

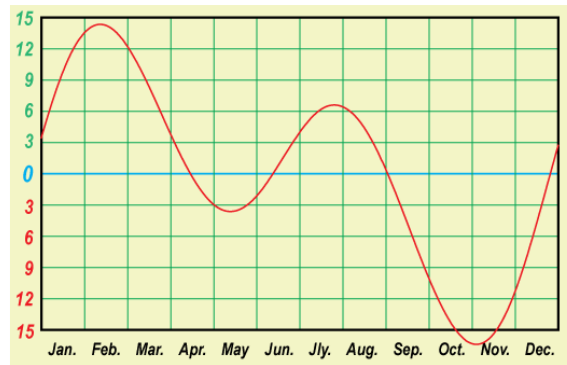
Some constants and formulae

Speed of light in vacuum, c	299 792 458 ms ⁻¹
Constant of gravitation, G	6.674×10 ⁻¹¹ Nm ⁻² kg ⁻²
Solar constant, A	1367 Wm ⁻²
Mean value, Hubble parameter	68
Diapason of values, H ₀	50-100 kms ⁻¹ Mpc ⁻¹
Plank constant, h	6.626×10 ⁻³⁴ J s
Charge of electron, e	1.602×10 ⁻¹⁹ C
Mass of electron, m _e	9.109×10 ⁻³¹ kg
Proton-to-electron mass ratio	1836.15
Faraday constant, F	96 485 C/mol
Magnetic constant, μ ₀	1.257×10 ⁻⁶ Hm ⁻¹
Universal gas constant, R	8.314 Jmol ⁻¹ K ⁻¹
Boltzmann constant, k	1.381×10 ⁻²³ JK ⁻¹
Stefan-Boltzmann constant, σ	5.67 ×10 ⁻⁸ Wm ⁻² K ⁻⁴
Wien's displacement constant, b	0.002897 mK
Laboratory wavelength of H _α	6562.81 Å
Tropical year length, T	365.242199 days
Sidereal year length, T	365.25636 days
Anomalistic year length, T	365.259636 days
Nodal period of lunar orbit	-18.6 years
Standard atmosphere	101 325 Pa
Visible light extinction by the terrestrial atmosphere in zenith (minimum)	19%, 0.23m
Height of homogeneous atmosphere	7991 m
Refractive index of water at 20°C, n	1.334
Moment of inertia of a solid ball	$I = \frac{2}{5} MR^2$
Moment of inertia of sphere	$I = \frac{2}{3} MR^2$
Volume of a ball	$V = \frac{4}{3} \pi R^3$
Area of sphere	$A = 4\pi R^2$
π	3.14159265
e	2.71828183
Golden ratio, φ	1.61803399

