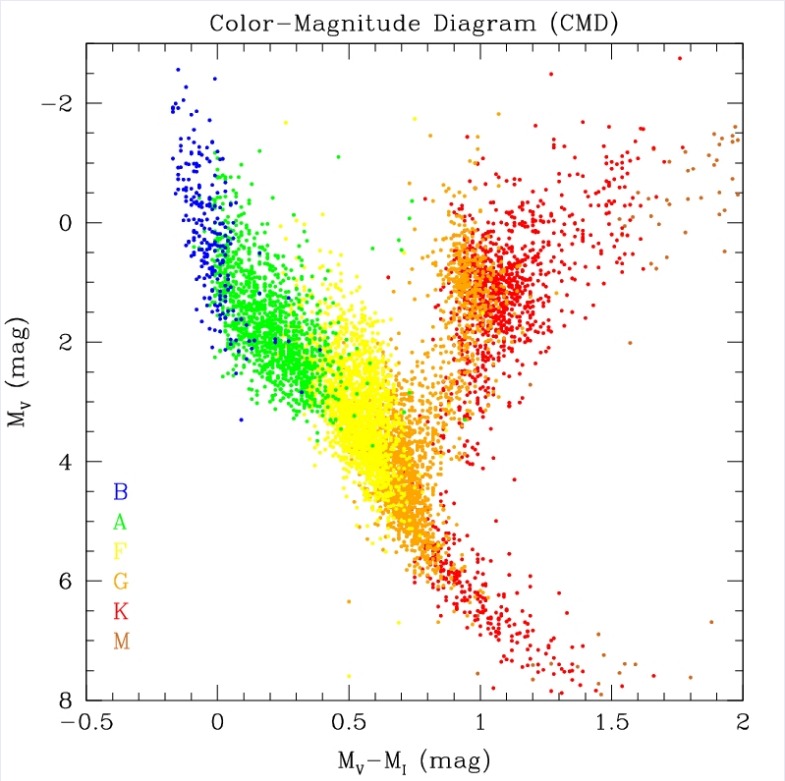


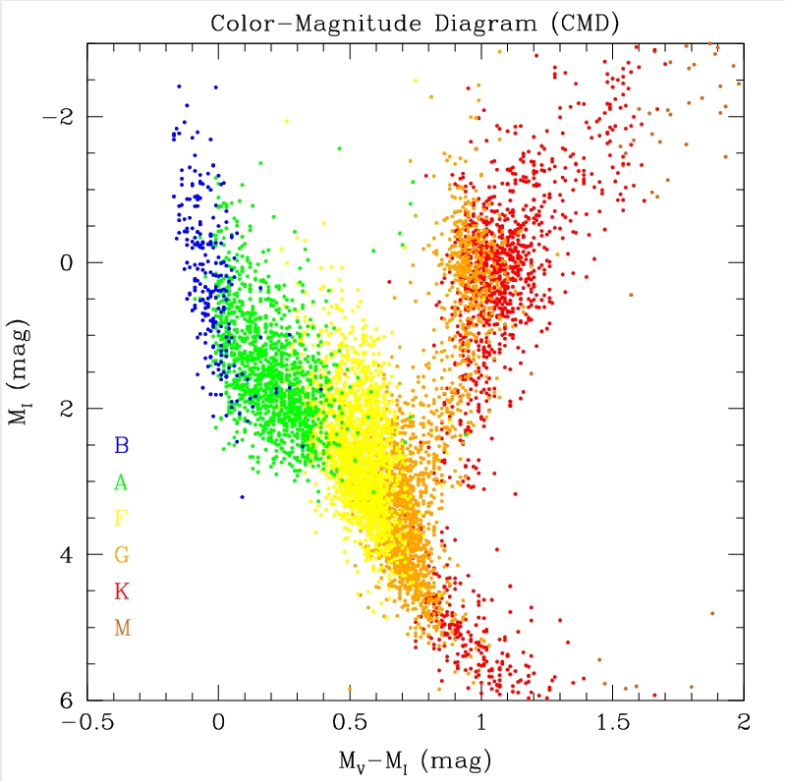
Odległości: $D(pc) = 1/p(")$

Satelita Hipparcos

Satelita Hipparcos (wystrzelony przez Europejską Agencję Kosmiczną w 1989 r.) mierzył precyzyjne paralaksy z dokładnością około 1 mas. Hipparcos zmierzył paralaksy dla około 100 000 gwiazd. Uzyskał 10% dokładność odległości do około 100 pc. Dobre odległości dla jasnych gwiazd do 1 kpc.

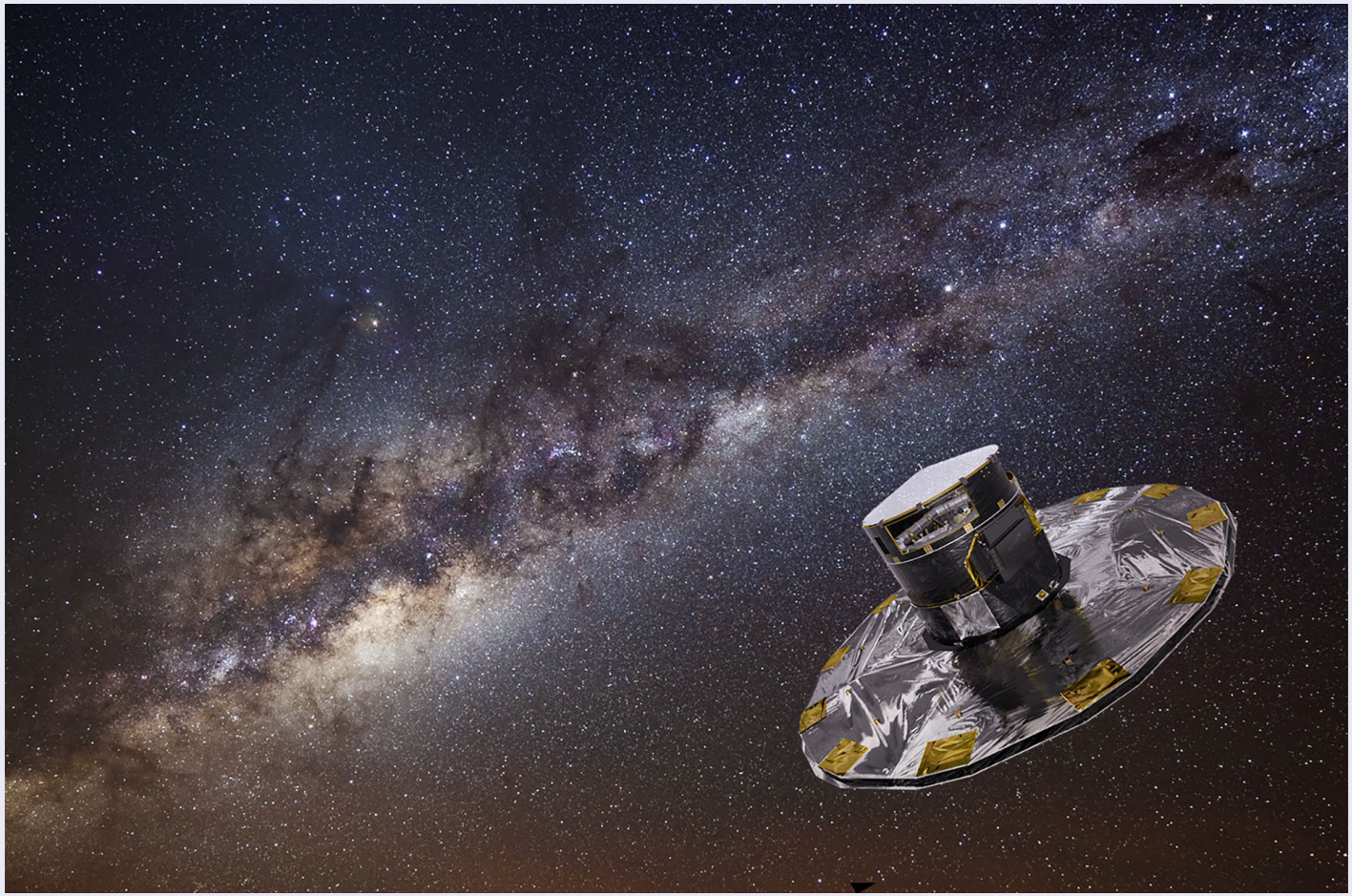
Satelita Hipparcos





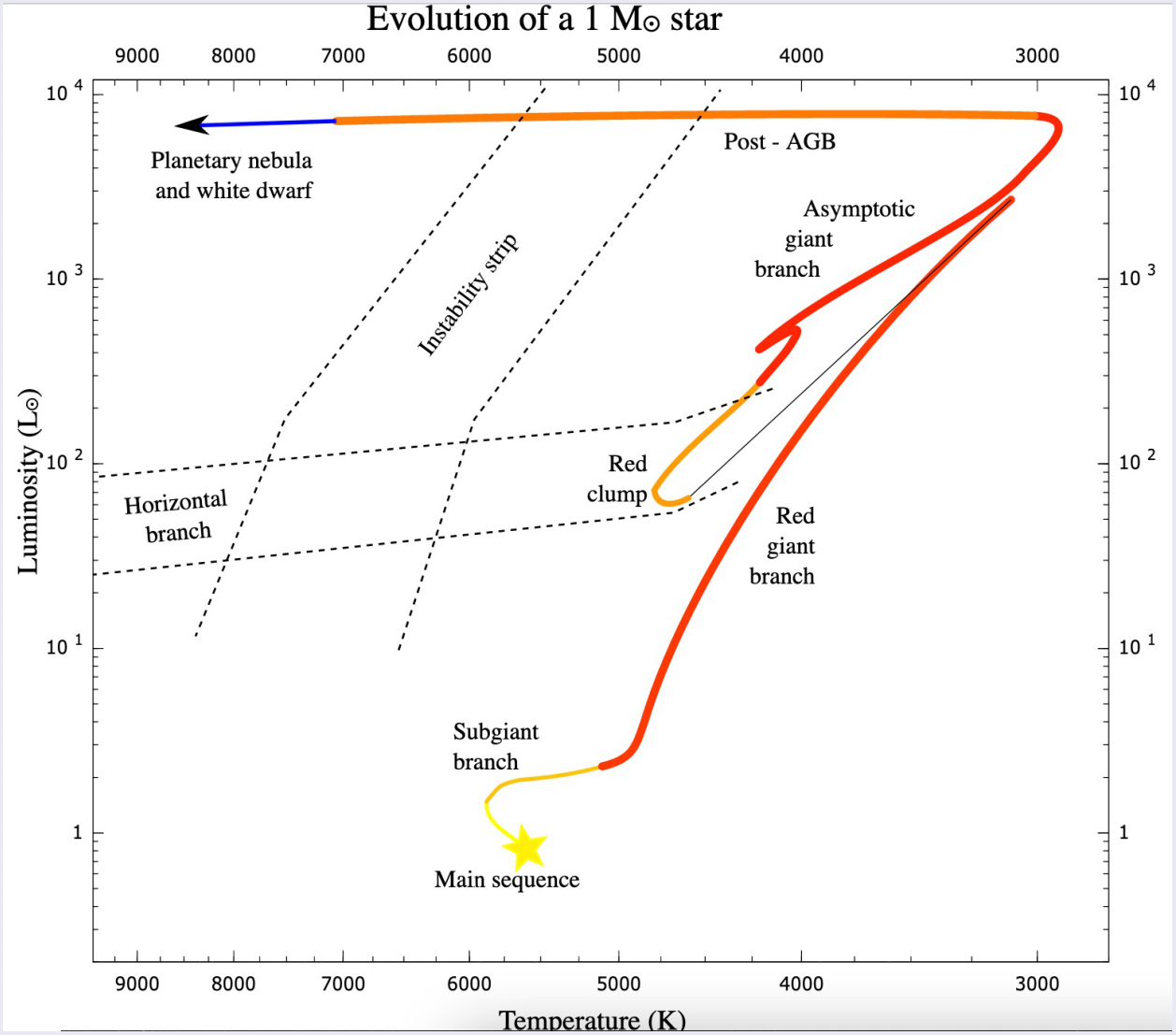
$$m - M = 5\log(D) - 5 \qquad (1)$$

Satelita Gaia

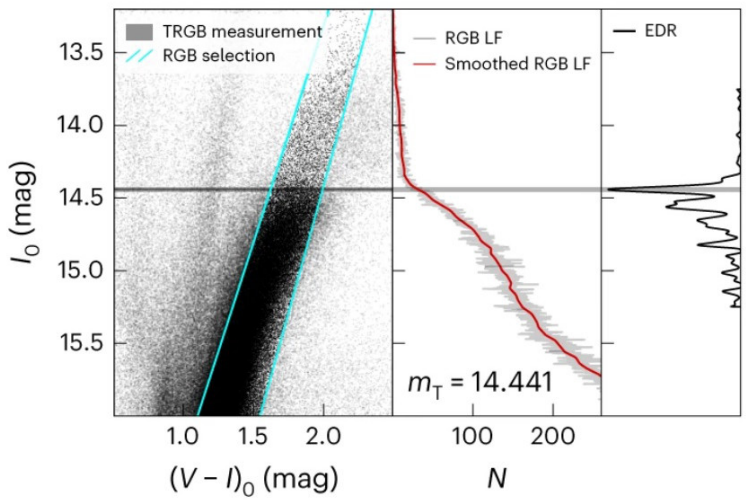


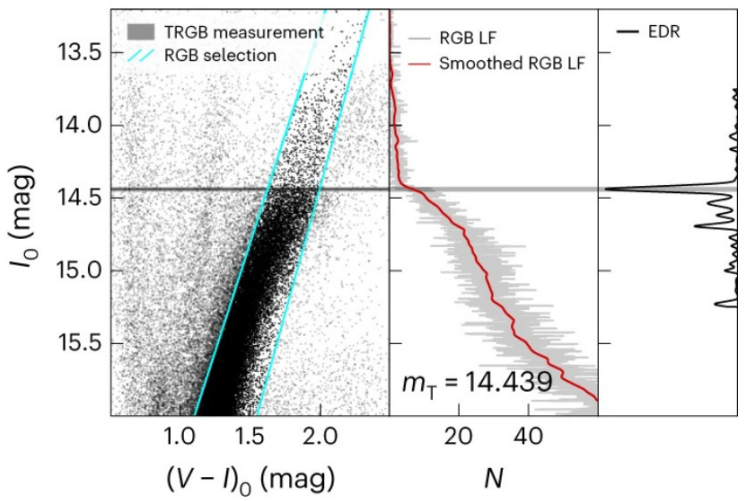
Dobre odległości dla gwiazd do $\sim$3 kpc.

