THE STARS

- **APPARENT BRIGHTNESS** energy per unit area per second arriving at observer (B_*)

COLOUR gross distribution of light over different wavelengths — indicates <u>TEMPERATURE</u>

SPECTRUM detailed distribution of light over different wavelengths — indicates <u>CHEMICAL COMPOSITION</u> and <u>TEMPERATURE</u>

- For <u>nearby</u> stars:-

PARALLAX provides estimate of <u>DISTANCE</u> (d_*)

DISTANCE (d_*) +
APPARENT BRIGHTNESS (B_*)
→ <u>LUMINOSITY</u> (L_*)
energy per second emitted <u>by the star</u>.

$$L_* = B_* \times 4\pi d_*^2$$

For components of <u>double stars</u> at known distances:-

SIZE OF MUTUAL ORBIT
TIME TO COMPLETE ORBIT
give ACCELERATIONS OF COMPONENTS AROUND EACH OTHER

- GRAVITY THEORY + ACCELERATIONS → STAR <u>MASSES</u>

Stellar Properties

LUMINOSITY RELATIVE TO SUN (⊙)	$L_* = 10^{-6} L_\odot$ TO $10^{5} L_\odot$
MASS RELATIVE TO SUN	$M_* = 0.05 M_\odot$ TO $100 M_\odot$
SURFACE TEMPERATURES	2,000°K TO 60,000°K (Sun 5800°K)
CONTENT OF ELEMENTS HEAVIER THAN HELIUM	0.01% to 5% (Sun about 2%)

THE SUN IS AN "AVERAGE" STAR IN ALL THESE PROPERTIES

THE MASS-LUMINOSITY LAW

For stars that are members of binary systems at known distances, we can measure <u>luminosity</u> L_* and <u>mass</u> M_* independently of one another.

Find <u>by experiment</u> that $L_* \propto M_*^3$

EXPLANATION

Large M_* → great gravitational self-squeezing
→ high <u>central</u> temperature in star
→ rapid rate of nuclear fusion reactions
→ high rate of energy release (L_*)

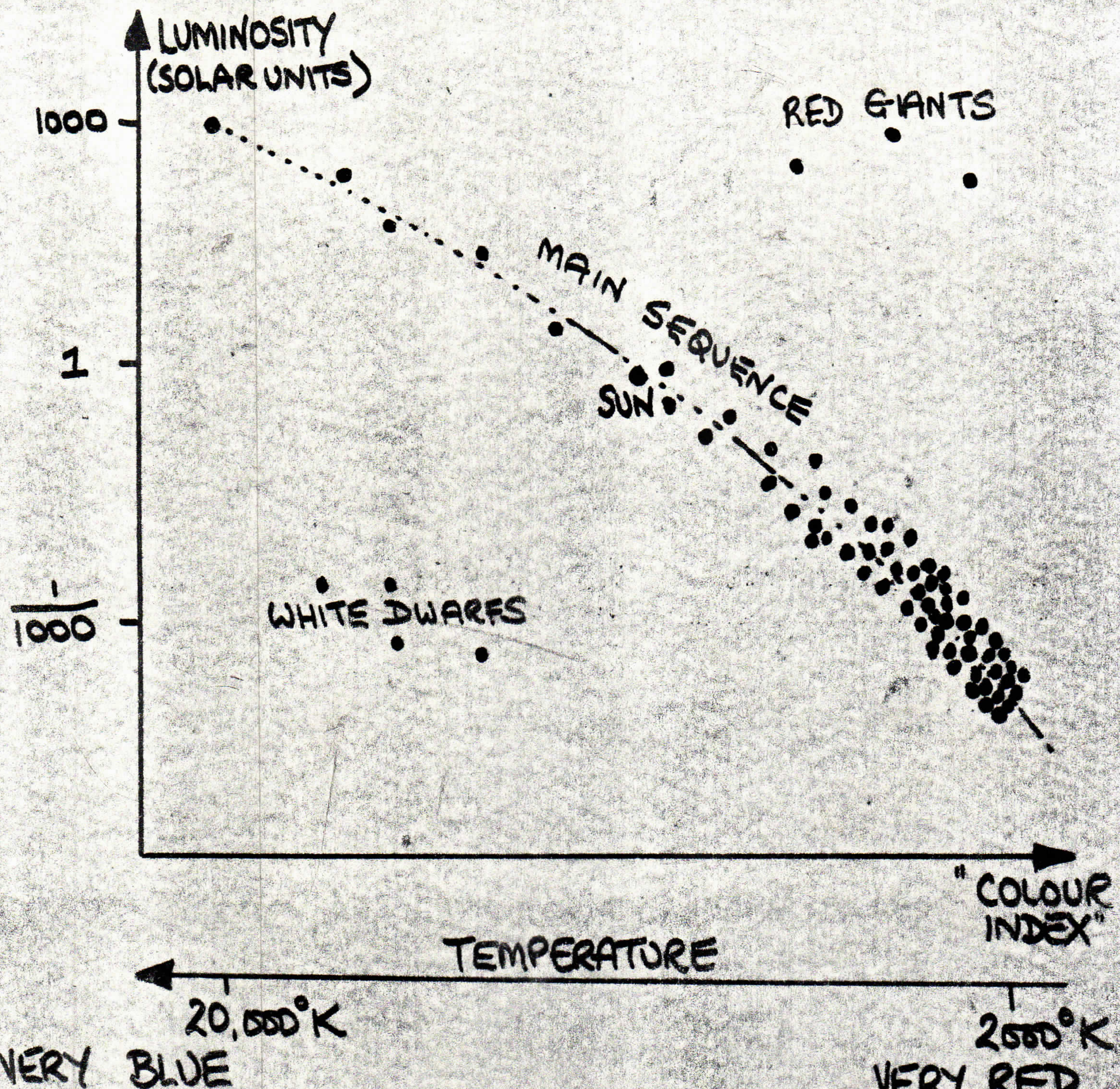
CONSEQUENCE FOR STELLAR "LIFETIME"

