

OUR GALAXY

• SPIRAL GALAXY [NORMAL!]

~ 100 BILLION STARS

~ DISK $\approx$ 30,000 pc DIAMETER , 500 pc THICK
AT SUN

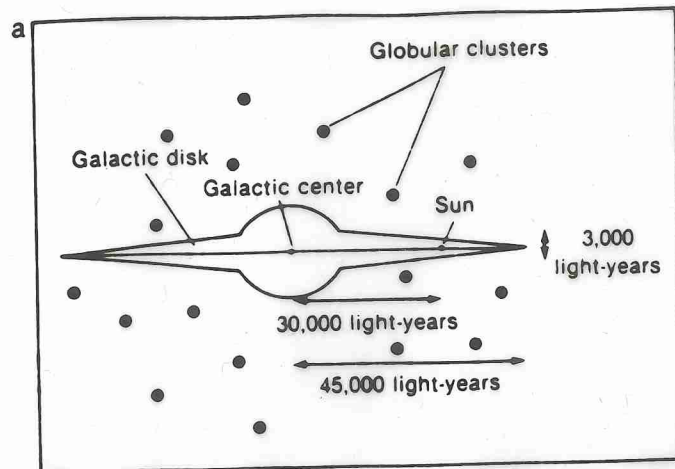
~ 'ALL' STARS + GAS IN DISK

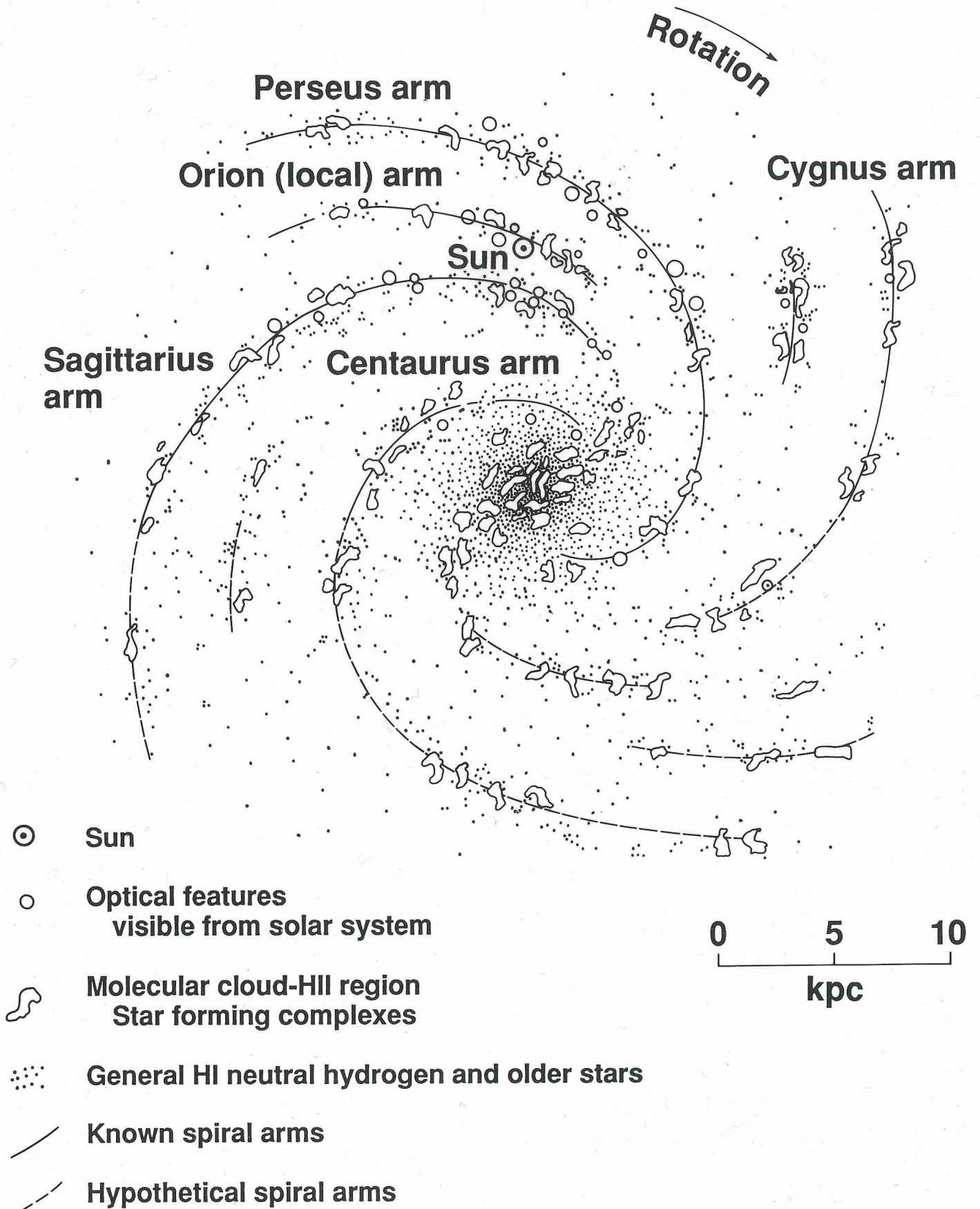
- DISK

- HALO + NUCLEUS

- BULGE

- 'CORONA'





Milky Way galaxy map

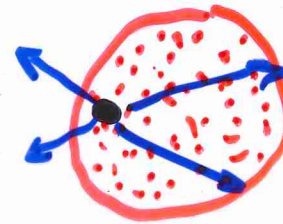
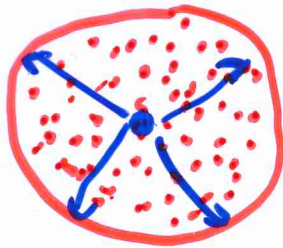
OUR LOCATION IN GALAXY?

