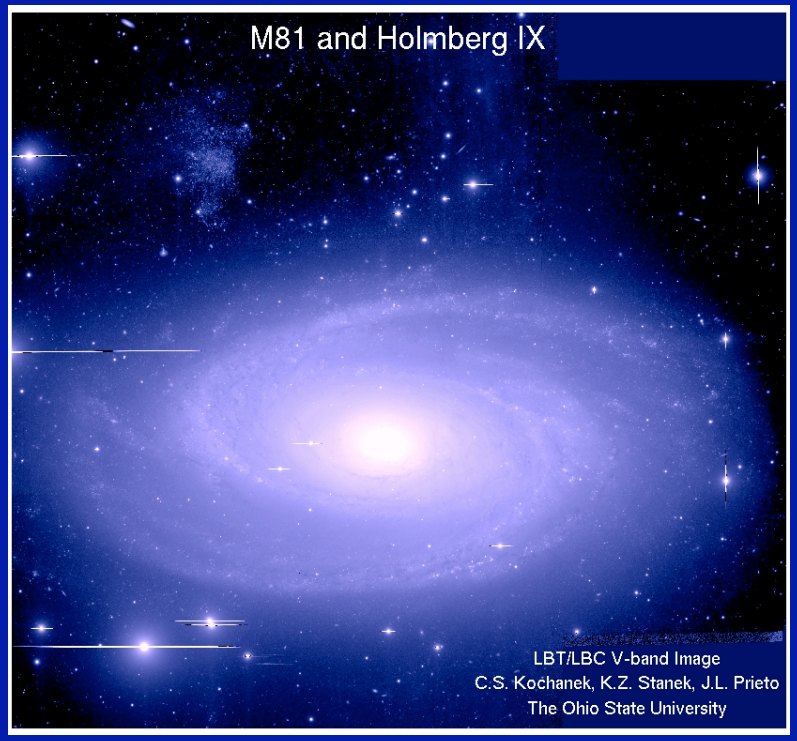
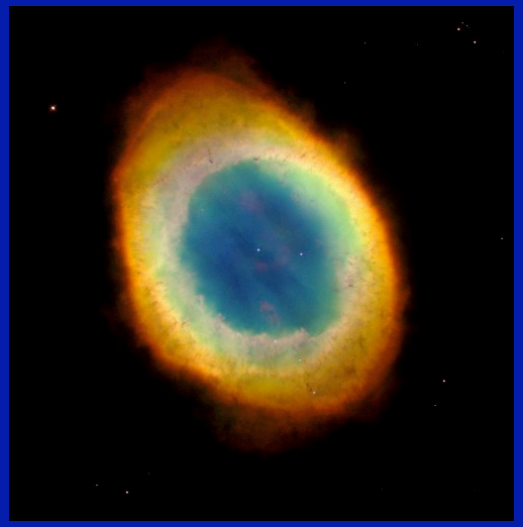
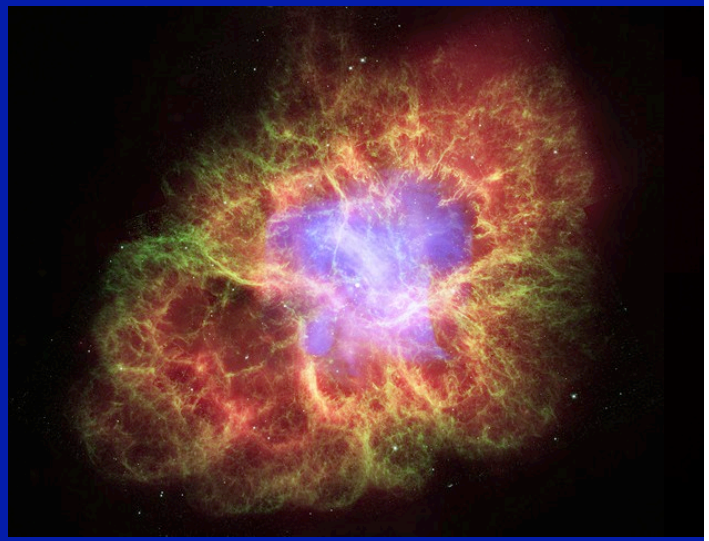
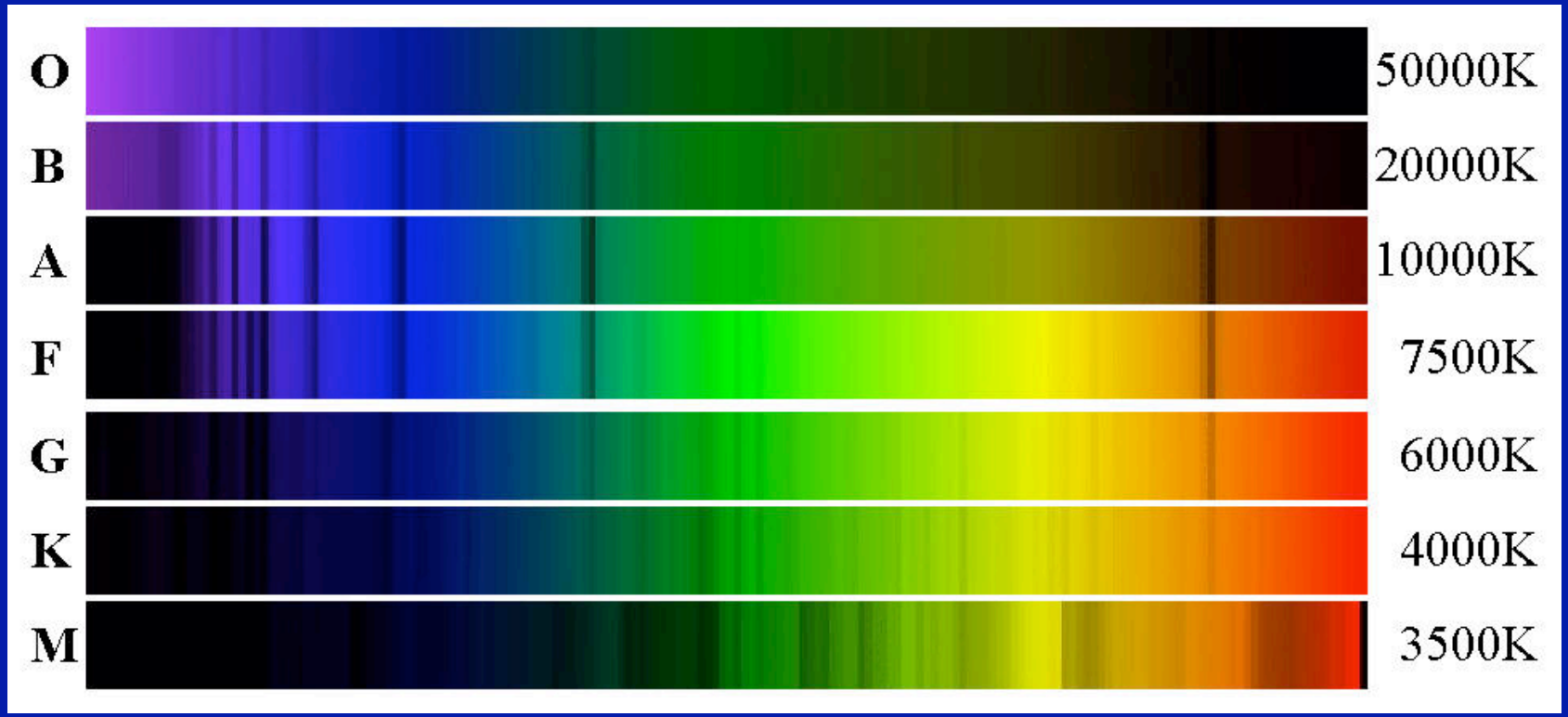