$$\text{Time to "exhaust" nuclear energy supply} \propto \frac{\text{Total energy store } (M_*)}{\text{Rate of using it } (L_*)}$$

$$\propto \frac{M_*}{M_*^3} \quad \text{or} \quad \frac{1}{M_*^2}$$

i.e. THE MOST MASSIVE STARS HAVE THE SHORTEST "LIFE EXPECTANCIES" FOR FUSION-SUPPORTED EQUILIBRIUM

The HERTZSPRUNG-RUSSELL Diagram



Schematic H-R Diagram for Stars (•) Near the Sun (•)

INTERPRETING THE H-R DIAGRAM

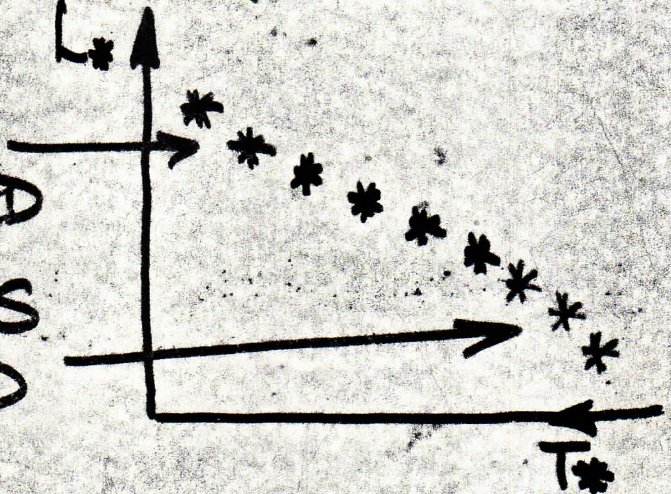
1. The Main Sequence

The same 90% of stars that obey the Mass-Luminosity Law occupy the Main Sequence in the H-R Diagram.

i.e. the MAIN SEQUENCE is a "map" of $L_* - T_*$ conditions for stars of different masses when in equilibrium.

MASSIVE, LUMINOUS. HOT, BLUE, SHORT-LIVED

UNMASSIVE, UNLUMINOUS COOL, RED, LONG-LIVED



If stars are supported by nuclear fusion energy release, they must EVOLVE as heavy elements accumulate. Internal chemistry changes from light to heavy elements.

Most common condition in which to find star will be condition in which each individual spends longest. This will be condition in which MOST EFFICIENT nuclear fuel (released energy per unit mass) is being fused, i.e. HYDROGEN-FUSING stage.

Interpreting Stellar Evolution.

1. Young star clusters.

Expected main-sequence (hydrogen-fusing) "lifetime" of star of 1 solar mass ~ 10 billion yrs.
10 solar masses ~ 100 million yrs
100 solar masses ~ 1 million yrs.

Therefore: HOT BLUE MAIN-SEQUENCE STARS (MANY SOLAR MASSES) OCCUR WHERE STAR FORMATION HAS HAPPENED "RECENTLY".

Observe such regions in Milky Way, find:
- GAS CLOUDS (excited by stellar ultraviolet)
- DUST (dark matter)
- PROTOSTARS (e.g. Herbig-Haro objects)

High abundances of heavy elements

2. Old star clusters

Absence of hot blue main-sequence stars in a cluster → older stellar population.