- **MILKY WAY** : RIBBON OF STARS + NEBULAE AROUND SKY (N & S)

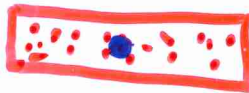
→ IN A FLAT THIN DISK

- **STAR COUNTS** : TO DETERMINE OUR LOCATION

TOP



SIDE



SAME # STARS
IN ALL
DIRECTIONS

← FEW
STARS
LOTS →

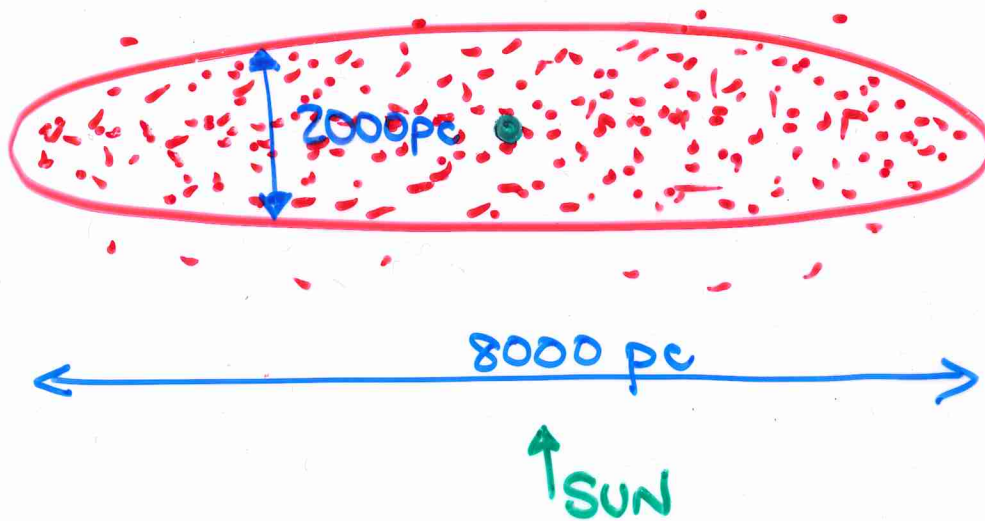
PIONEERS

- SIR WILLIAM HERSCHEL (1785)
- JACOBUS C. KAPTEYN (1922)

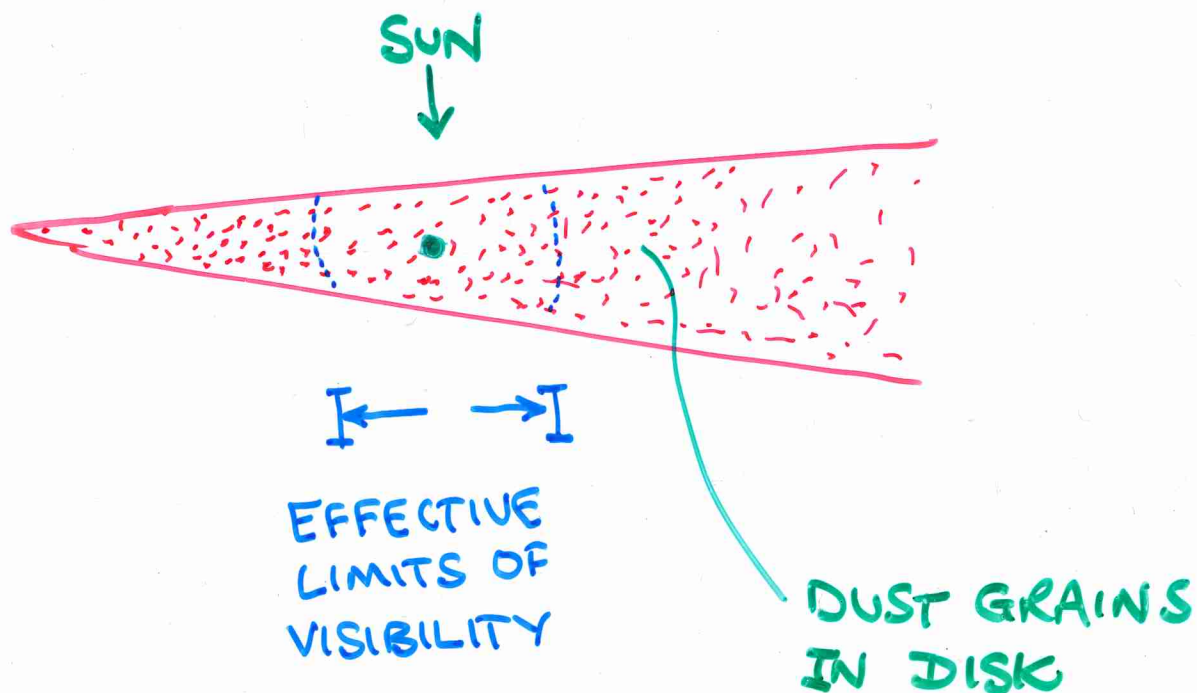
SUN IN CENTRE
OF MILKY WAY

BUT . . .