Tip of the RGB

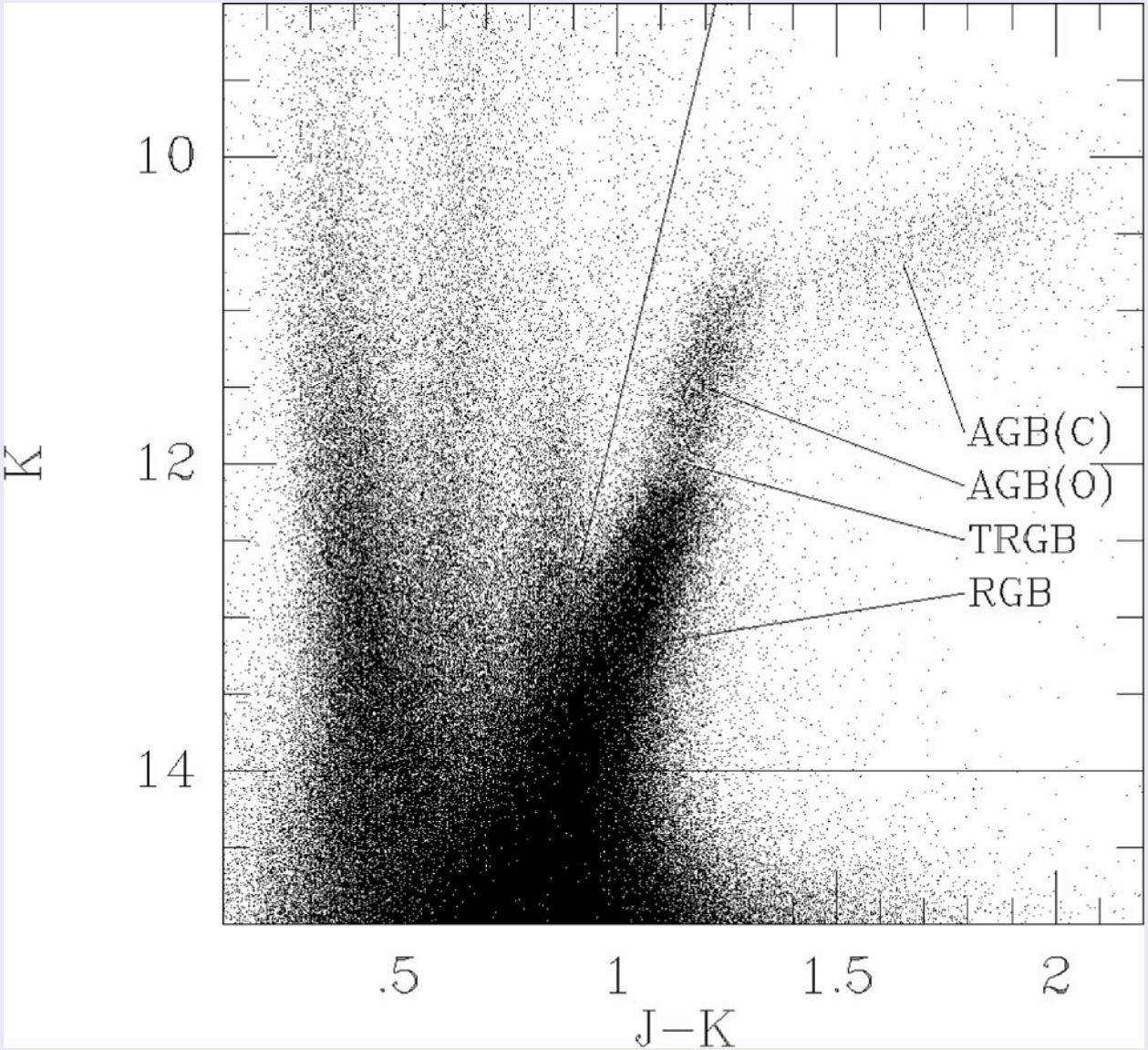


Tip of the RGB

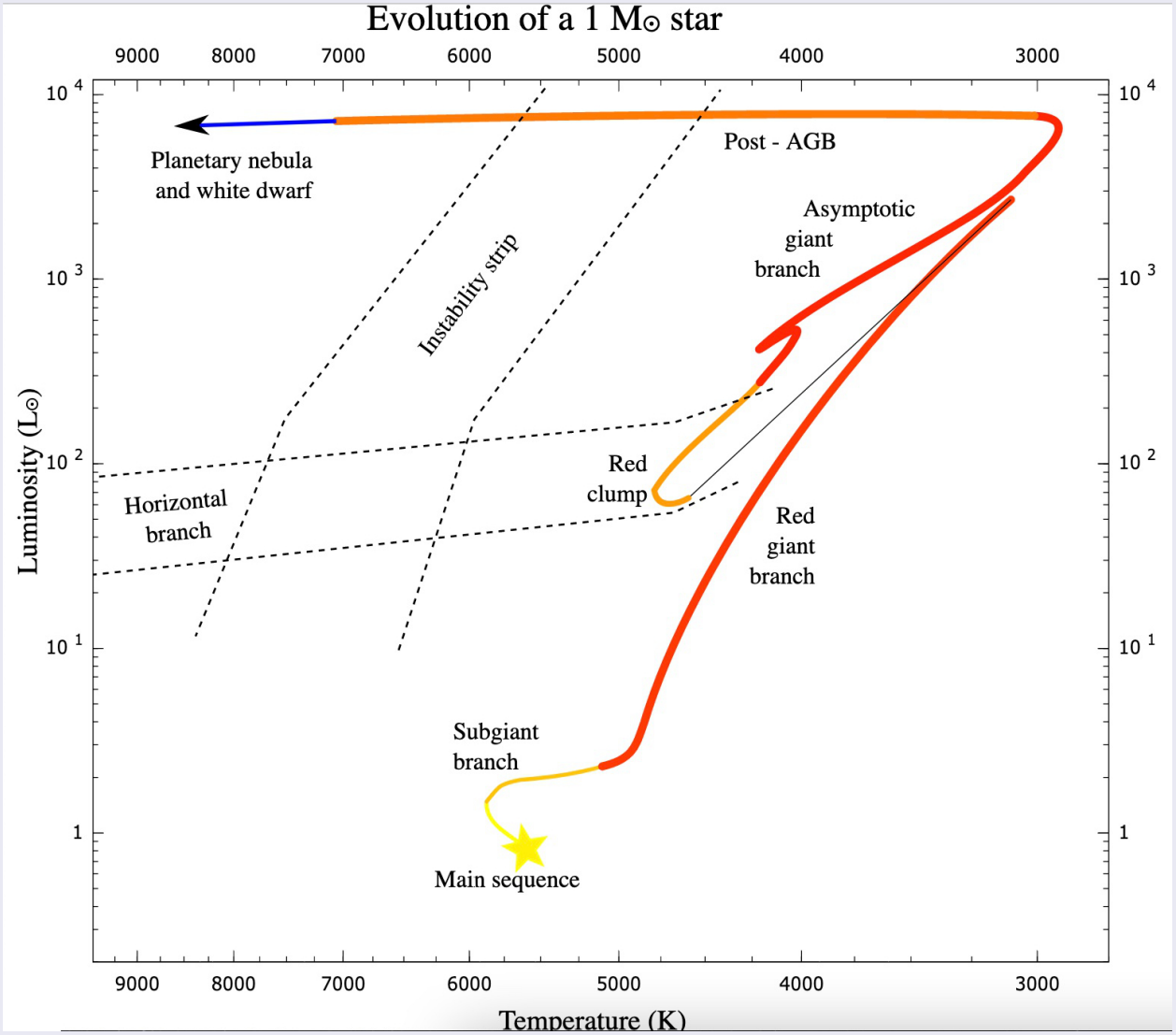




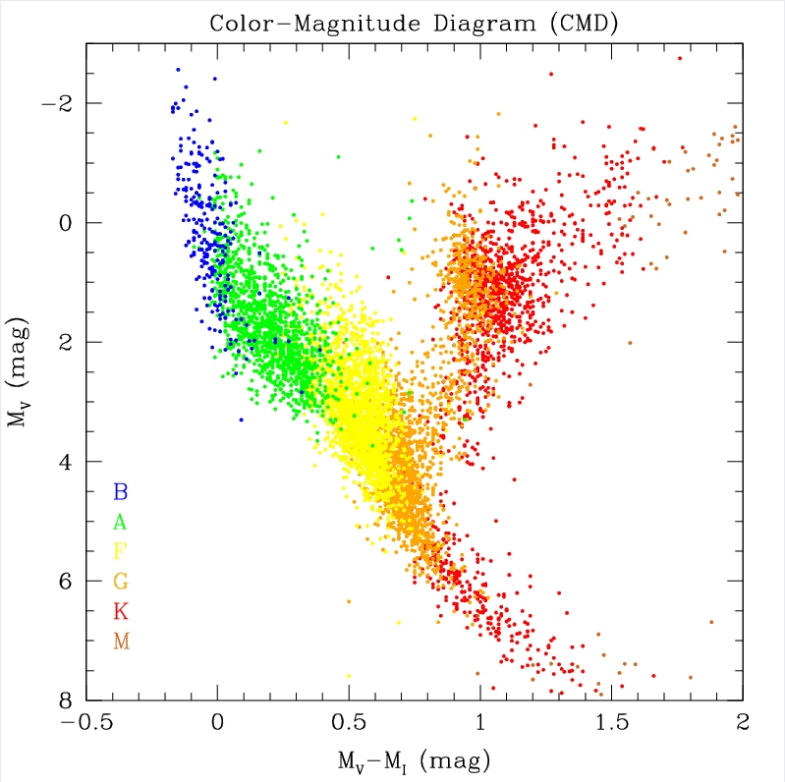
Tip of the RGB

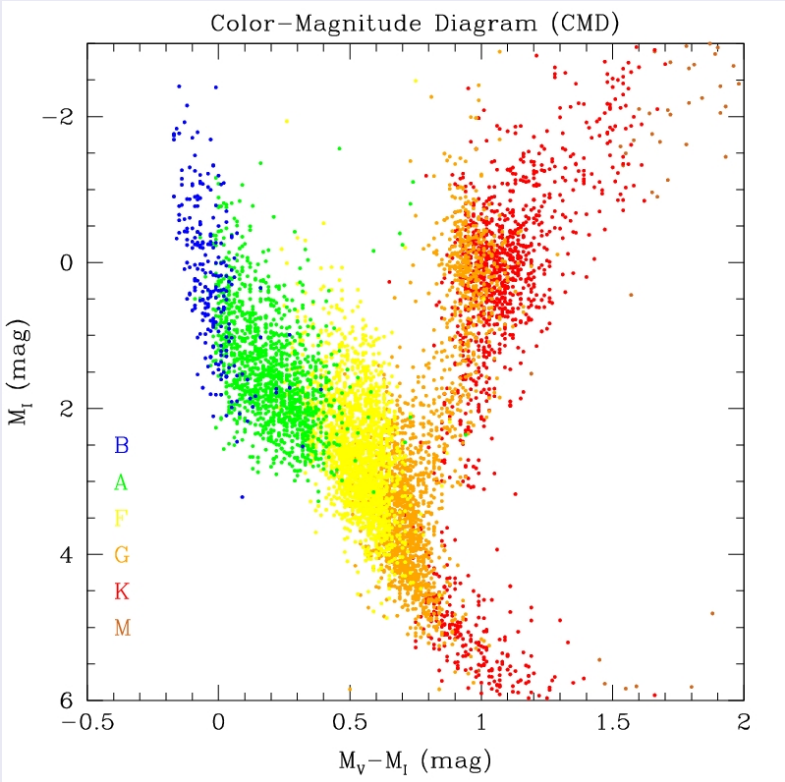


Red Clump


Evolution of a 1 M⊙ star
9000
8000
7000
6000
5000
4000
3000
10 4
10 3
10 2
10 1
1
Luminosity (L⊙)
Temperature (K)
Planetary nebula
and white dwarf
Post - AGB
Asymptotic
giant
branch
Instability strip
Red
clump
Horizontal
branch
Red
giant
branch
Subgiant
branch
Main sequence