M81 and Holmberg IX
LBT/LBC V-band Image
C.S. Kochanek, K.Z. Stanek, J.L. Prieto
The Ohio State University

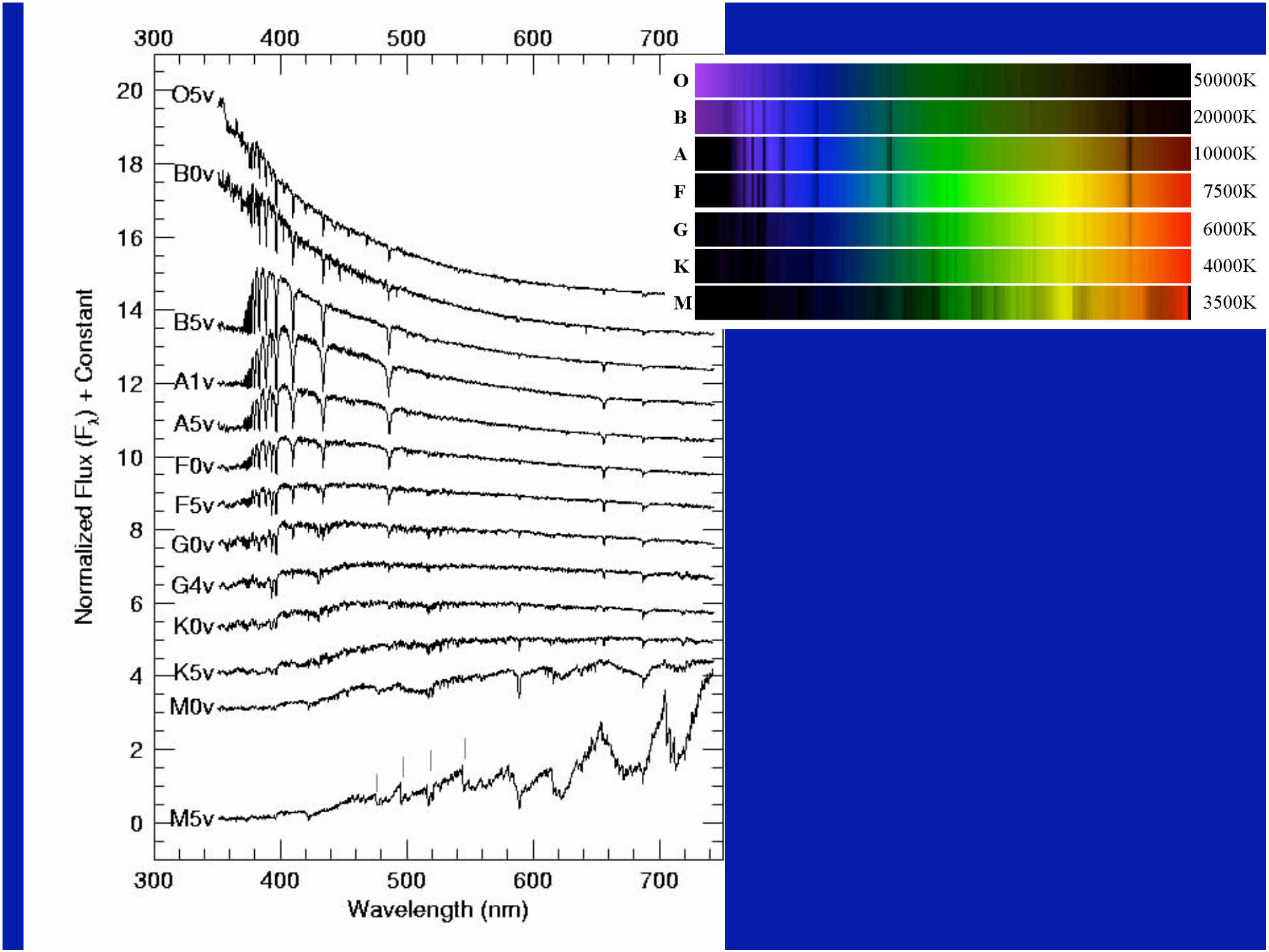




Spectra of Stars



Wavelength →


300
400
500
600
700
20
18
16
14
12
10
8
6
4
2
0
O5v
B0v
B5v
A1v
A5v
F0v
F5v
G0v
G4v
K0v
K5v
M0v
M5v