KAPTEYN UNIVERSE



RUBBISH!



- ASSUME GC DISTRIBUTION IS
CENTERED ON CENTER OF GALAXY

GCs ORBIT CENTER OF MASS
UNDER FORCE OF GRAVITATION

- SIGHT LINE TO MOST GCs DOES NOT
TRAVERSE MUCH OF DISK $\therefore$ DUST IN DISK
OF MINIMAL IMPORTANCE

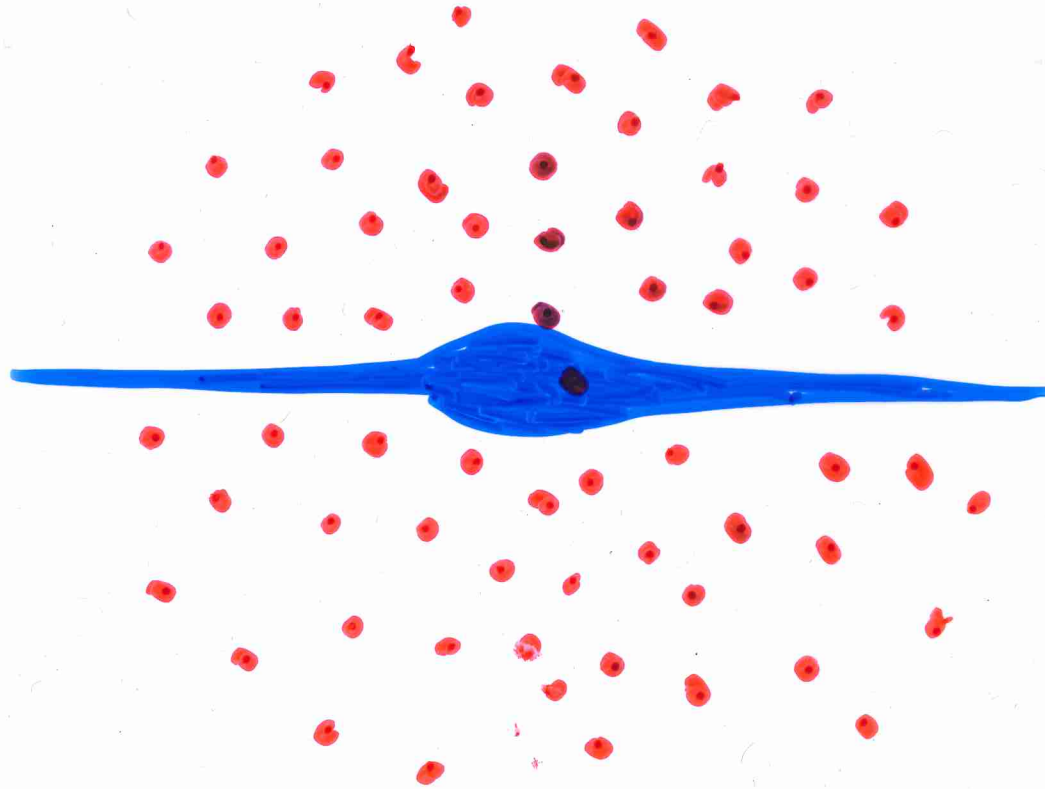
VITAL CLUE

MAJORITY OF GCs SEEN
TOWARD SAGITTARIUS

$\therefore$ WE ARE WAY OFF-CENTER

HARLOW SHAPLEY

- USED GLOBULAR CLUSTERS
- IN GALACTIC HALO



- = GLOBULAR CLUSTER { 100,000⁺ OLD METAL-POOR $\times$ s
~ few hundred GCs

- DISTANCES TO GC

SHAPLEY USED - CEPHEID VARIABLE STARS
FOR NEARER GC

- CLUSTER DIAMETERS
FOR DISTANT GC

GOOFED!