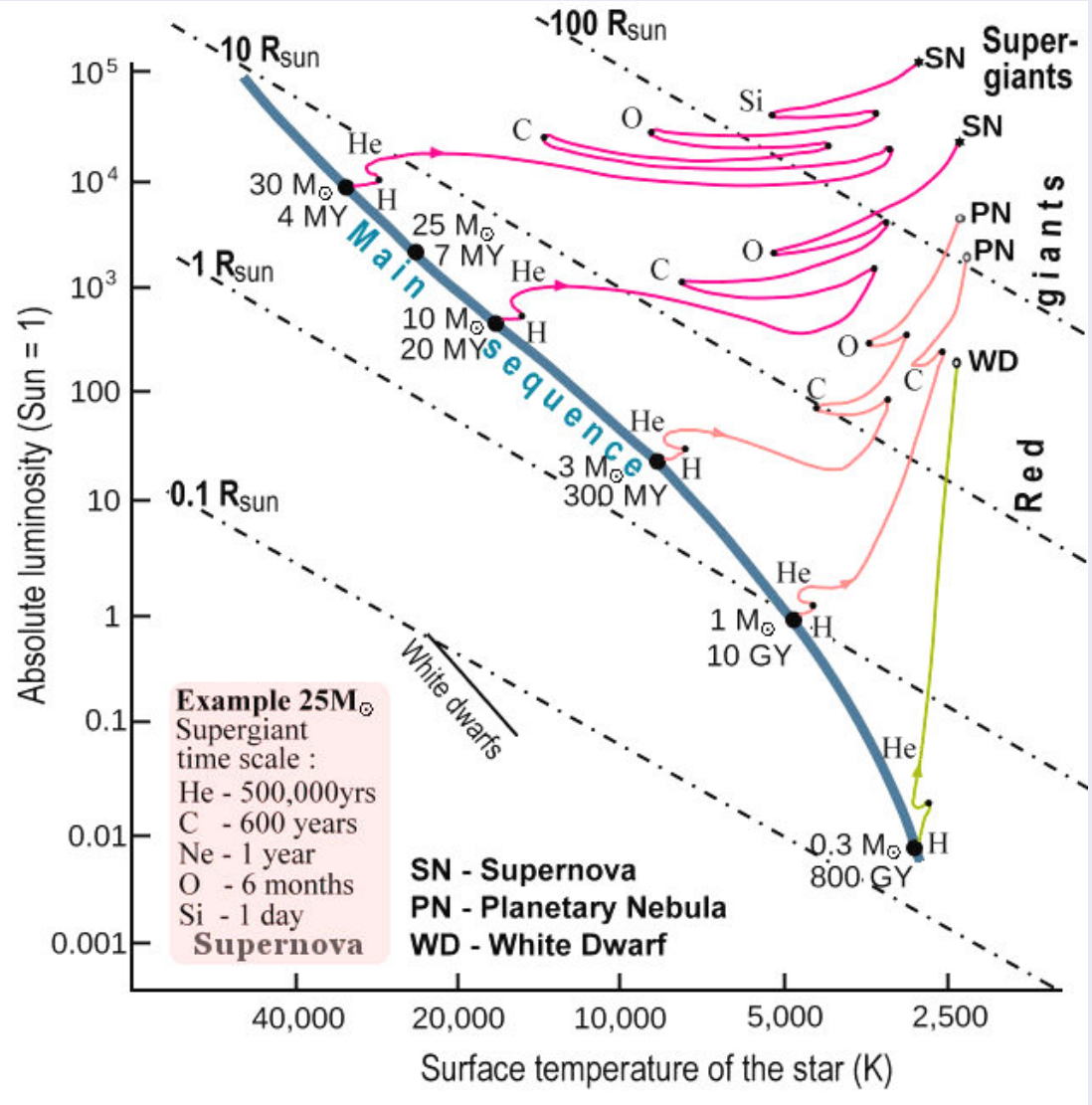
Red Clump



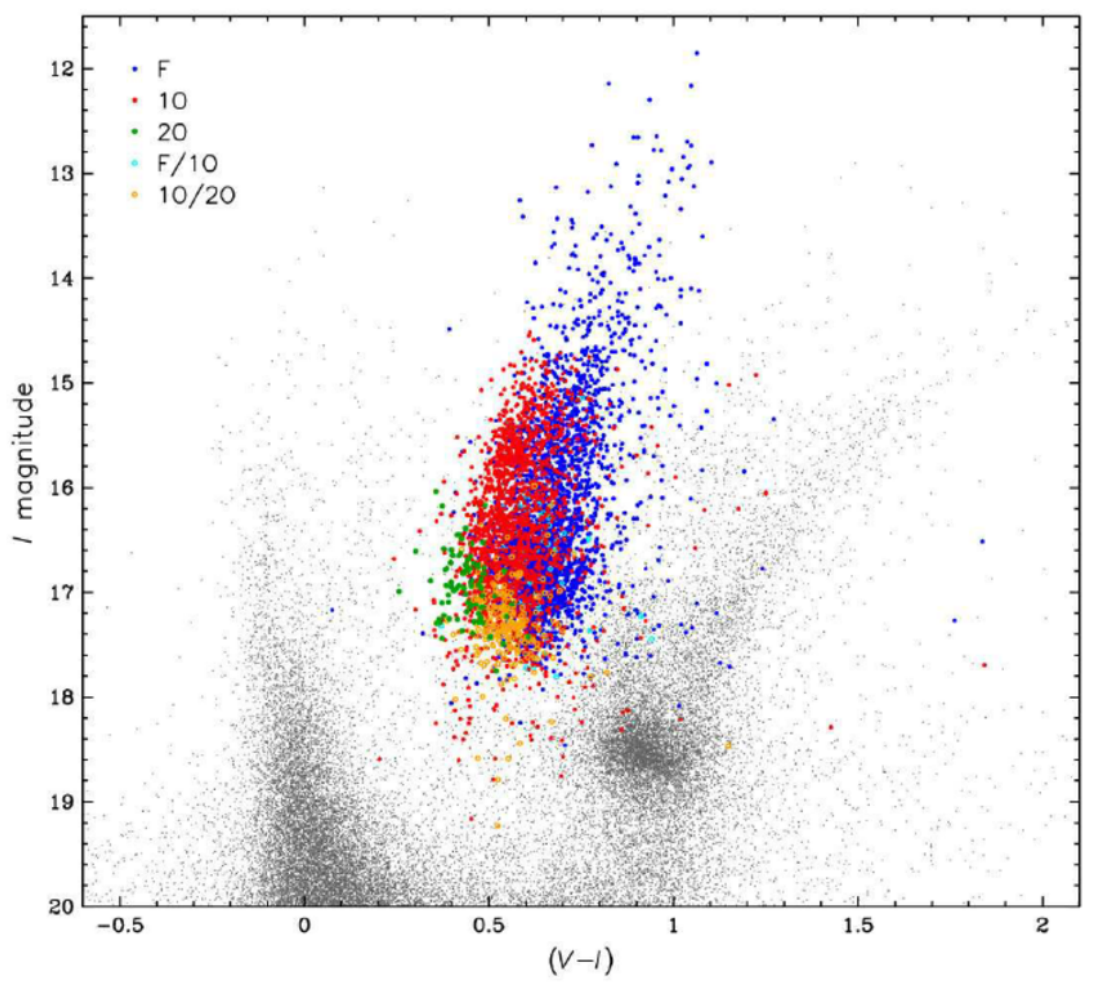


$$(V-I) = 1.0 \text{ mag} \qquad M_I = -0.2 \text{ mag} \qquad m - M = 5\log(D) - 5 \qquad (2)$$

Masywne gwiazdy i pulsacje

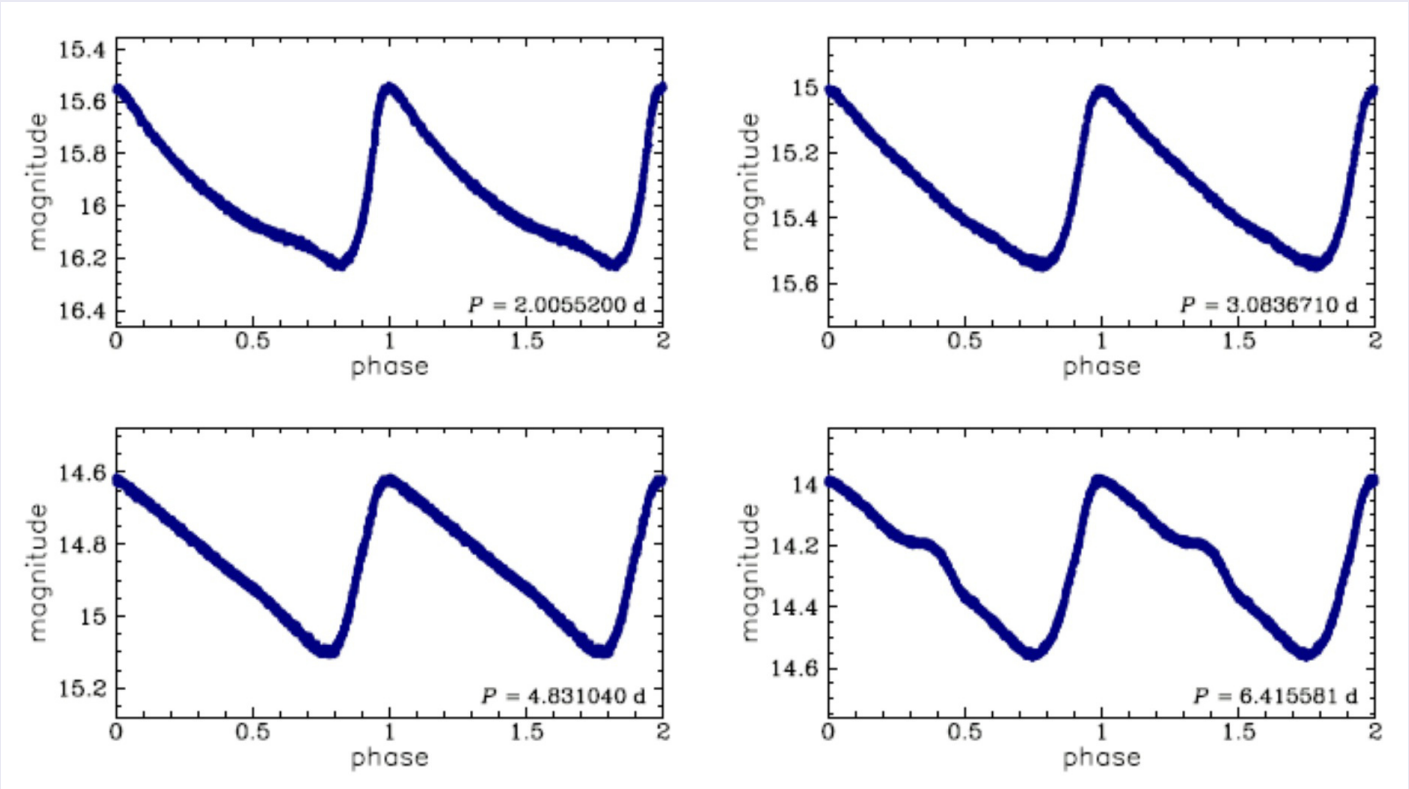


Cefeidy

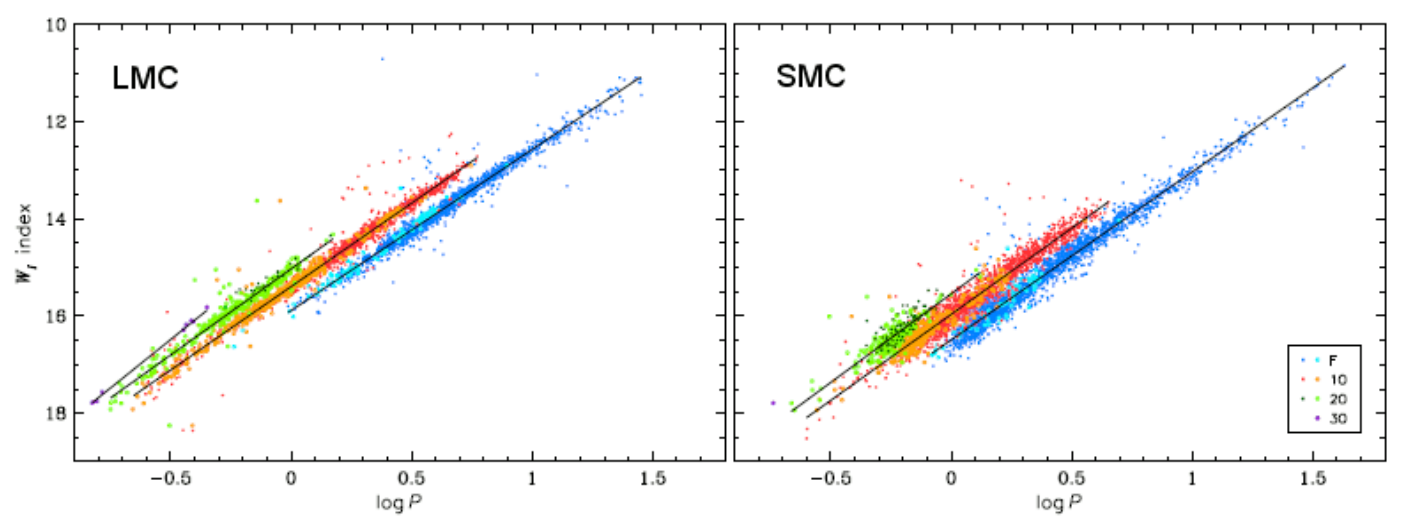


Gwiazdy populacji I, młode, obserwowalne do ∼100 mln ly.