Find such populations in GLOBULAR star clusters

Lack of hot blue stars.
Many RED GIANTS

Low abundances of heavy elements

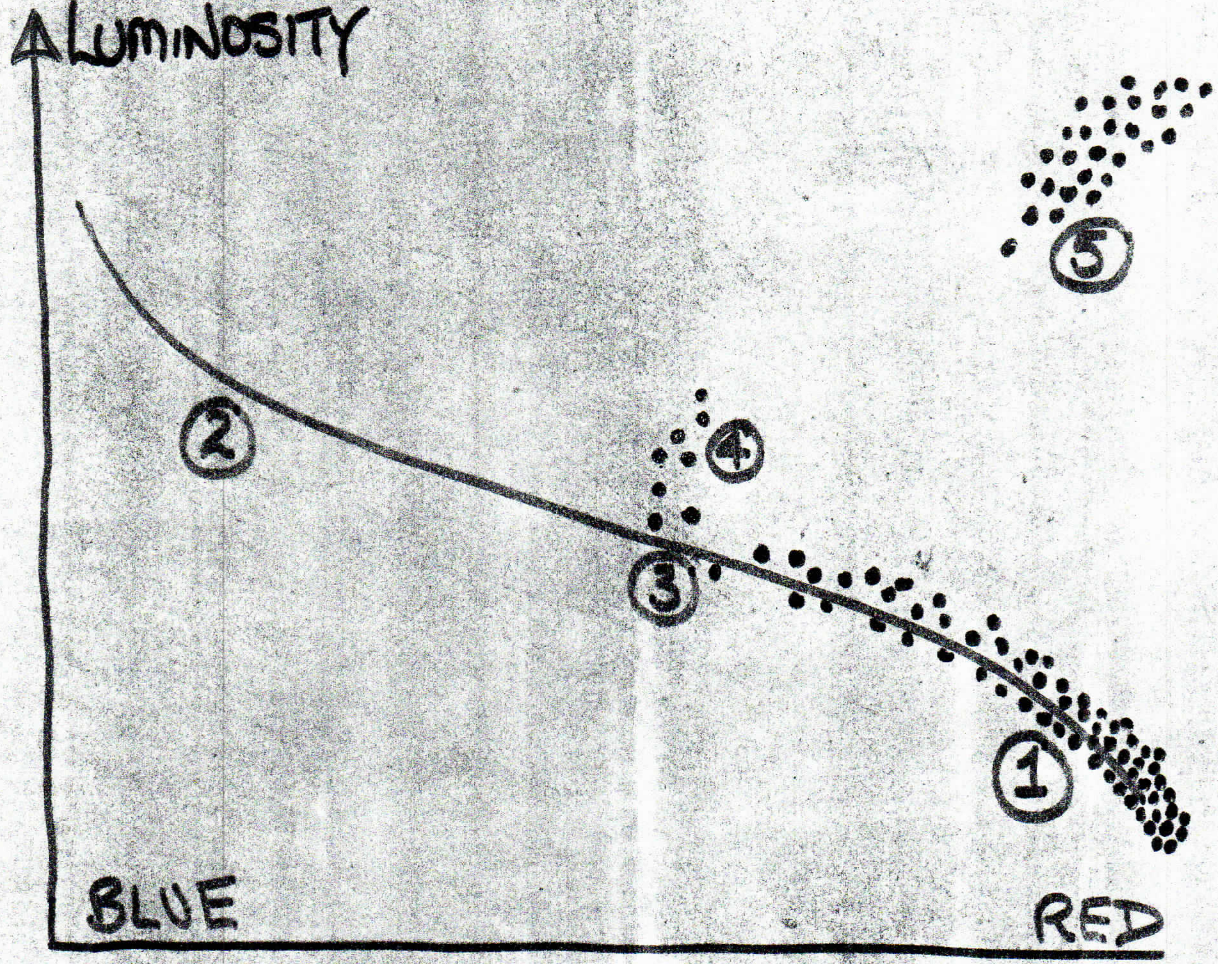
Therefore OBSERVATION SUGGESTS THAT RED GIANTS ARE "OLD AGE" STATE OF STARS ONCE ON MAIN SEQUENCE.

Stellar Sizes and Densities

STAR	DIAMETER (SUN = 1)	MASS (SUN = 1)	DENSITY (SUN = 1)
α Vir	8	13	0.05
α Lyr (Vega)	2.4	3	0.22
α Cen A	1.0	1.1	1.1
61 Cyg A	0.7	0.58	1.7
Barnard's *	0.15	0.18	53
α Aur	17	2.5	0.0005
α Tau	85	3.7	0.000006
α Ori	580	20	0.0000001
Sirius B	0.022	0.99	90,000
40 Eri B	0.018	0.41	70,000
Van Maanen's *	0.007	0.14	400,000

First Group – MAIN-SEQUENCE stars
Second – RED GIANTS
Third – WHITE DWARFS

Hertzsprung-Russell Diagram of Old Star Cluster (Schematic)



POSITION OF THE MAIN SEQUENCE

① Low-mass stars still on main sequence
② High-mass stars have left main sequence
③ Stars about to leave main sequence — their mass is age indicator for cluster
④ Stars leaving main sequence — luminosity is increasing
⑤ Red giants. Gap ④ → ⑤ means <u>RAPID</u> evolution