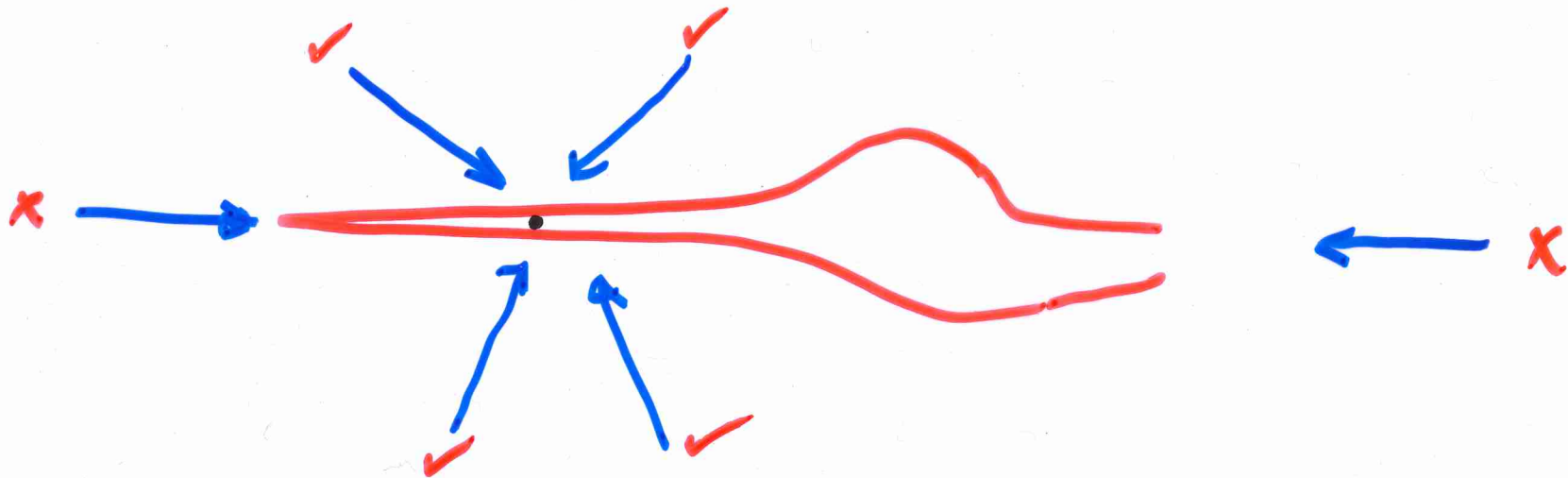
- SUN IS $\sim 10,000$ pc OUT FROM CENTER

INTERSTELLAR DUST

- ZONE OF AVOIDANCE
- DARK CLOUDS
- REDDENING OF STARLIGHT
- REFLECTION NEBULAE

ZONE OF AVOIDANCE

- DEFICIT OF EXTERNAL GALAXIES (AND GCs) ALONG THE MILKY WAY



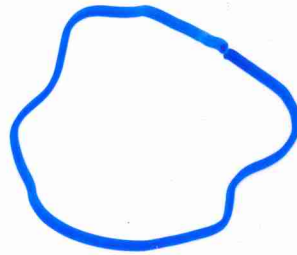
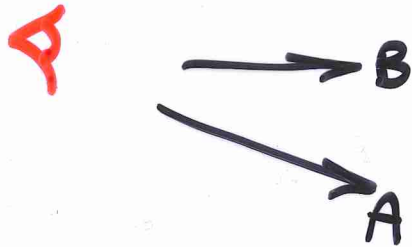
✓ GALAXIES VISIBLE