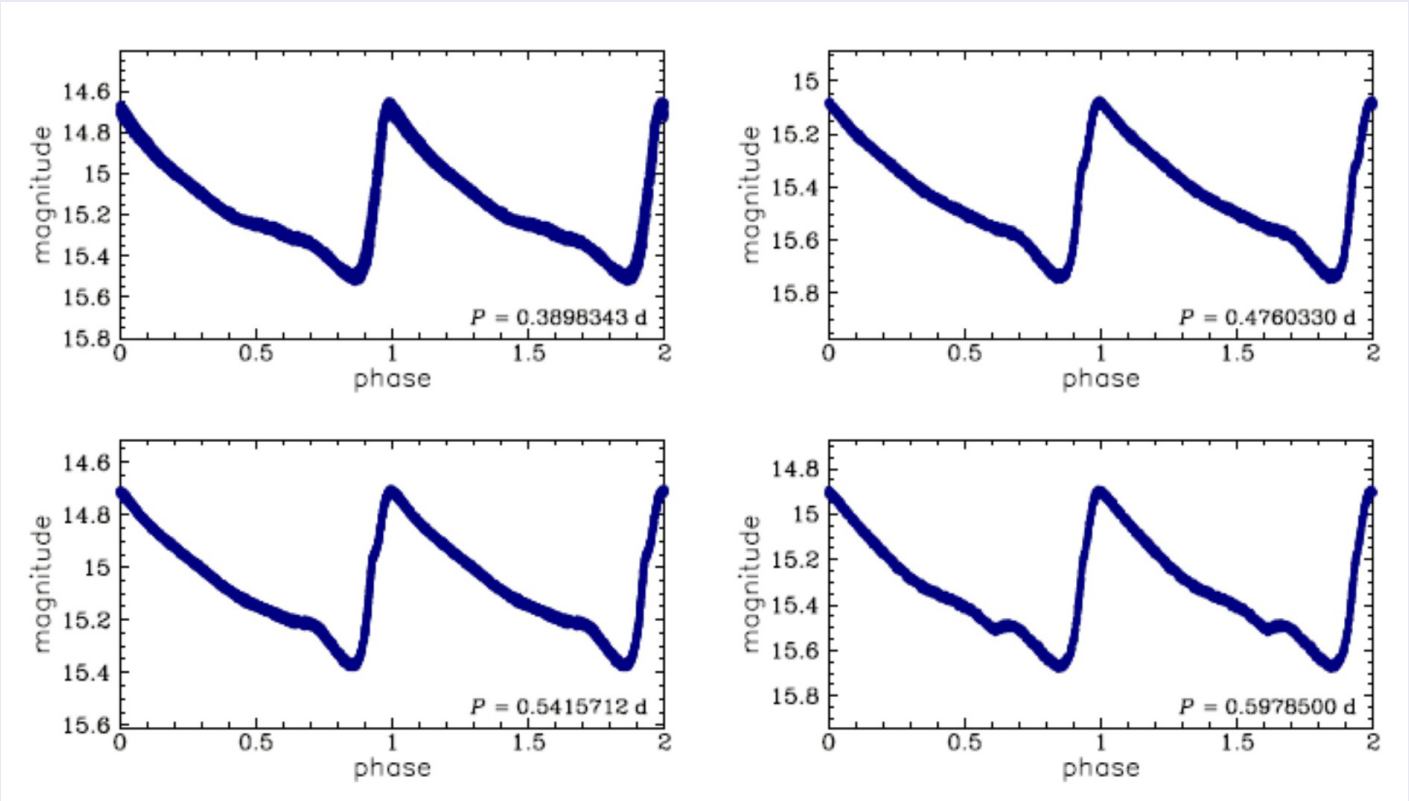
Cefeidy


magnitude
phase
P = 2.0055200 d
P = 3.0836710 d
P = 4.831040 d
P = 6.415581 d

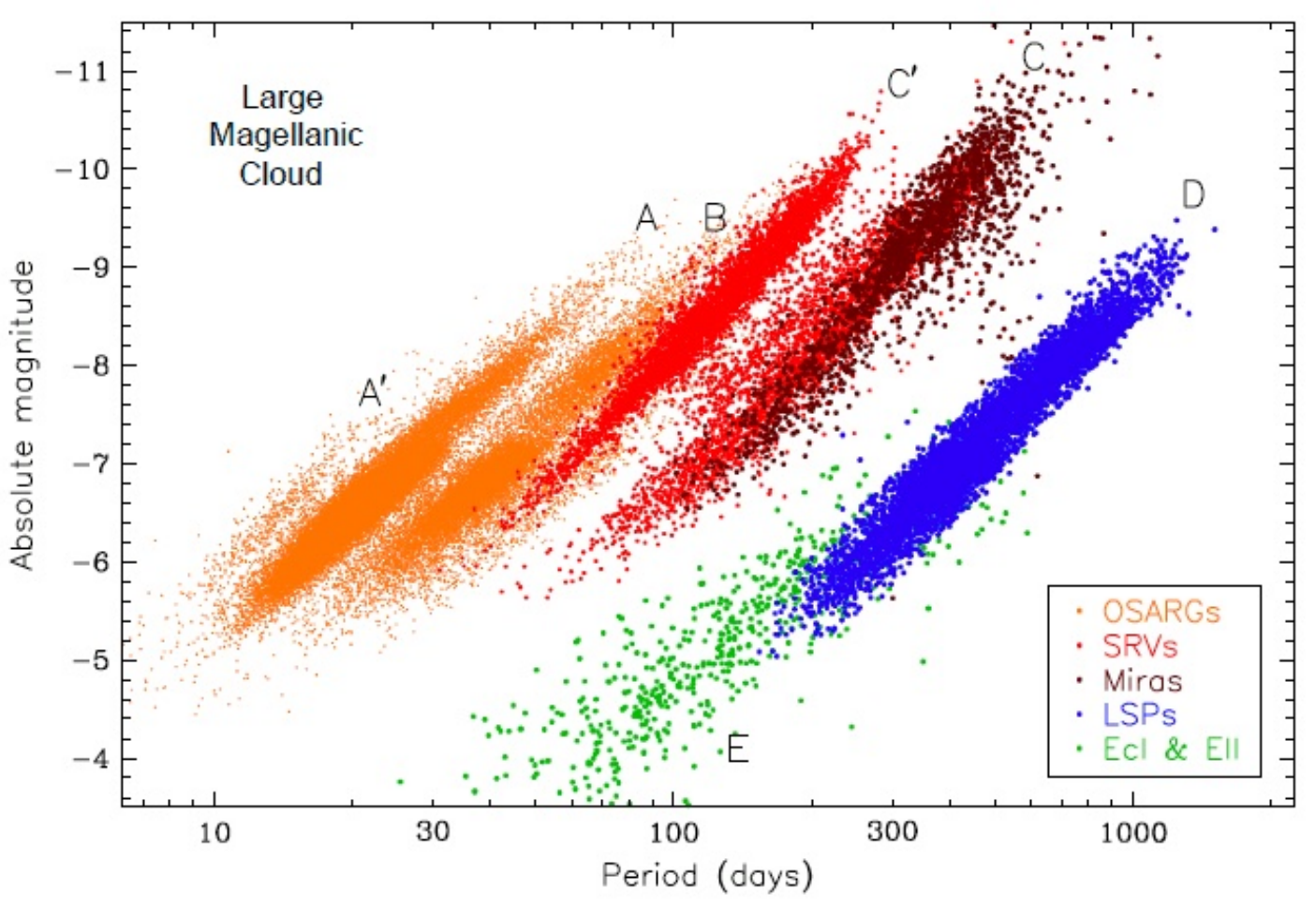
Cefeidy



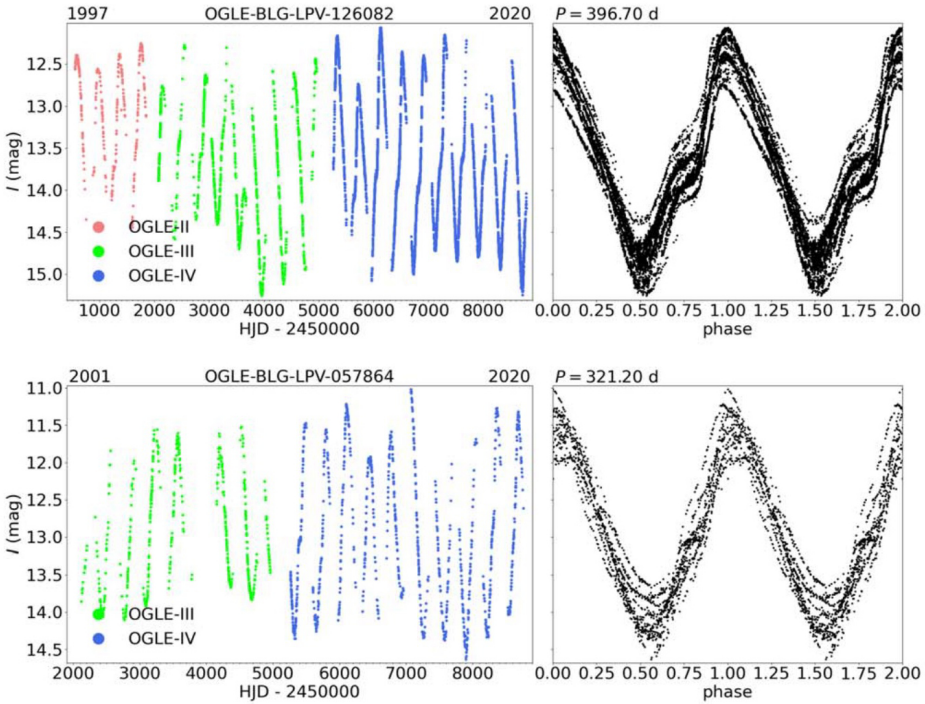
RR Lyr

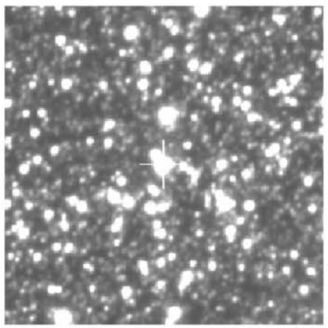

magnitude
phase
P = 0.3898343 d
P = 0.4760330 d
P = 0.5415712 d
P = 0.5978500 d

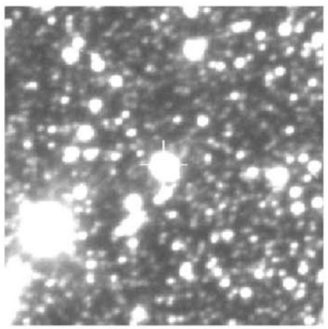
Long Period Variables