Normalized Flux (F_λ) + Constant
Wavelength (nm)
O
B
A
F
G
K
M
50000K
20000K
10000K
7500K
6000K
4000K
3500K

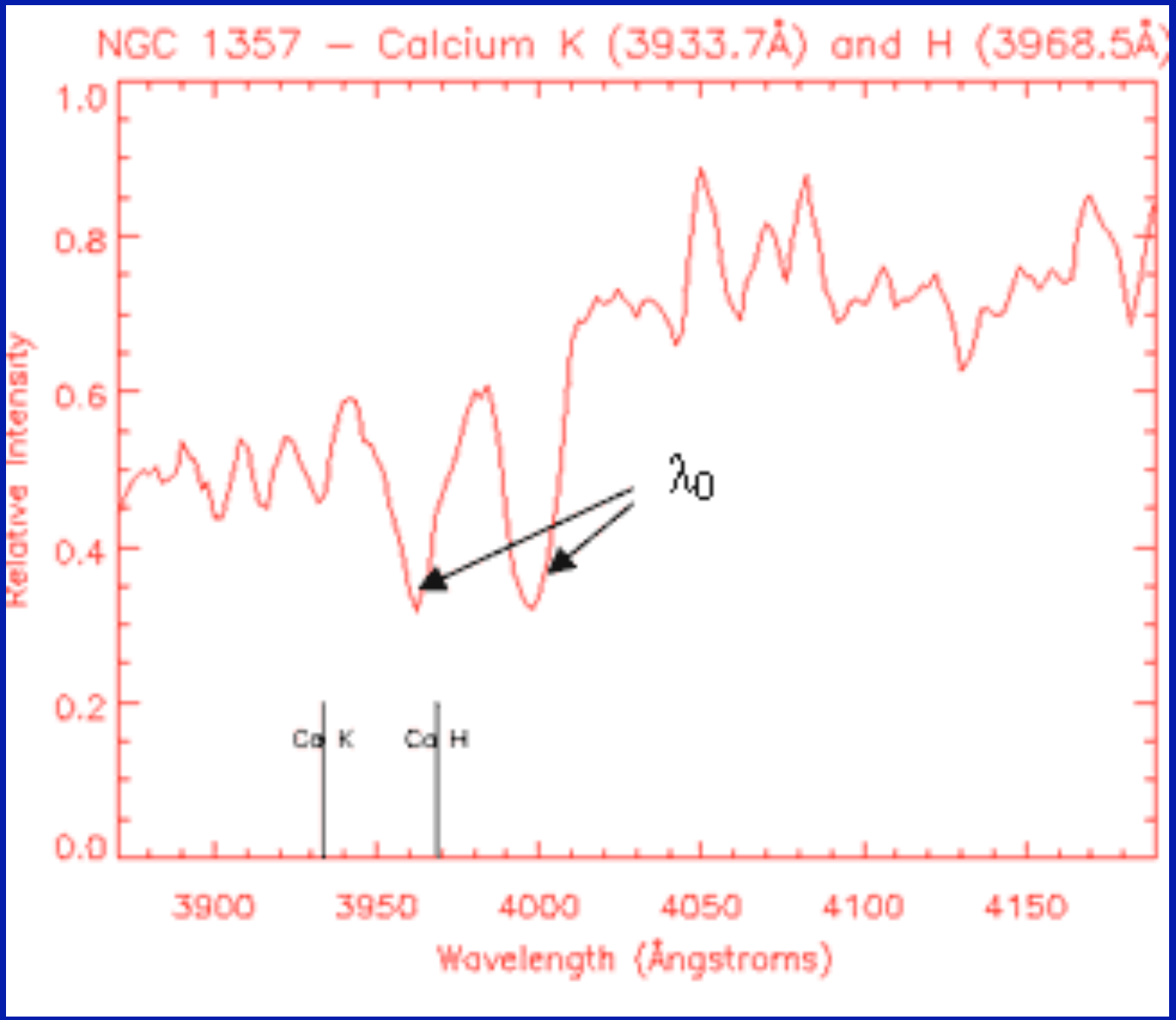

NGC 1357 – Calcium K (3933.7Å) and H (3968.5Å)
Relative Intensity
1.0
0.8
0.6
0.4
0.2
0.0
λ0
Ca K
Ca H
3900
3950
4000
4050
4100
4150
Wavelength (Ångstroms)