X GALAXIES NOT EASILY SEEN

X • GALAXIES IN ALL DIRECTIONS

BUT LOCAL DUST IN MILKY WAY
DIMS GALAXIES IN THESE DIRECTIONS

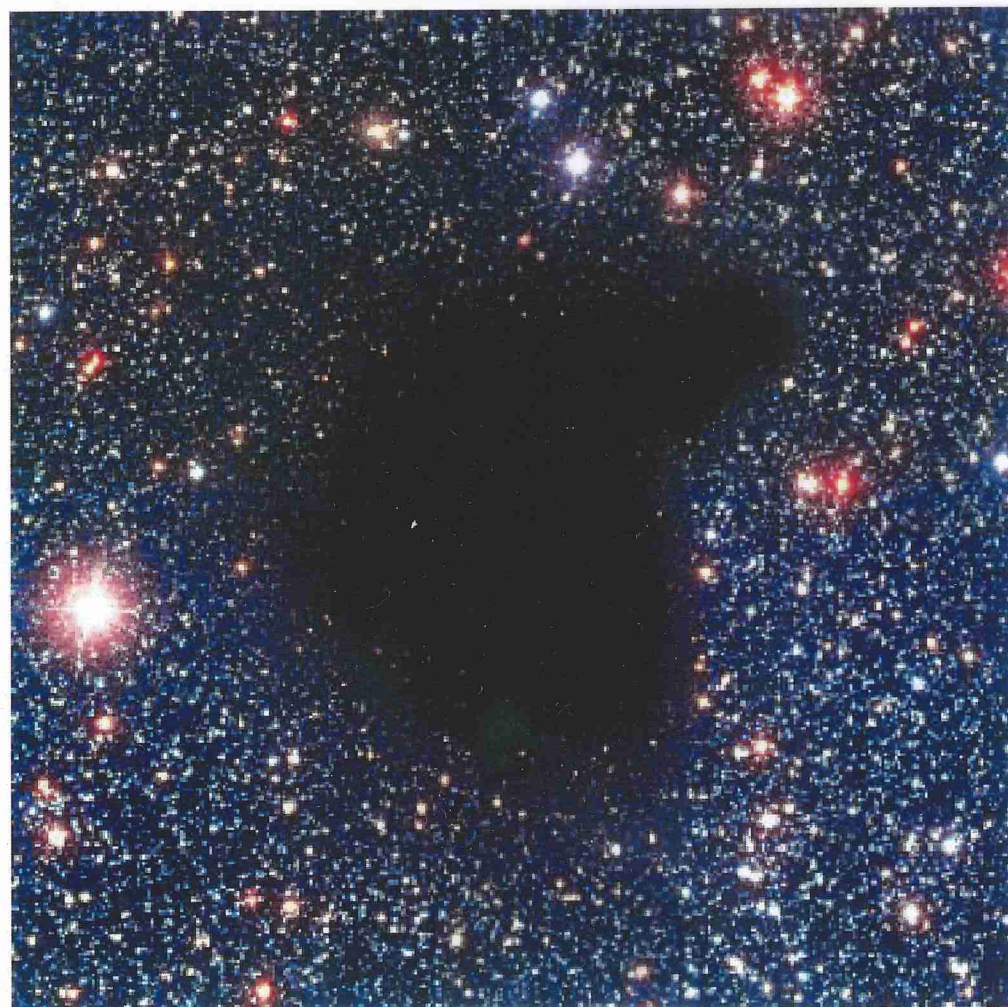
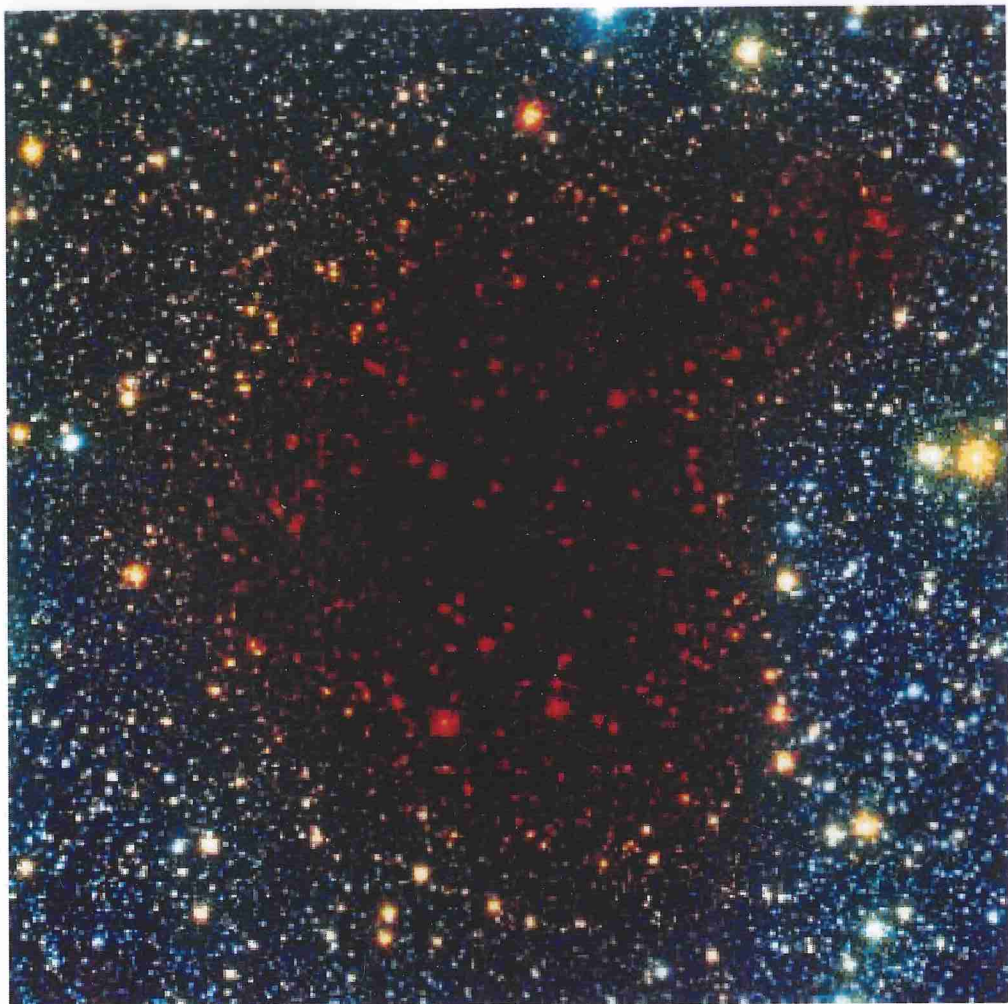
DARK CLOUDS



Ⓐ VIEW OF STARS - DIRECT

Ⓑ VIEW OF STARS - THRU' CLOUD

STARS ARE DIMMED & REDDENED



REDDENING OF STARLIGHT

- OBJECTS OF SIZE $\gg$ WAVELENGTH OF LIGHT
SCATTER ALL WAVELENGTHS ABOUT EQUALLY

OBJECTS ARE DIMMED

- OBJECTS OF SIZE $<$ WAVELENGTH OF LIGHT
SCATTER SHORTEST WAVELENGTHS MORE
EFFICIENTLY THAN LONG WAVELENGTHS

DUST | AEROSOLS | MOLECULES IN OUR ATMOSPHERE

→ BLUE SKY

→ RED SUN AT SUNSET

- WHY IS CLOUDY SKY WHITE?

- STARS SEEN THROUGH DUST
ARE REDDENED

- DIMMED MORE IN BLUE THAN
RED LIGHT

AND SPECTRAL TYPE AND COLOR ARE
'INCONSISTENT'.

e.g.