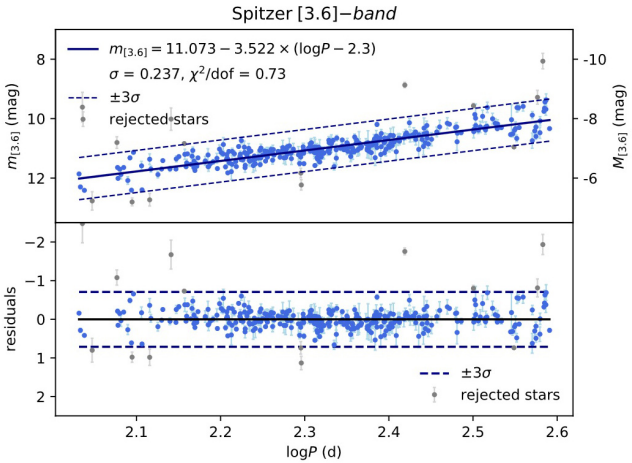
Long Period Variables - Miras

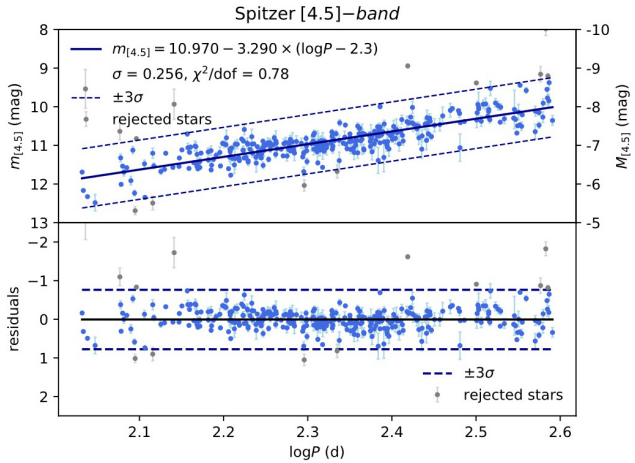




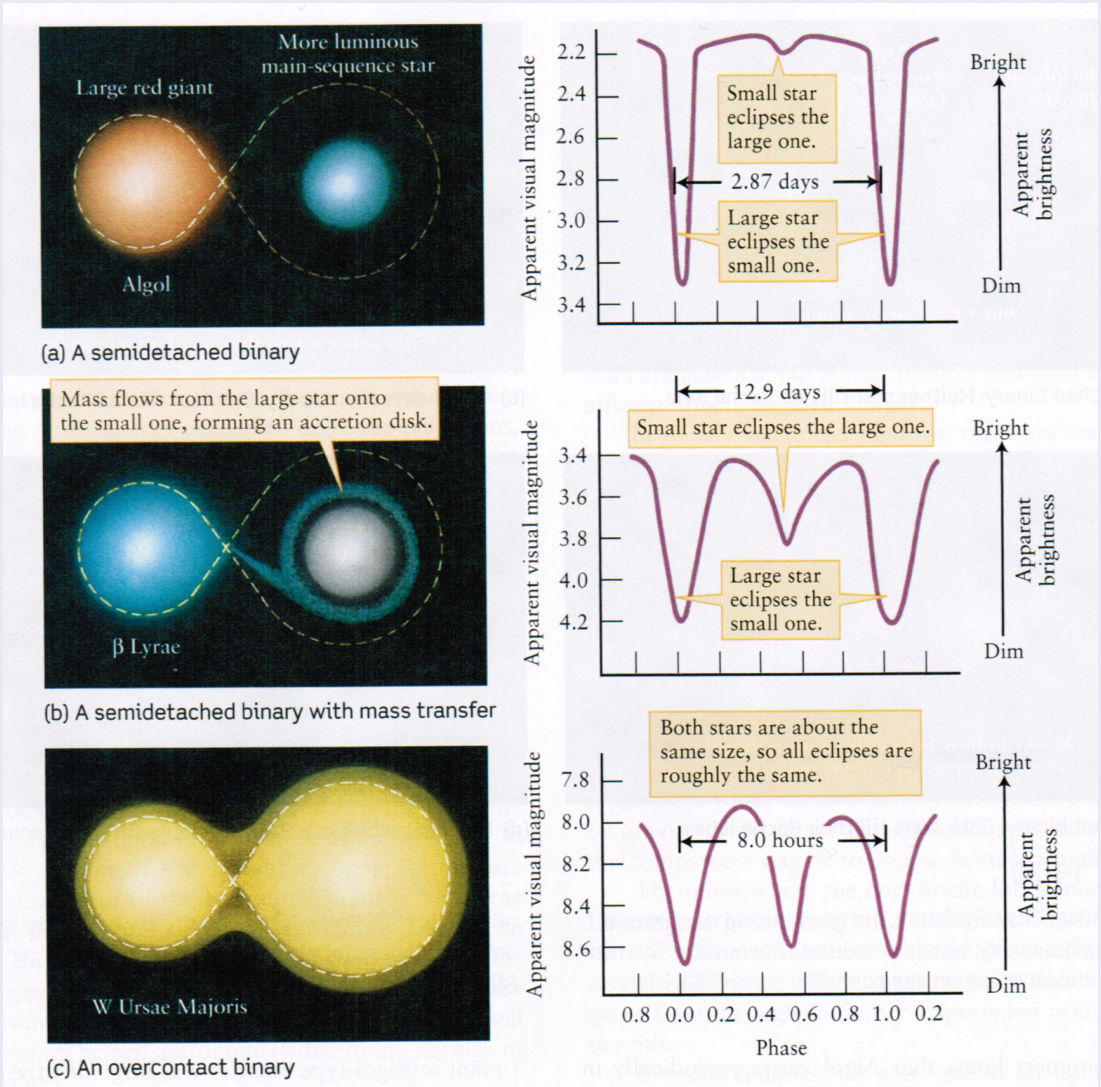


Long Period Variables - Miras

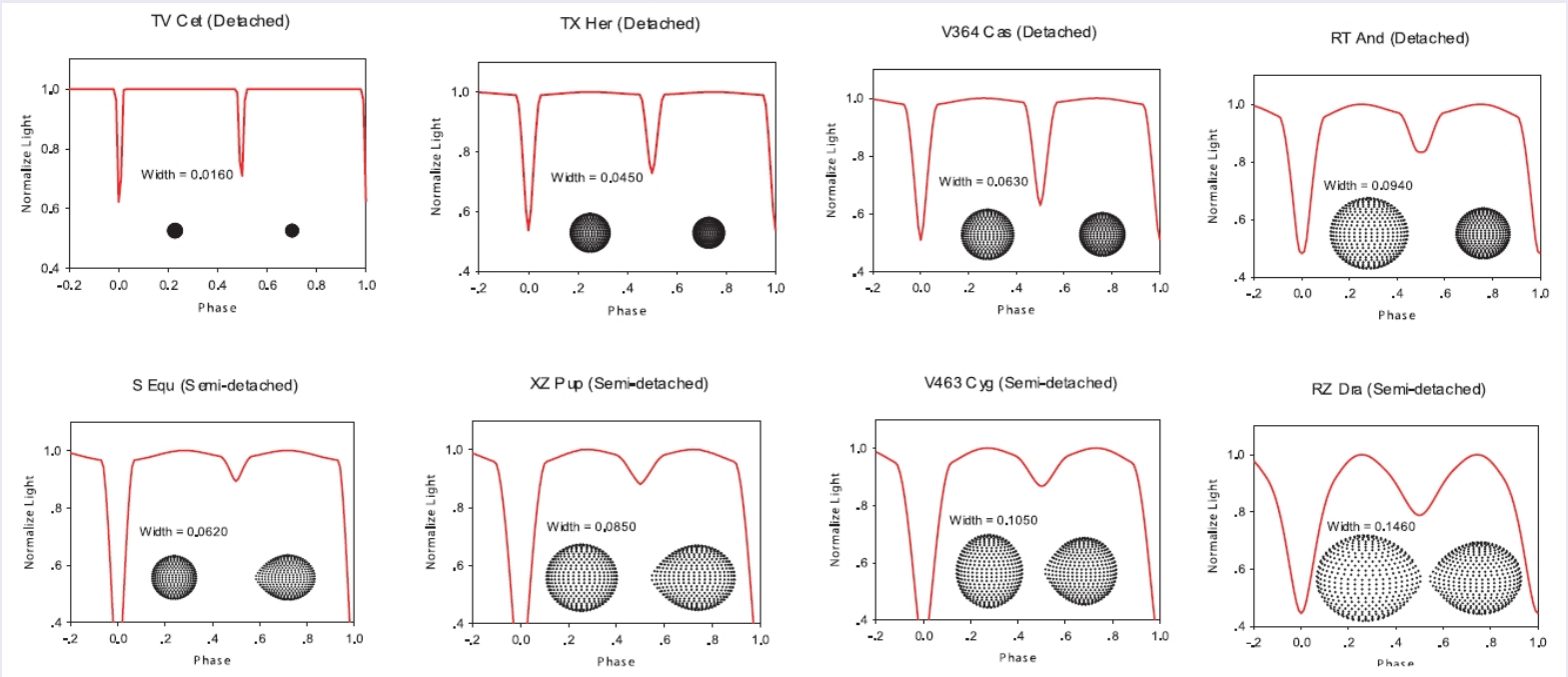




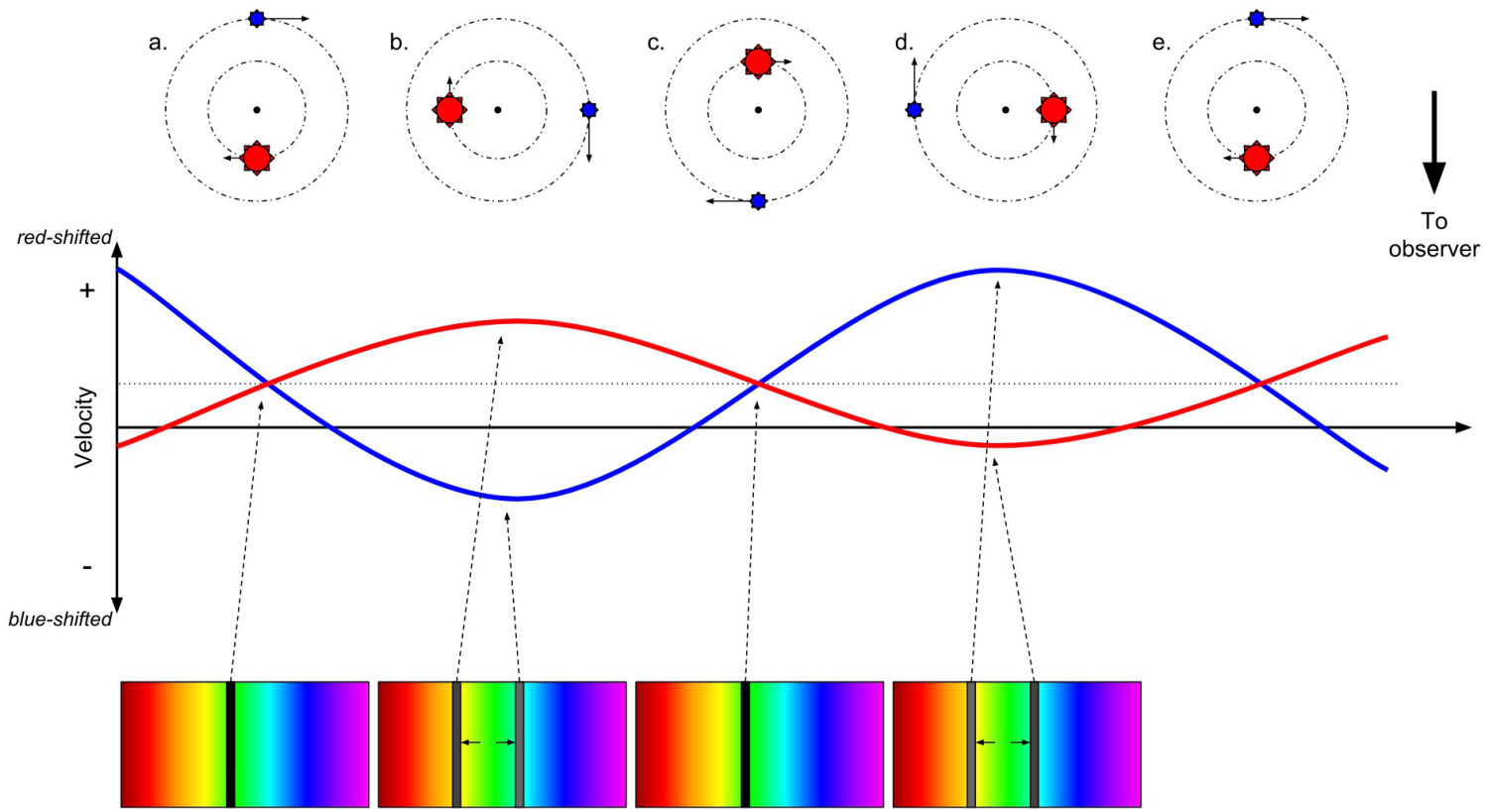
Gwiazdy zaćmieniowe



Gwiazdy zaćmieniowe



Gwiazdy zaćmieniowe



How spectral lines from each star appear to shift due to the relative motion of each star in the binary pair.