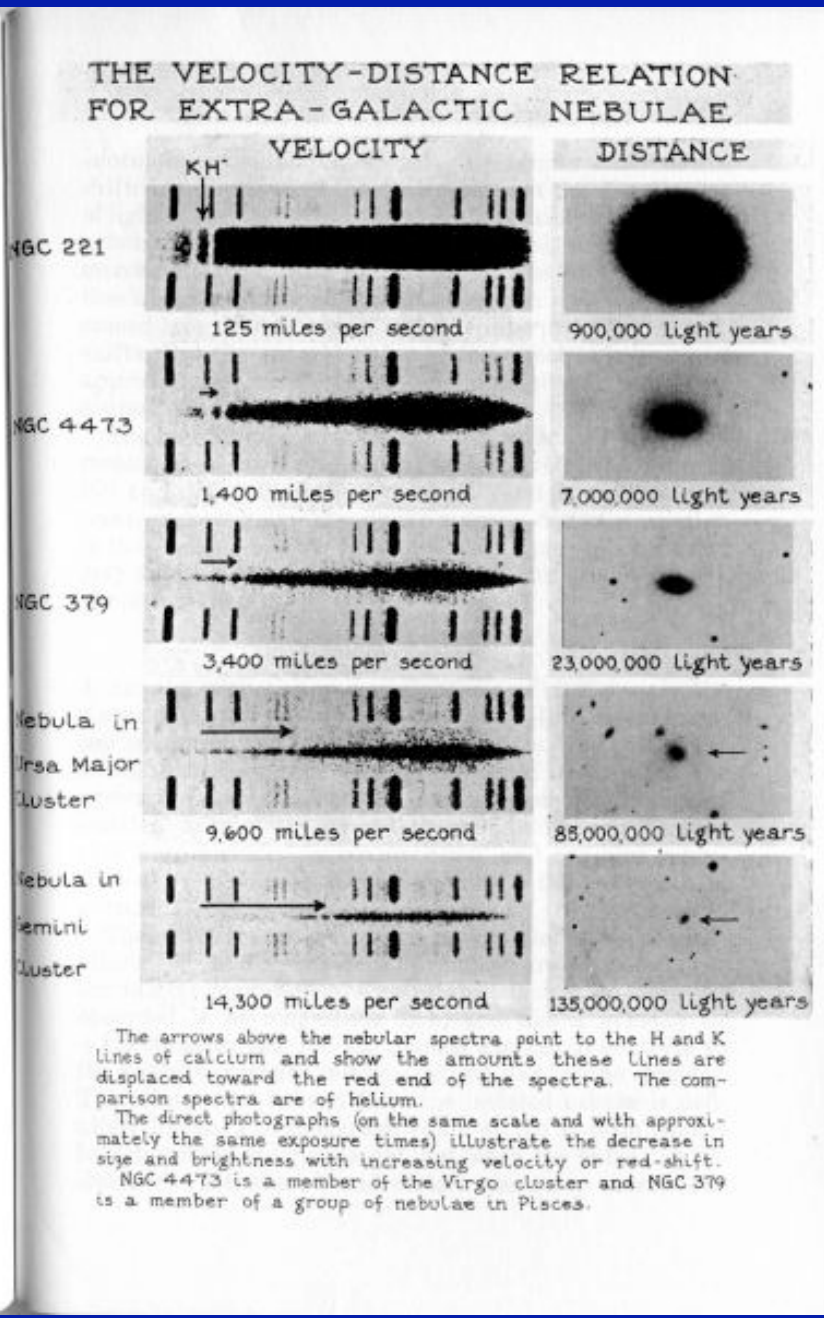
PLATE VIII

The Velocity-Distance Relation.

THE five examples in the Plate illustrate the empirical law that red-shifts in the spectra of nebulæ increase with the apparent faintness of the nebulæ. Since apparent faintness measures distance, the law can be stated in the form that red-shifts increase with distance. Detailed investigation shows that the relation is linear (red-shifts = constant × distance).

Red-shifts resemble velocity-shifts, and no other satisfactory explanation is available at the present time: red-shifts are due either to actual motion of recession or to some hitherto unrecognized principle of physics. Therefore, the empirical law is generally described as the *velocity-distance relation* (velocity = constant × distance), and is often considered as visible evidence of the expanding universe of general relativity.