B-type STAR can appear RED
NOT BLUE

DUST ABSORPTION

- CONCENTRATED TO DISK
- VARIABLE - ADJACENT SIGHTLINES DIFFER
- AVERAGE : 1000 pc DIMS LIGHT BY $\sim 50\%$
AT VISIBLE WAVELENGTHS

MORE IN UV

LESS IN IR

NONE IN RADIO

ORIGIN OF DUST GRAINS?

INTERSTELLAR GAS CLOUDS ?

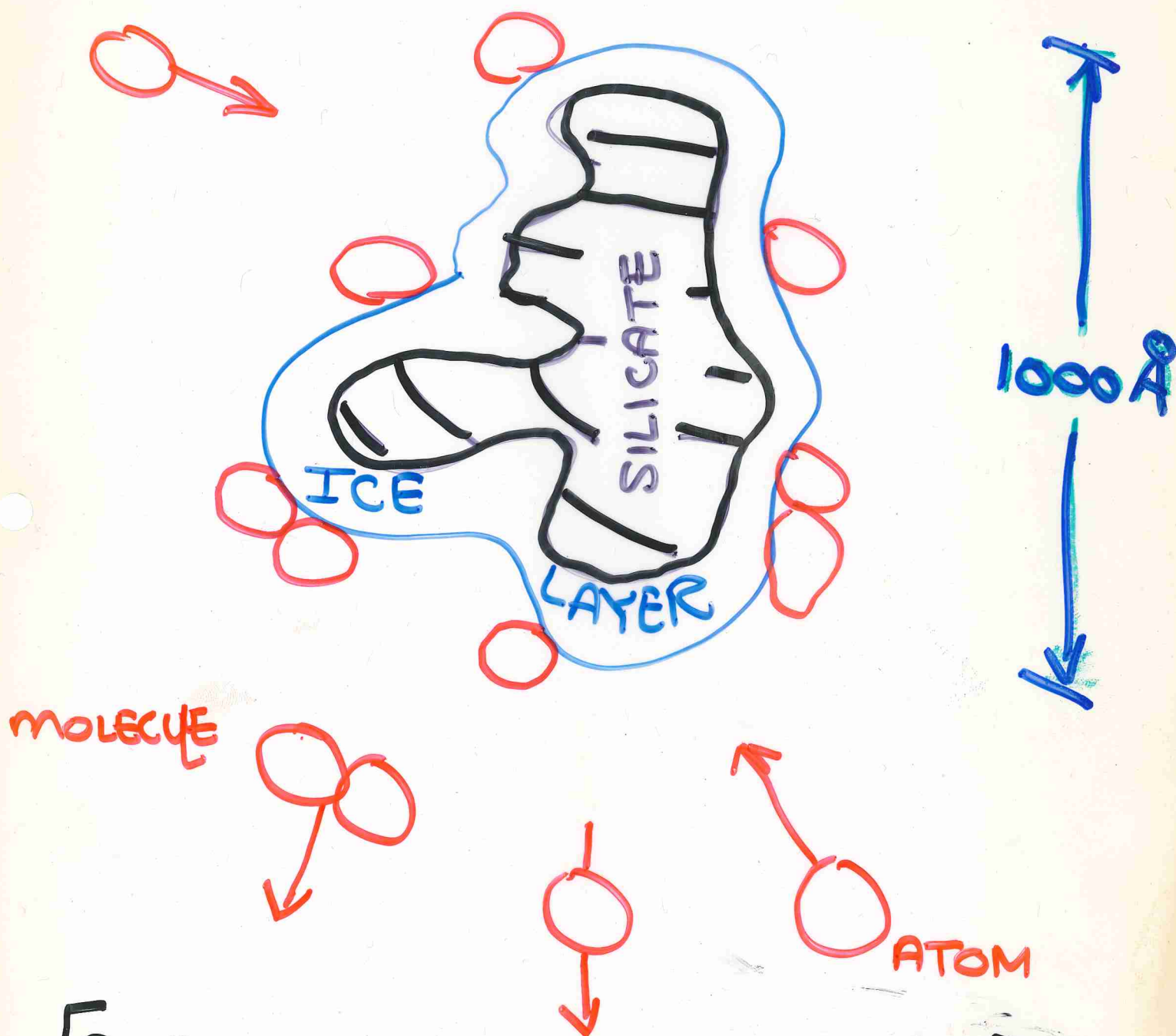
- DENSITIES TOO LOW*
- ORIGIN OF ICE LAYERS ?

RED GIANTS / SUPER GIANTS IN NEAR TERMINAL PHASES

- DUST IS OBSERVED IN
WINDS FROM THESE STARS
- "PREDICT" GRAINS CAN FORM
- OBSERVE SILICATES AROUND
OXYGEN-RICH STARS &
GRAPHITE AROUND CARBON-RICH
STARS

* SOME DESTRUCTION
PARTIAL RECONSTRUCTION
IN COLD CLOUDS

A DUST GRAIN



[CORE : SILICATE OR GRAPHITE]

$$1000 \text{ \AA} = 10^{-5} \text{ cm}$$

EVIDENCE FOR INTERSTELLAR GAS

- EMISSION NEBULAE / H II REGIONS
- INTERSTELLAR ABSORPTION LINES
- 21 CM LINE OF NEUTRAL HYDROGEN
- MOLECULAR MILLIMETER / RADIO LINES