Gwiazdy zaćmieniowe

Mamy dwie gwiazdy wzajemnie okrążające wspólny środek masy.

$$L_1 = 4\pi R_1^2 \sigma T_1^4 \quad (3)$$
$$L_2 = 4\pi R_2^2 \sigma T_2^4 \quad (4)$$
$$S_X = \sigma T_X^4 \quad (5)$$

S_X - surface brightness

Zależność jasność powierzchniowa-kolor

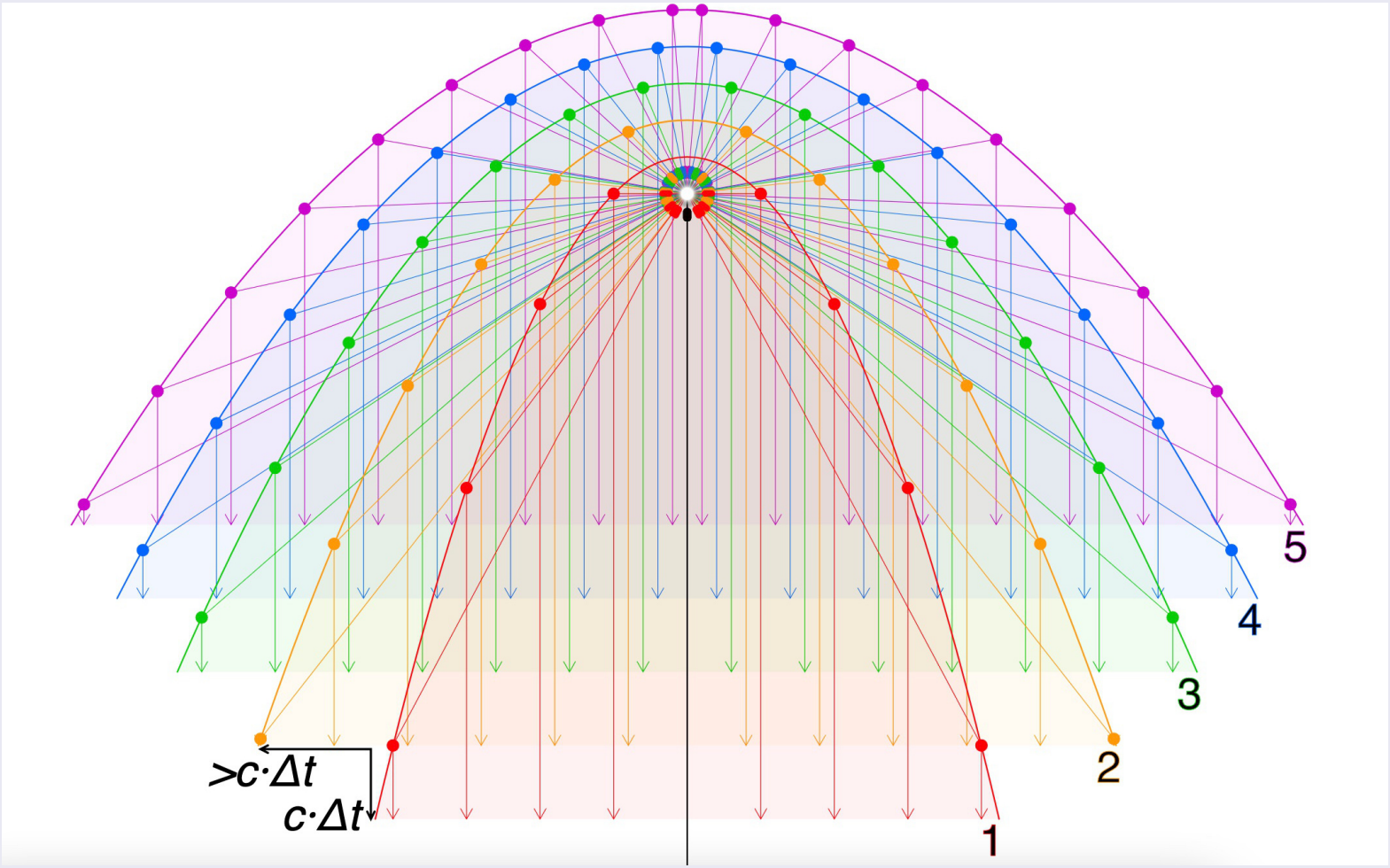
$$S_V = \alpha \left[(V-K)_0 - 2.405 \right] + \beta \quad (6)$$

$$(\alpha, \beta) = (1.330, 5.869) \text{ – Pietrzyński i in. (2019)}$$

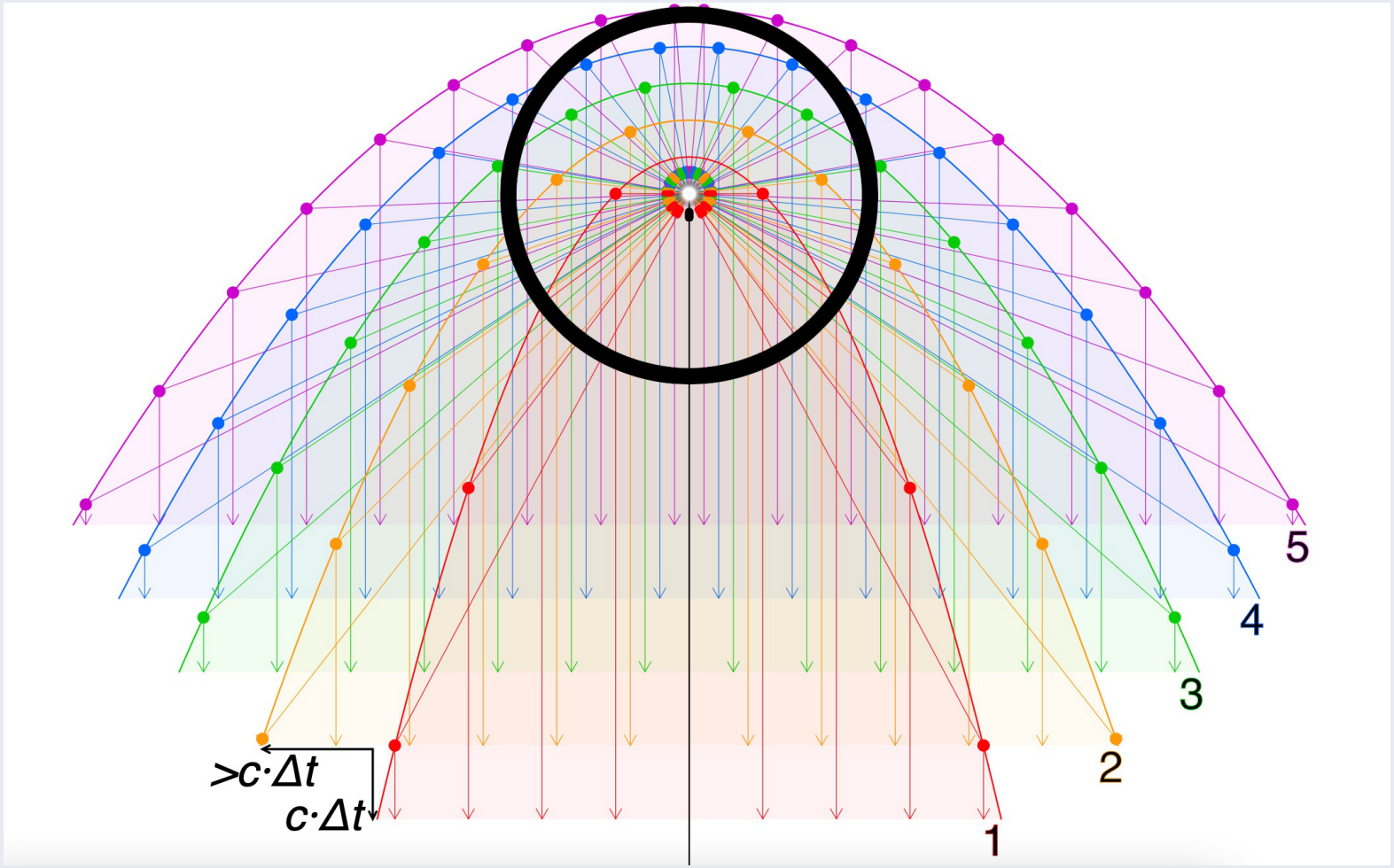
Gwiazdy zaćmieniowe

Potrzenujemy jeszcze promienie gwoazd R_1 i R_2. Wyliczamy je z długości trwania zaćmień, rozmiarów orbity i prędkości orbitalnych gwiazd.

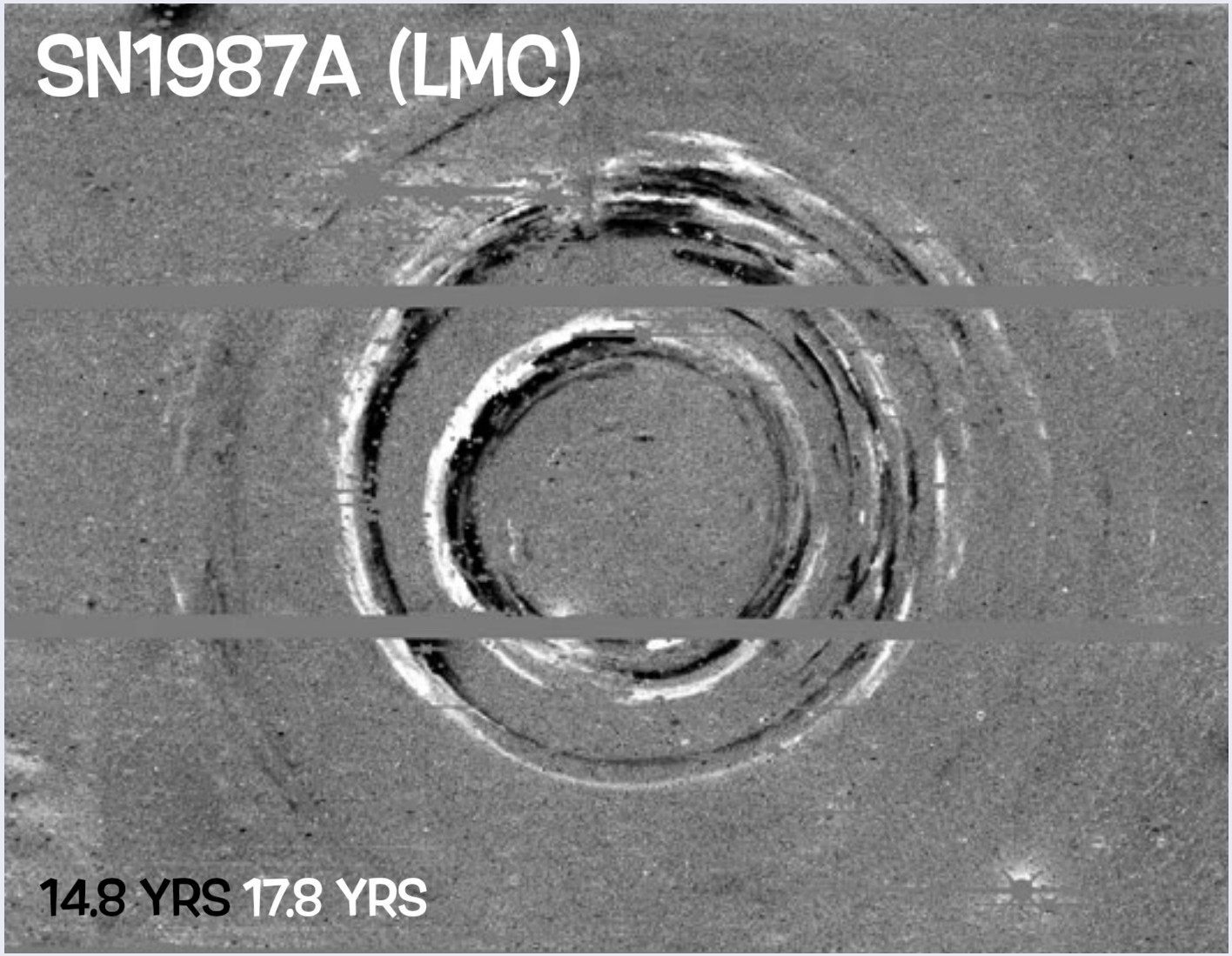
Echo świetlne



Echo świetlne



Echo świetlne



Relacja Faber-Jackson - galaktyki eliptyczne

$$L_B \propto \sigma^{\gamma} \qquad \gamma = 4 \pm 1$$

L_B – jasność
σ – dyspersja prędkości
Dokładność: Rozrzut 40%.

Relacja Dressler i in. (1987)

$$D_n \propto \sigma^{\frac{4}{3}}$$

D_n – średnica apertury dla średniej jasności powierzchniowej $\Sigma_e = 20.75$ mag/arcsec^2.