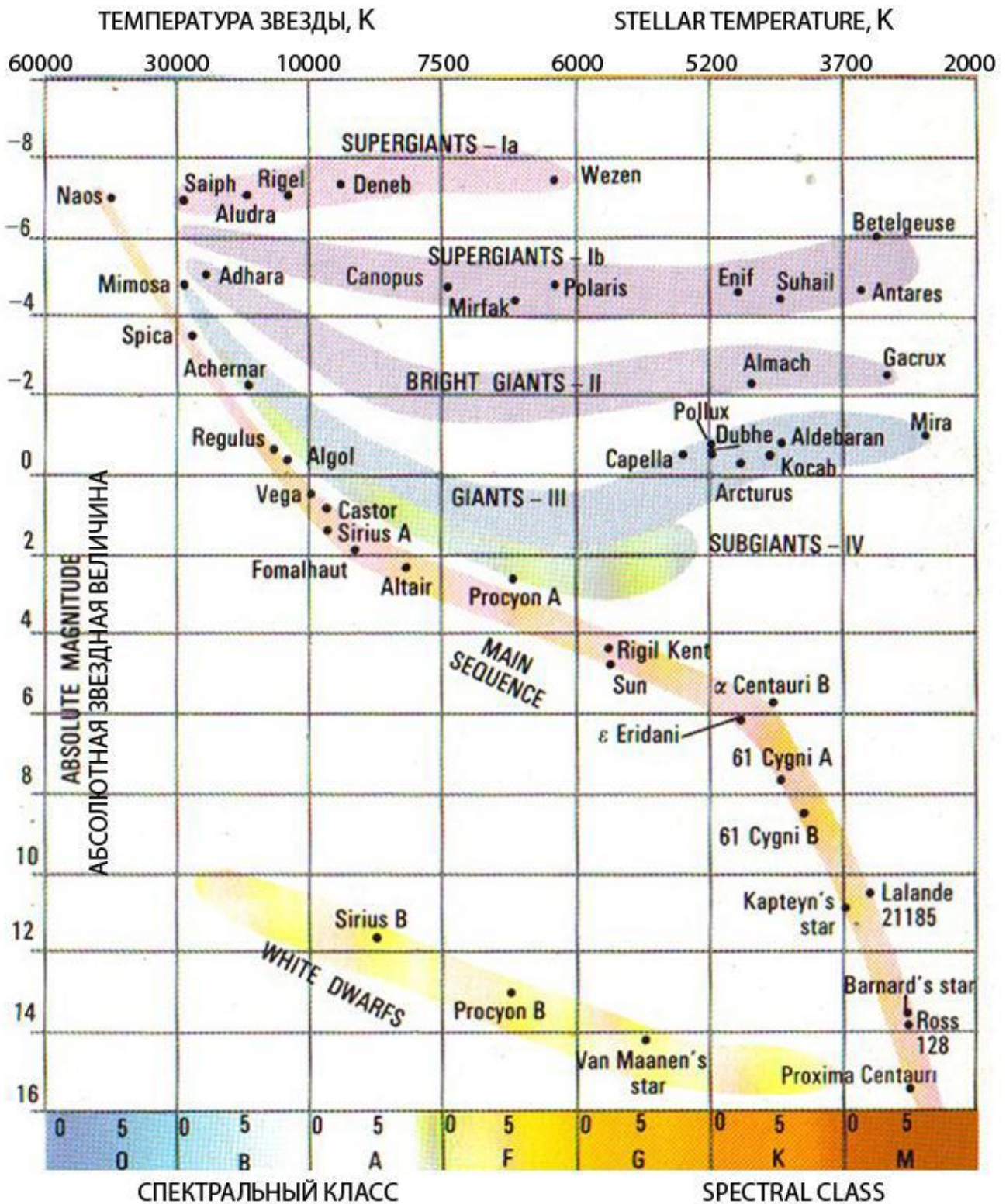
Parameters of orbits and physical characteristics of planets, Sun and Moon

Body, planet	Average distance to central body		Sidereal (or analogous) period		Eccentricity, e	Equat. Diameter (km)	Mass (10 ²⁴ kg)	Av. Density (g/cm ³)	Grav. acc. at surface (m/s ²)	Max. mag. from Earth* (m)	Albedo
	A.U	10 ⁶ km	Tropical years	days							
Sun	1.6×10 ⁹	2.5×10 ¹¹	2.2×10 ⁸	8×10 ¹⁰		1392 000	1989 000	1.409		-26.8	
Mercury	0.387	57.9	0.241	87.969	0.206	4 879	0.3302	5.43	3.70	-2.2	0.06
Venus	0.723	108.2	0.651	224.701	0.007	12 104	4.8690	5.24	8.87	-4.7	0.78
Earth	1.000	149.6	1.000	365.256	0.017	12 756	5.9742	5.52	9.81		0.36
Moon	0.00257	0.3844	0.0748	27.3217	0.055	3 475	0.0735	3.34	1.62	-12.7	0.07
Mars	1.524	227.9	1.880	686.980	0.093	6 794	0.6419	3.94	3.71	-2.0	0.15
Jupiter	5.204	778.6	11.862	4 332.59	0.048	142 984	1899.8	1.33	24.86	-2.7	0.66
Saturn	9.584	1433.7	29.458	10 759.2	0.054	120 536	568.50	0.70	10.41	0.7	0.68
Uranus	19.191	2871.0	84.015	30 685.93	0.046	51 118	86.625	1.30	8.44	5.5	0.74
Neptune	30.071	4498.6	164.778	60 187.64	0.008	49 532	102.78	1.76	11.20	7.8	0.58