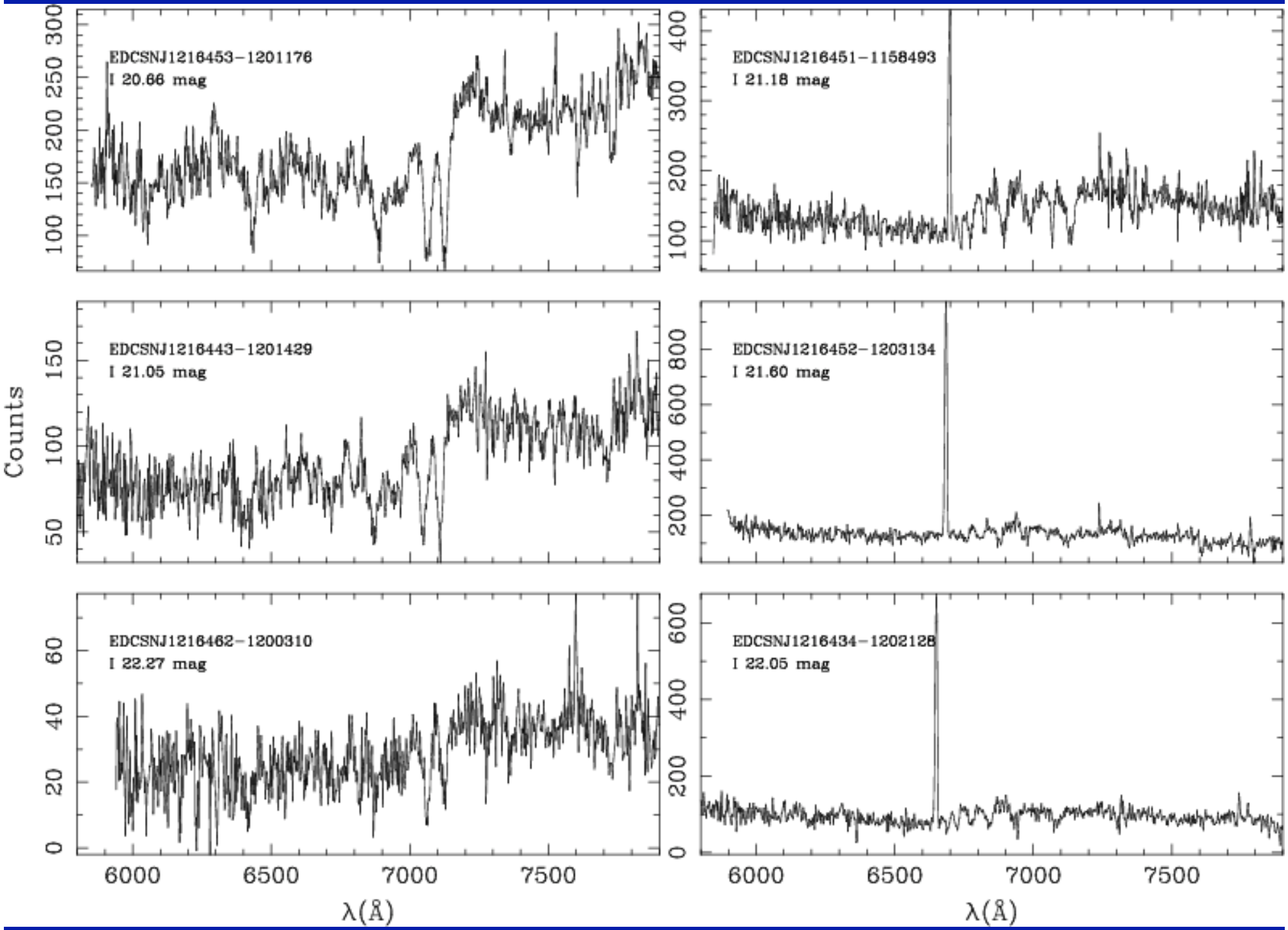
The spectra are by Humason. The velocity of NGC 221 is negative—toward the earth—and is a reflection of the sun's motion in its orbit about the center of the galactic system. The other velocities are positive—away from the earth. The distance of NGC 221 (M32) should read 700,000 light years. The revision takes into account the effects of local obscuration.