INTERSTELLAR SPACE

MOLECULAR CLOUDS

COLD

20-50K

DENSE

$10^3 - 10^5 \text{ cm}^{-3}$

HI CLOUDS

50-150K

$1 - 10^3$

BETWEEN CLOUDS

$10^3 - 10^4 \text{ K}$

0.01

CORONAL GAS

$10^5 - 10^6 \text{ K}$

$10^{-4} - 10^{-3}$

HII REGIONS

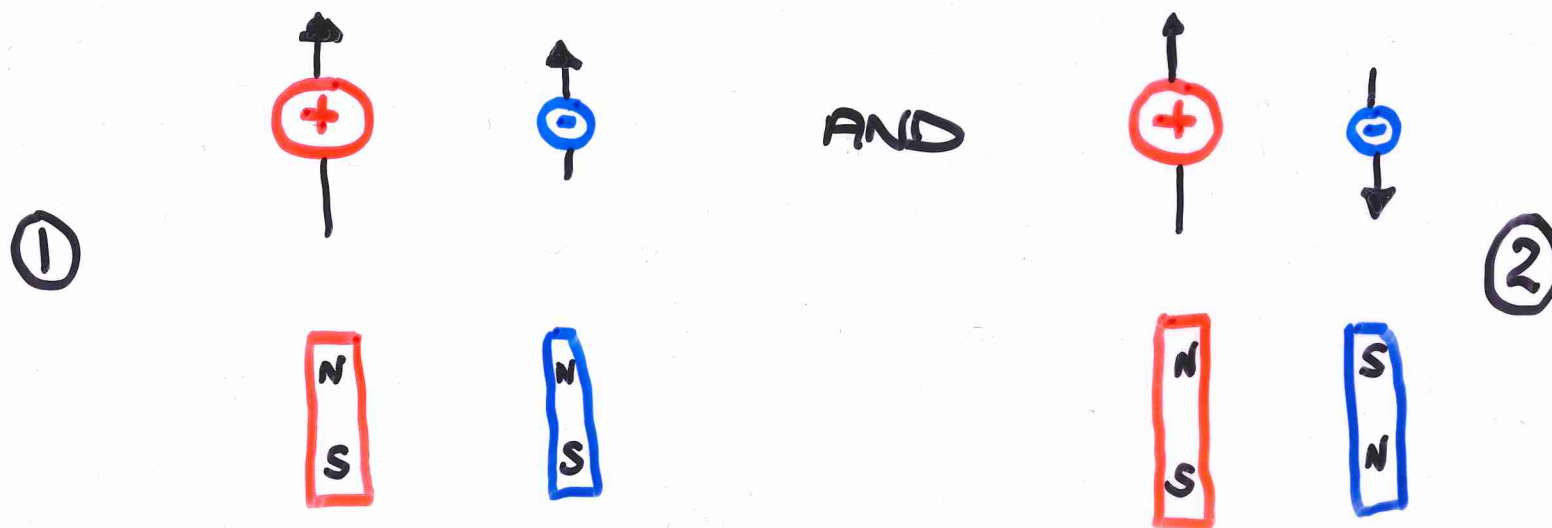
10^4 K

AROUND HOT
STARS

21 CM LINE OF NEUTRAL HYDROGEN

- PROTON : $\oplus$ AND A WEAK MAGNET
- ELECTRON : $\ominus$, ALSO A WEAK MAGNET

FIRST BOHR ORBIT IS TWO ORBITS OF ALMOST IDENTICAL ENERGY



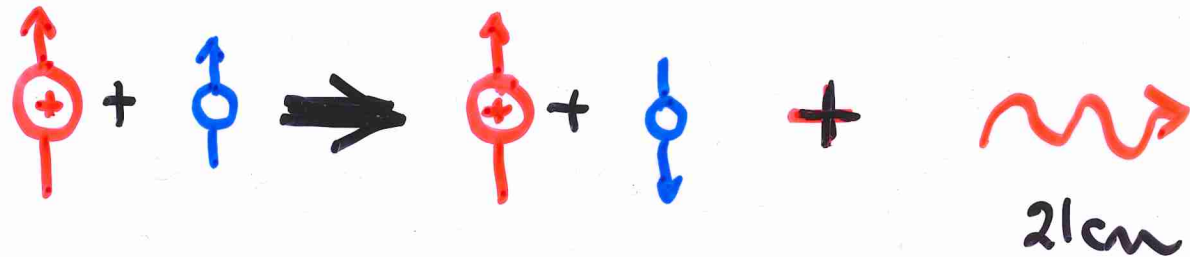
ENERGY DIFFERENCE BETWEEN ① AND ② IS V. SMALL
 $\Rightarrow$ PHOTON AT $\lambda = 21\text{-CM}$ [RADIO LINE]