Płaszczyzna fundamentalna (fundamental plane = FP)

$$L \propto \sigma^{3.45} \langle \mathrm{SB} \rangle^{-0.86}$$

SB – surface brightness (jasność powierzchniowa)

FP wersja kanoniczna (Djorgovski & Davis 1987)

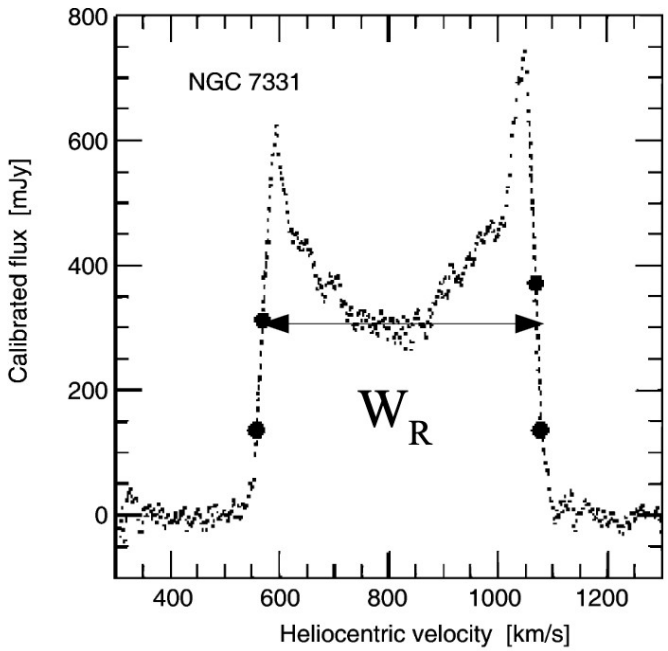
$$\log(r_e) = 1.39(\log(\sigma) + 0.26\langle\mu\rangle) - 6.71$$

μ – jasność powierzchniowa

lub

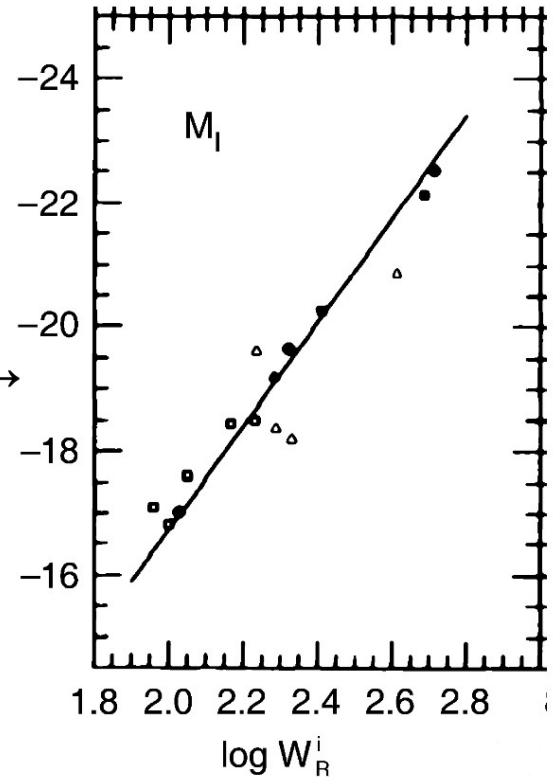
$$R \propto \sigma^{1.39} \langle \mathrm{SB} \rangle^{-0.90}$$

Relacja Tully-Fisher - galaktyki spiralne



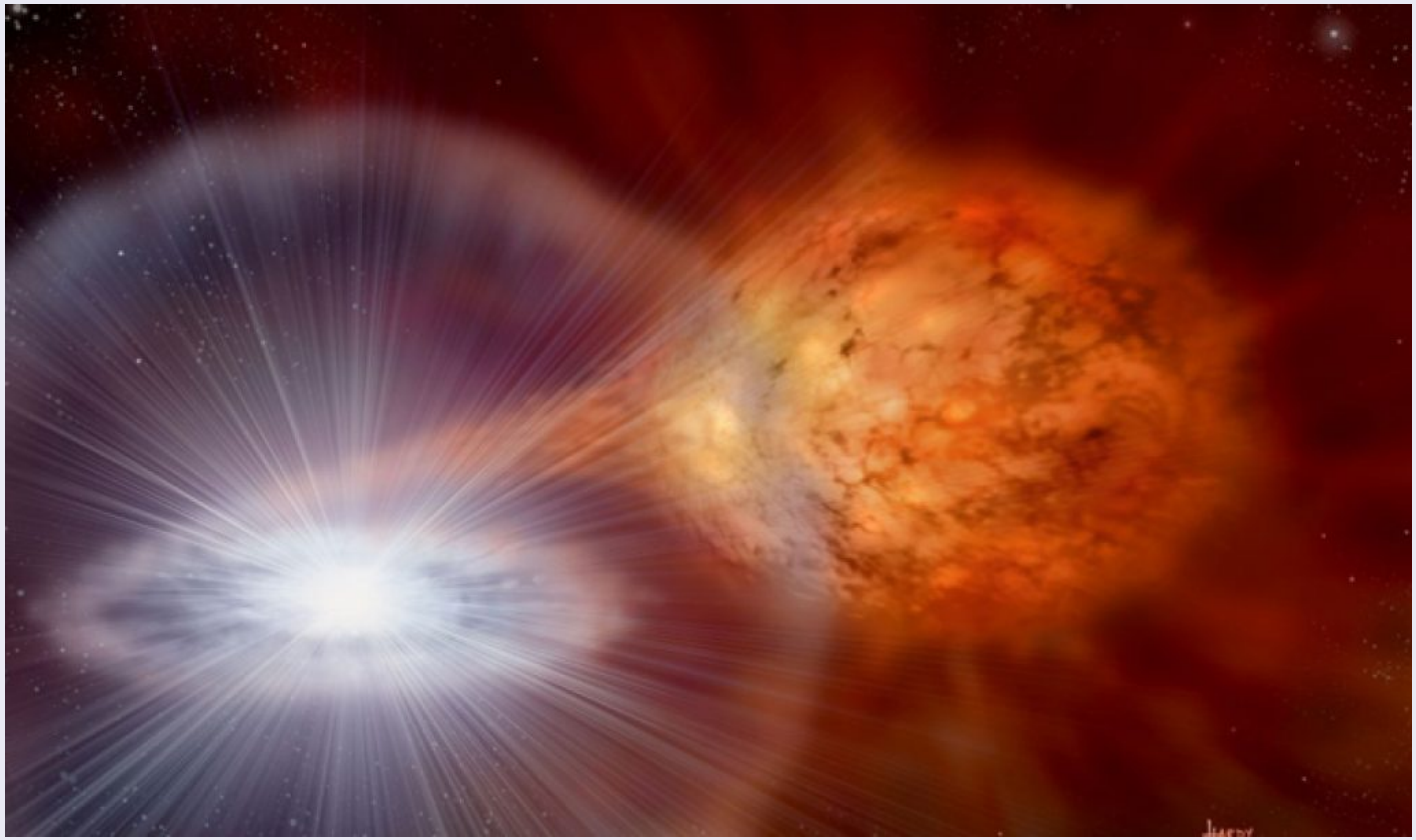
← velocity profile of gas

Luminosity vs velocity width →



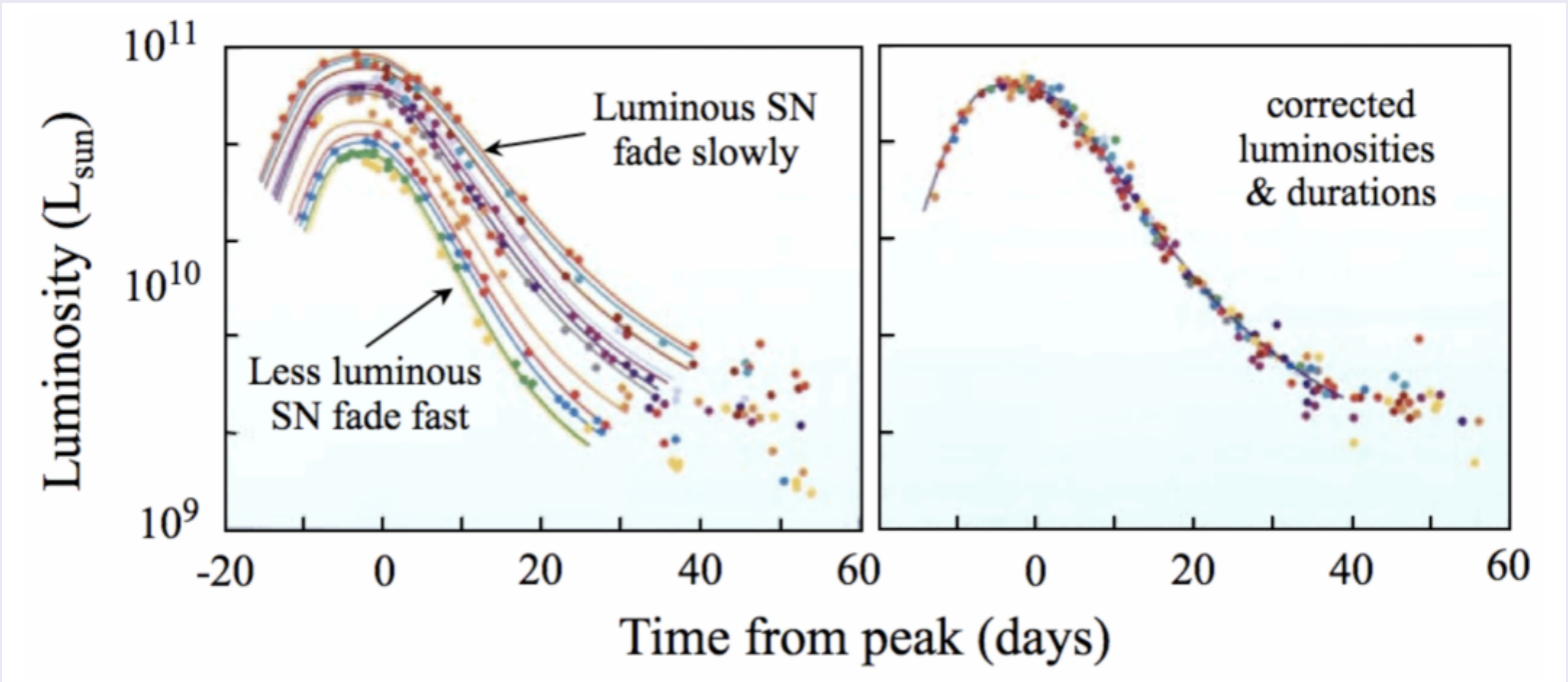
$$L \propto W^4$$

Supernovae Ia

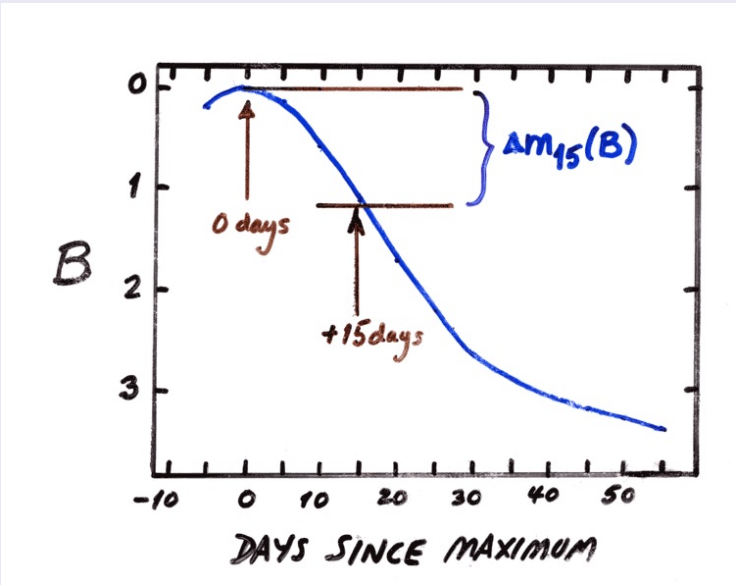


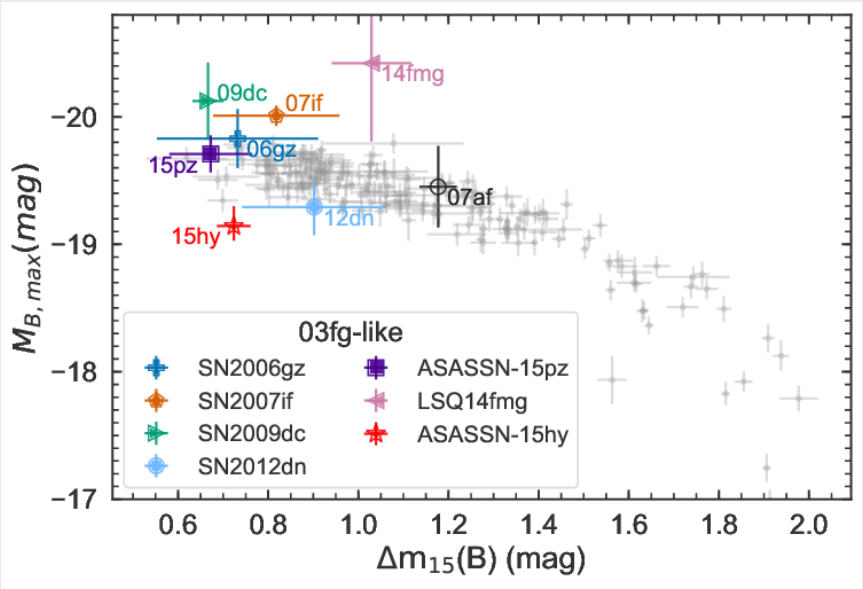
Distances to at least nine billion light-years for supernovae Ia.