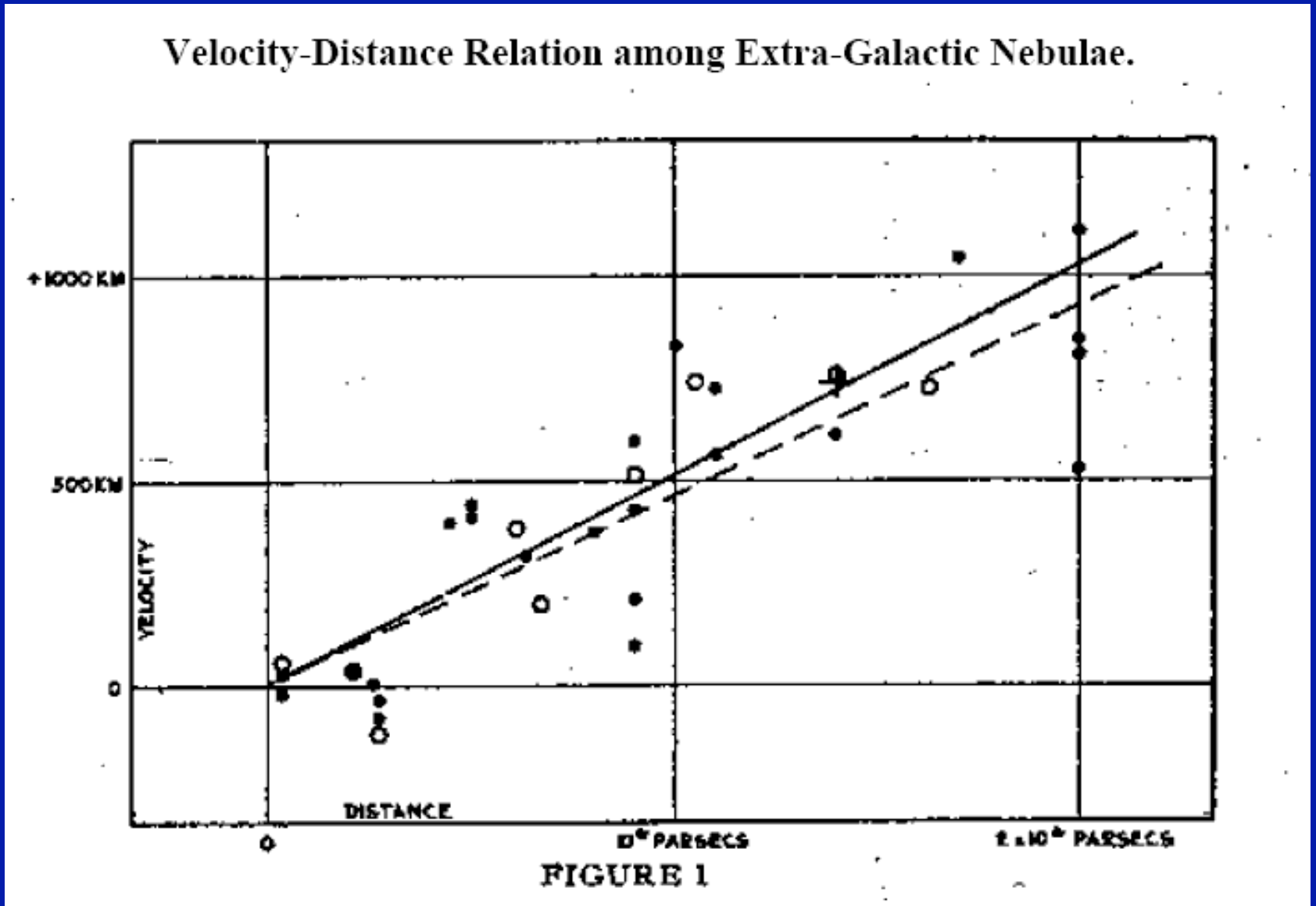


The arrows above the nebular spectra point to the H and K lines of calcium and show the amounts these lines are displaced toward the red end of the spectra. The comparison spectra are of helium.

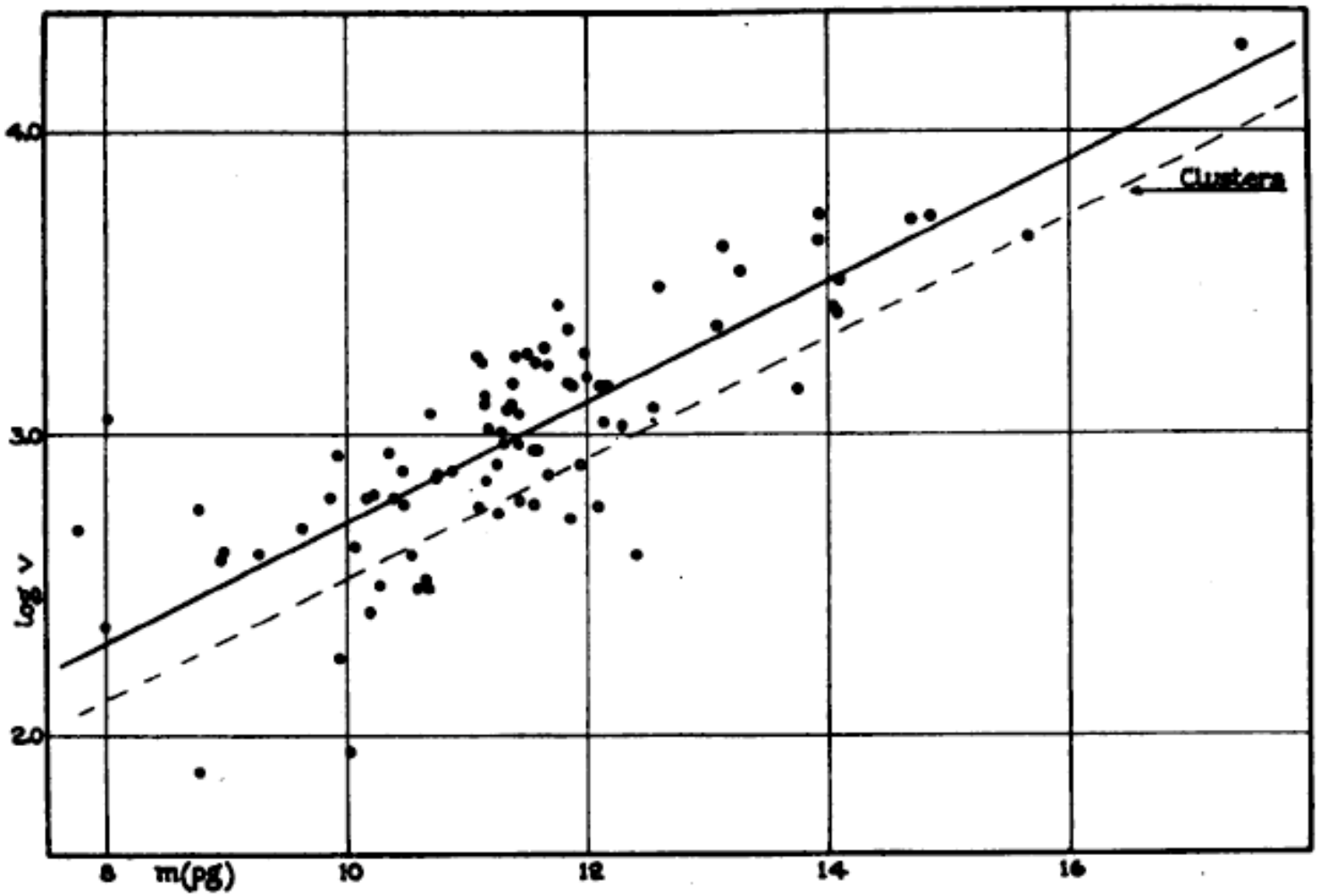
The direct photographs (on the same scale and with approximately the same exposure times) illustrate the decrease in size and brightness with increasing velocity or red-shift.

NGC 4473 is a member of the Virgo cluster and NGC 379 is a member of a group of nebulae in Pisces.