H ATOMS IN GAS CLOUDS

- ATOM-ATOM COLLISIONS LEAD TO SPIN FLIPS



- 21 cm WAVE EMITTED SPONTANEOUSLY



AVERAGE TIME TO EMIT PHOTON
IS A FEW MILLION YEARS

- 21 cm WAVES ALSO ABSORBED

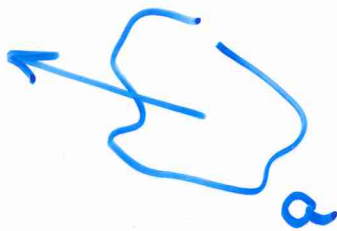
IMPORTANCE

- DUST TRANSPARENT AT 21 cm
∴ CAN DETECT H GAS ACROSS GALAXY
- PRECISE WAVELENGTH
∴ CAN MEASURE RADIAL VELOCITIES

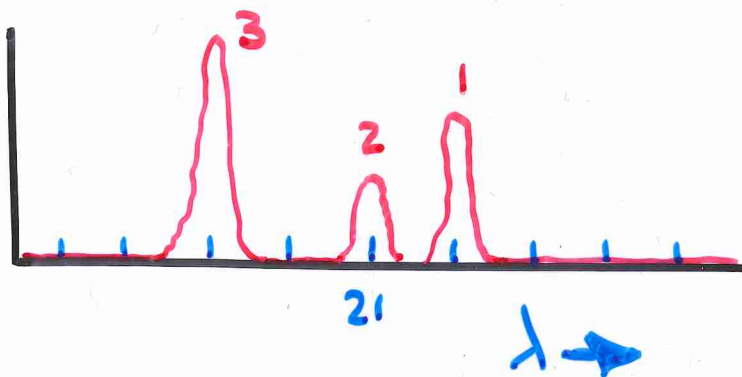
PREDICTED 1944 by H.C. van de HULST

DETECTED 1951 by E. PURCELL + H. EWEN

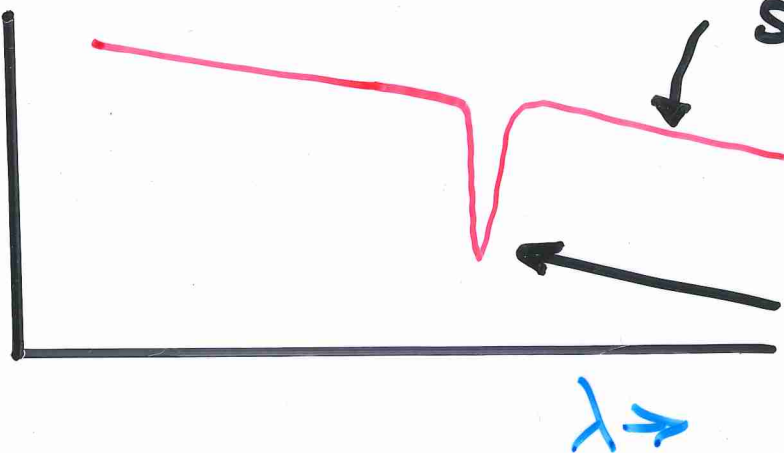
POWERFUL TOOL FOR RADIO ASTRONOMY



↑
Int.



↑
Int.

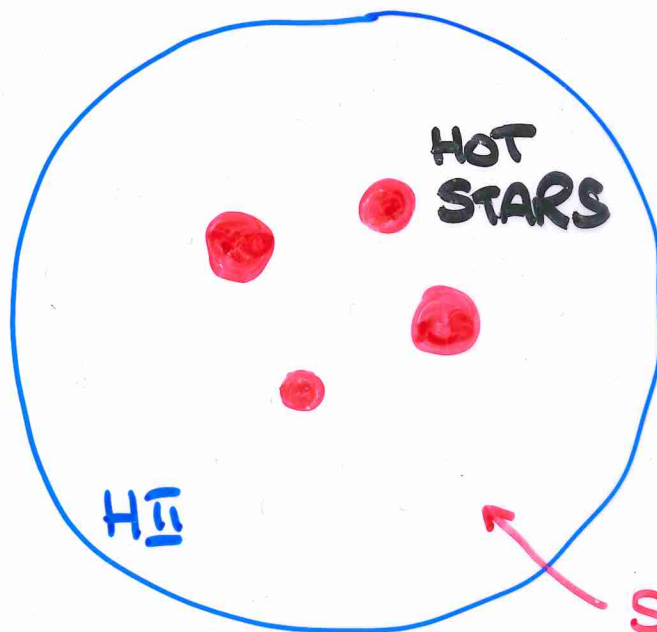


CONTINUOUS
SPECTRUM
OF
GALAXY

ABS.
LINE
PRODUCED
BY CLOUD

H II REGIONS

H^+



GAS CLOUD
SURROUNDS
STARS

H I

STRÖMGREN
SPHERE

- UV (LYMAN CONTINUUM, $\lambda < 912 \text{ \AA}$)
PHOTONS FROM HOT STARS **IONIZE**
H ATOMS IN GAS
- PROTONS + ELECTRONS RECOMBINE
BUT ARE QUICKLY **REIONIZED**
BALMER (AND OTHER PHOTONS)
EMITTED AS A RESULT OF
RECOMBINATIONS.
- **H II REGION BOUNDARY**
 - **LYMAN PHOTONS ALL CONSUMED**
 - **GAS CLOUD BOUNDARY**

- GAS TEMPERATURE IN $H II$ REGION $\sim 10,000$ K
 - HEATED BY ABSORBING UV OF STARS
 - COOLED BY FORBIDDEN LINES, H EMISSION LINES, ...
-

WHY WILL AN $H II$ REGION SHRINK AS A CLUSTER AGES?