Supernovae Ia



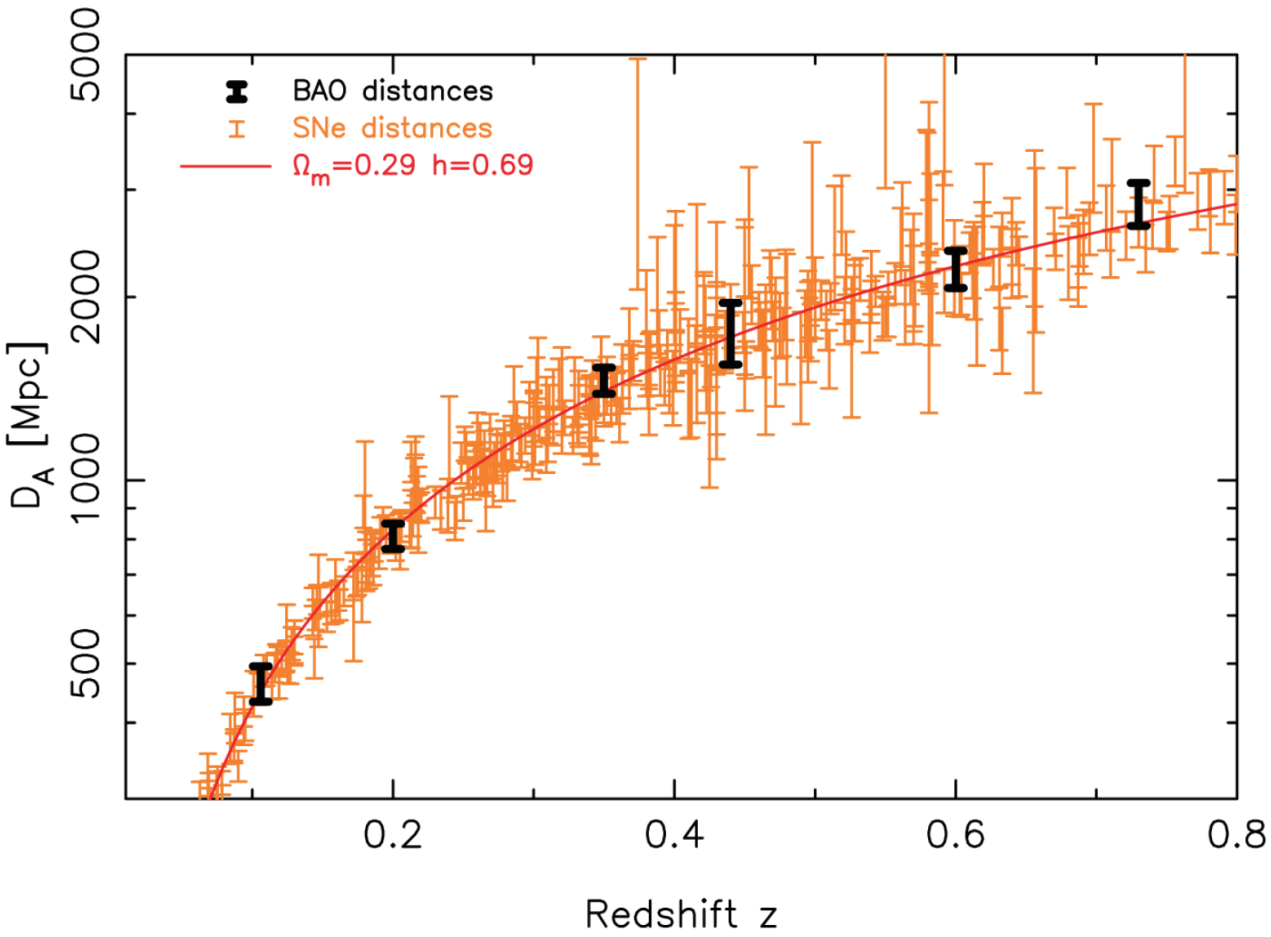
Supernovae Ia





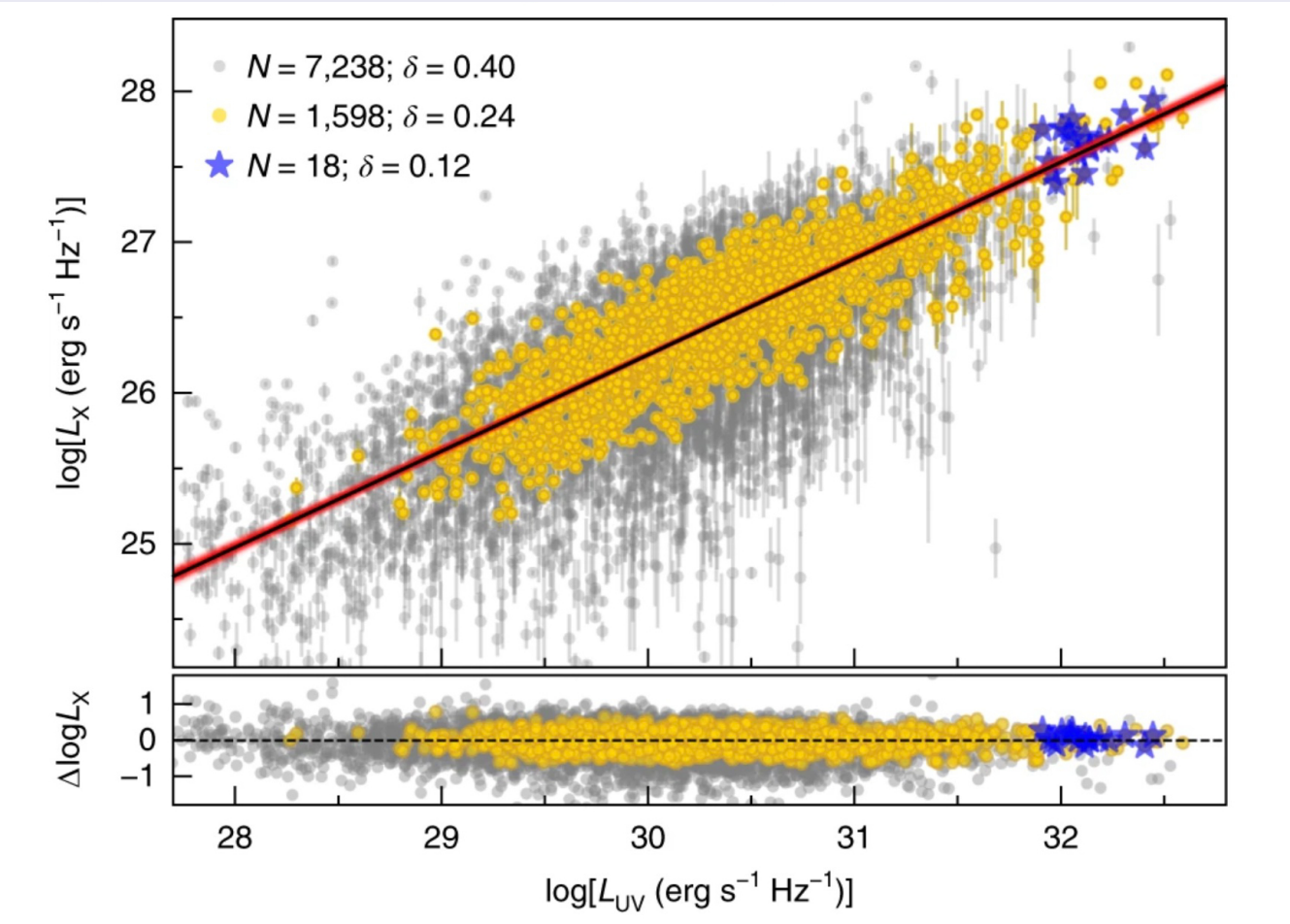
Supernovae Ia - Mark Phillips

SNe i BAO na Diagramie Hubble'a



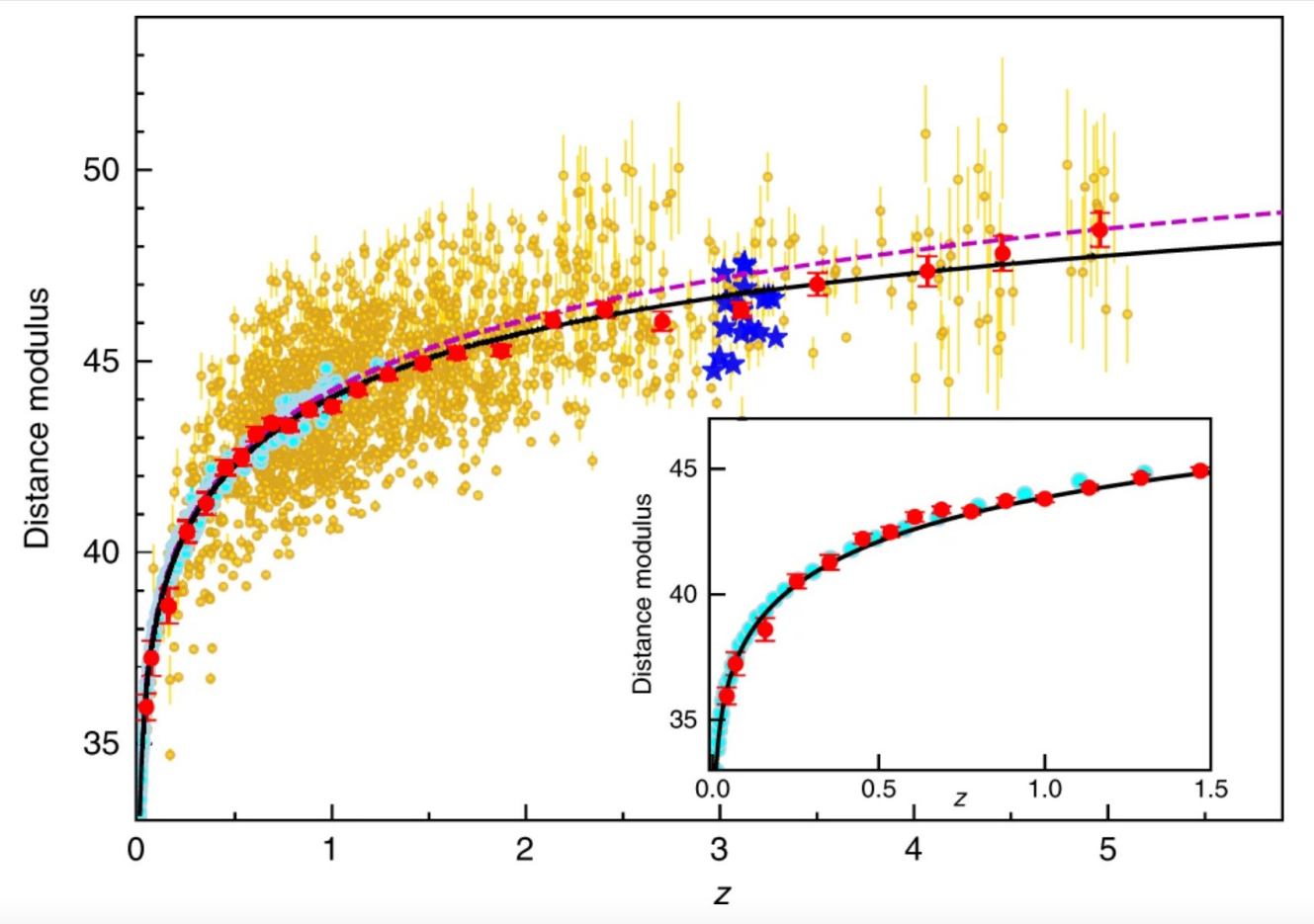
WiggleZ – Blake et al. (2011), MNRAS, 418, 1707

Active Galactic Nuclei (AGN)



Risaliti & Lusso, 2019, Nature Astron., 272–277

Active Galactic Nuclei (AGN)



Risaliti & Lusso, 2019, Nature Astron., 272–277