EDCSNJ1216453−1201176
I 20.66 mag
EDCSNJ1216451−1158493
I 21.18 mag
EDCSNJ1216443−1201429
I 21.05 mag
EDCSNJ1216452−1203134
I 21.60 mag
EDCSNJ1216462−1200310
I 22.27 mag
EDCSNJ1216434−1202128
I 22.05 mag
Counts
λ(Å)
λ(Å)


Velocity-Distance Relation among Extra-Galactic Nebulae.
+1000 KM
500 KM
0
VELOCITY
DISTANCE
0
PARSECS
PARSECS
FIGURE 1

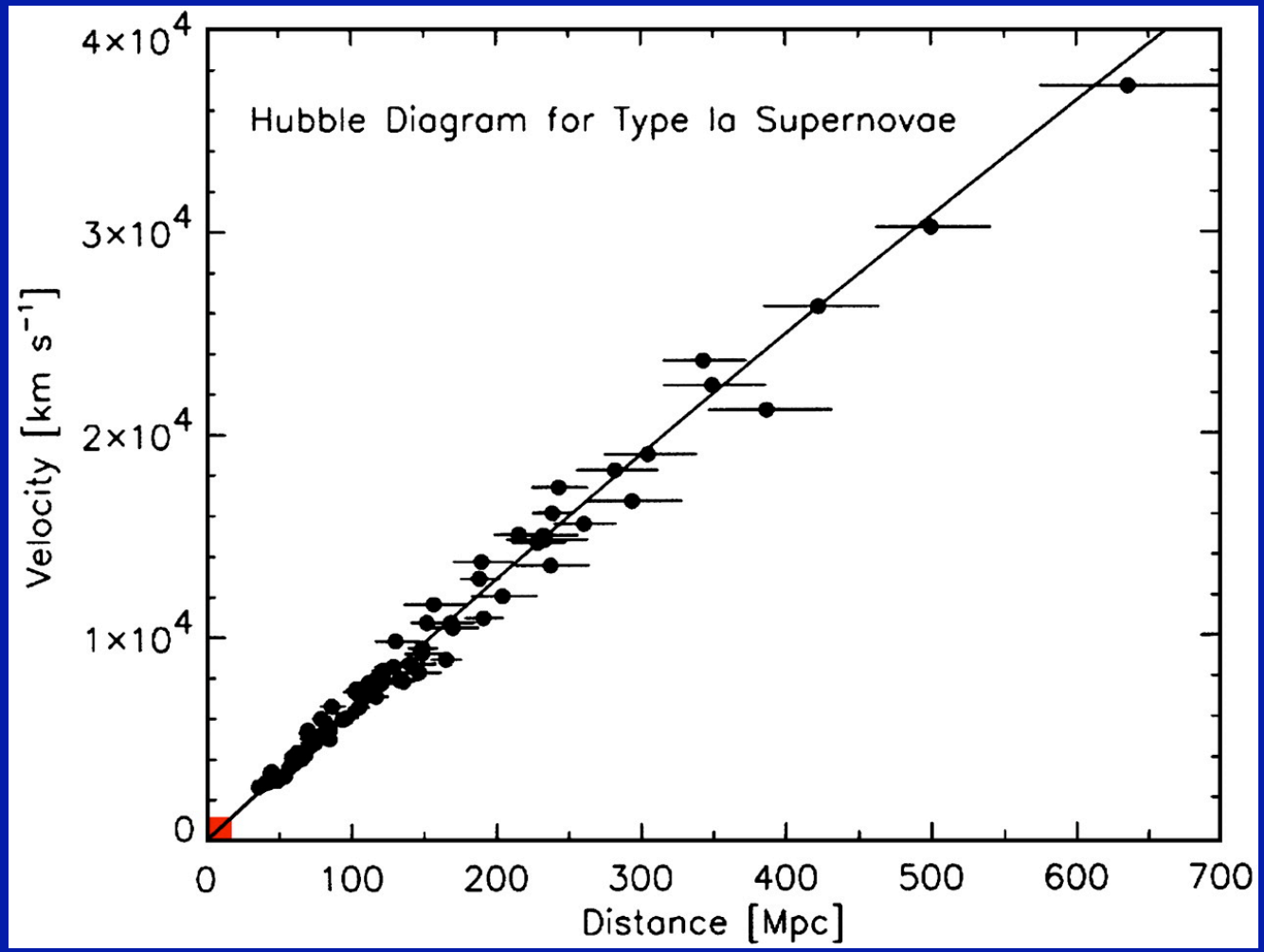
Hubble 1929

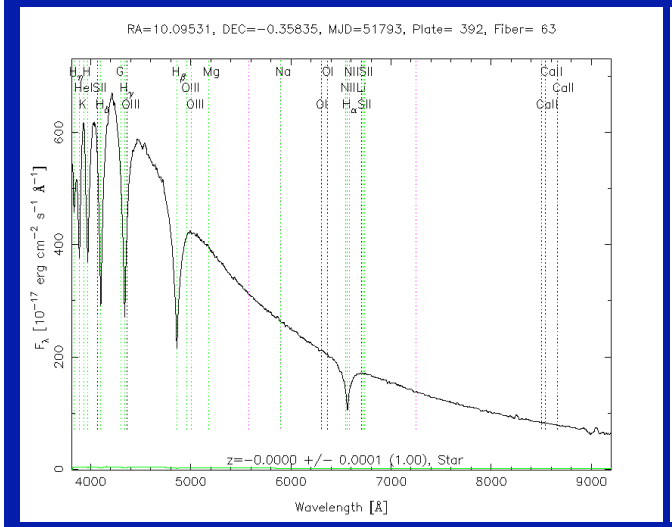


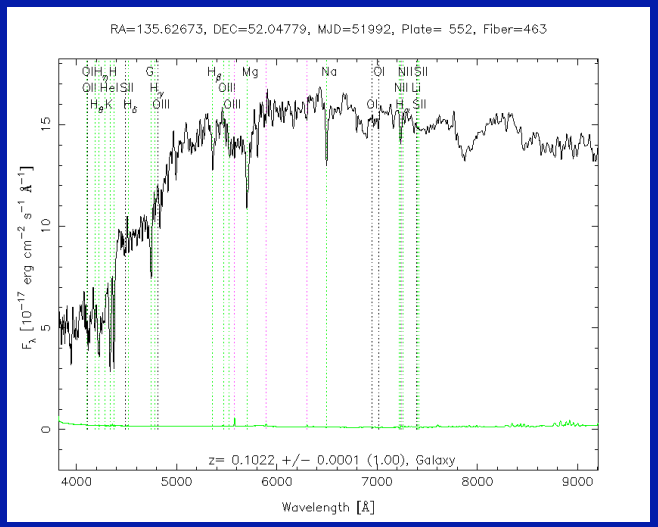
Velocity-Distance Relation for Isolated Nebulae

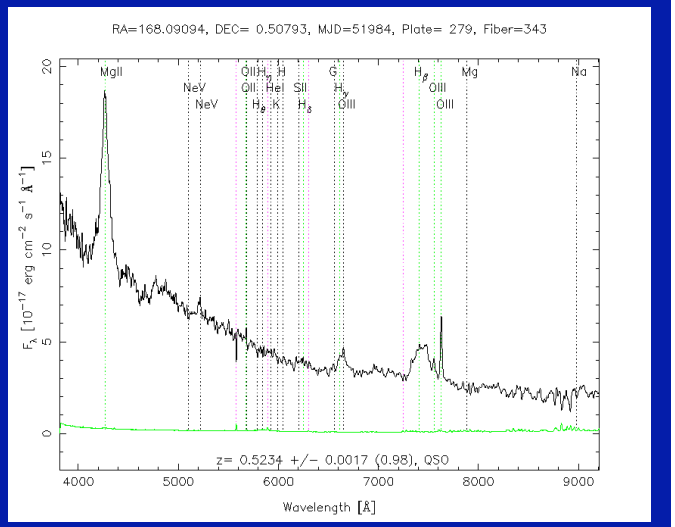
FIGURE 1

Hubble & Humason 1935


Hubble Diagram for Type Ia Supernovae
Velocity [km s^{-1}]
Distance [Mpc]
4×10^4
3×10^4
2×10^4
1×10^4
0
0
100
200
300
400
500
600
700



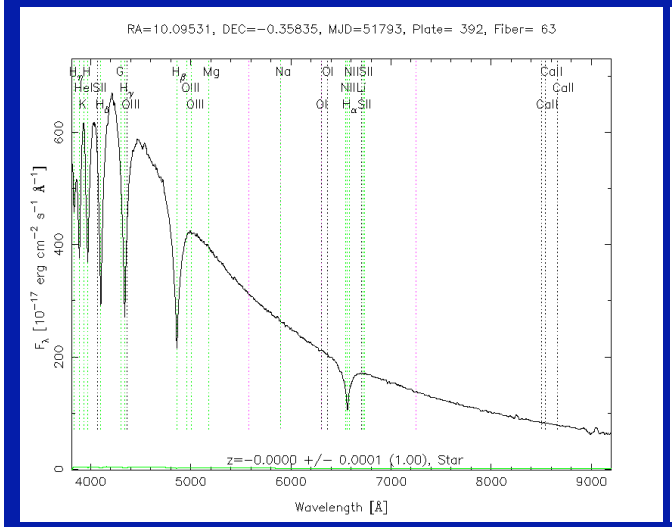


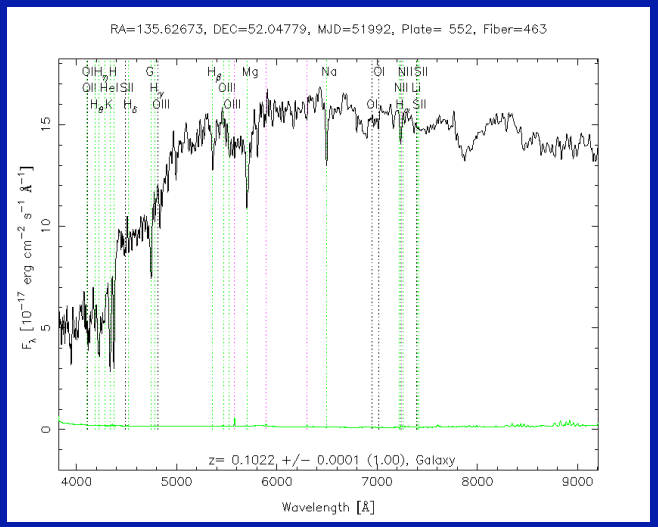


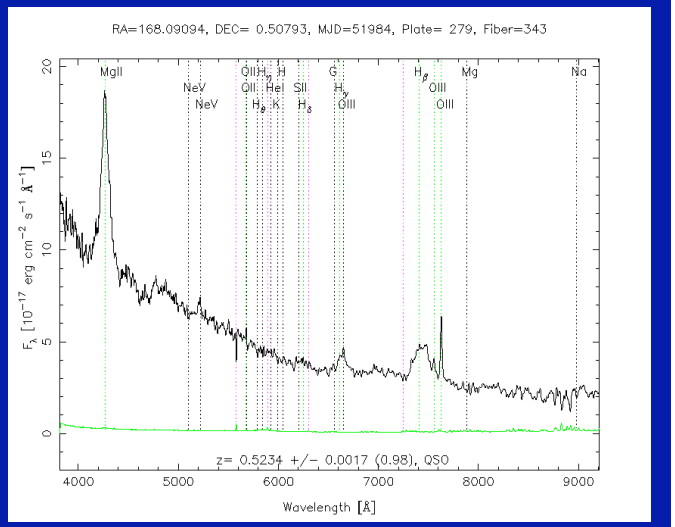
White dwarf

Galaxy

Quasar







White dwarf

Galaxy

Quasar