*for outer planets and Moon – in mean position



Equation of time



20 brightest stars in the sky

		RA	Dec	p	m	SC
Altair	α Aql	19 ^h 50 ^m 47 ^s	08° 52' 06"	0".195	0 ^m .77	A7
Capella	α Aur	05 ^h 16 ^m 41 ^s	45° 59' 53"	0".073	0 ^m .08	G5+G0
Arcturus	α Boo	14 ^h 15 ^m 38 ^s	19° 10' 57"	0".089	-0 ^m .04V	K1
Canopus	α Car	06 ^h 23 ^m 57 ^s	-52° 41' 45"	0".028	-0 ^m .72	F0
Toliman (Rigel Kent)	α Cen ^A ^B	14 ^h 39 ^m 36 ^s	-60° 50' 07"	0".747	-0 ^m .01 1 ^m .33	G2 K1
Hadar	β Cen	14 ^h 03 ^m 49 ^s	-60° 22' 23"	0".009	0 ^m .61	B1
Sirius	α CMa	06 ^h 45 ^m 09 ^s	-16° 42' 58"	0".375	-1 ^m .46	A1
Procyon	α CMi	07 ^h 39 ^m 18 ^s	05° 13' 30"	0".288	0 ^m .38	F5
Acrux	α Cru	12 ^h 26 ^m 36 ^s	-63° 05' 57"	0".010	0 ^m .77	B0
Becrux	β Cru	12 ^h 47 ^m 43 ^s	-59° 41' 20"	0".009	1 ^m .30	B0
Deneb	α Cyg	20 ^h 41 ^m 26 ^s	45° 16' 49"	0".002	1 ^m .25	A2
Achernar	α Eri	01 ^h 37 ^m 43 ^s	-57° 14' 12"	0".026	0 ^m .46	B3
Pollux	β Gem	07 ^h 45 ^m 19 ^s	28° 01' 35"	0".097	1 ^m .14	K0
Vega	α Lyr	18 ^h 36 ^m 56 ^s	38° 47' 01"	0".123	0 ^m .03	A0
Betelgeuse	α Ori	05 ^h 55 ^m 10 ^s	07° 24' 25"	0".005	0 ^m .5V	M2
Rigel	β Ori	05 ^h 14 ^m 32 ^s	-08° 12' 06"	0".013	0 ^m .12	B8
Fomalhaut	α PsA	22 ^h 57 ^m 39 ^s	-29° 37' 20"	0".130	1 ^m .16	A3
Antares	α Sco	16 ^h 29 ^m 24 ^s	-26° 25' 55"	0".024	0 ^m .96	M1+B4
Aldebaran	α Tau	04 ^h 35 ^m 55 ^s	16° 30' 33"	0".048	0 ^m .85V	K5
Spica	α Vir	13 ^h 25 ^m 12 ^s	-11° 09' 41"	0".023	0 ^m .98	B1

Some other stars

Hamal	α Ari	02 ^h 07 ^m 10 ^s	23° 27' 45"	0".050	2 ^m .01	K2
Polaris	α UMi	02 ^h 31 ^m 49 ^s	89° 15' 51"	0".007	1 ^m .97V	F7
Kochab	β Umi	14 ^h 50 ^m 42 ^s	74° 09' 20"	0".025	2 ^m .07	K4
Proxima Centaruy	α Cen c	14 ^h 29 ^m 43 ^s	-62° 40' 46"	0".769	11 ^m .05	M5.5

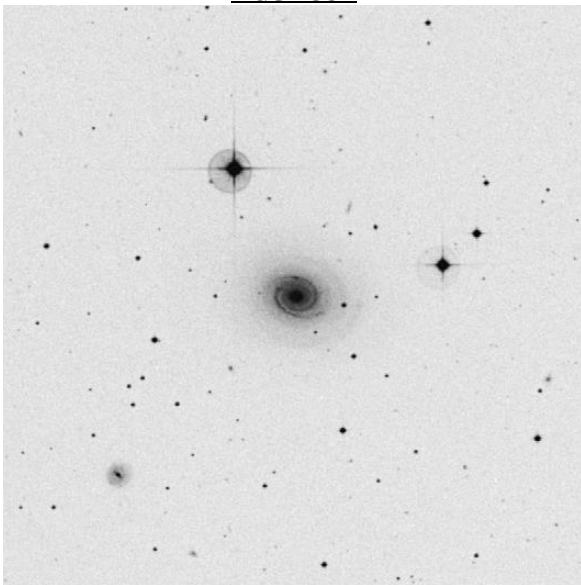
Greek Letters

A	α	alpha	I	ι	iota	P	ρ	rho
B	β	beta	K	κ	kappa	Σ	ζ	sigma
Γ	γ	gamma	Λ	λ	lambda	T	η	tau
Δ	δ	delta	M	μ	mu	Y	υ	upsilon
E	ε	epsilon	N	ν	nu	Φ	θ	phi
Z	δ	zeta	Ξ	ξ	xi	X	χ	chi
H	ε	eta	O	o	omicron	Ψ	ψ	psi
Θ	ζ	theta	Π	π	pi	Ω	ω	omega

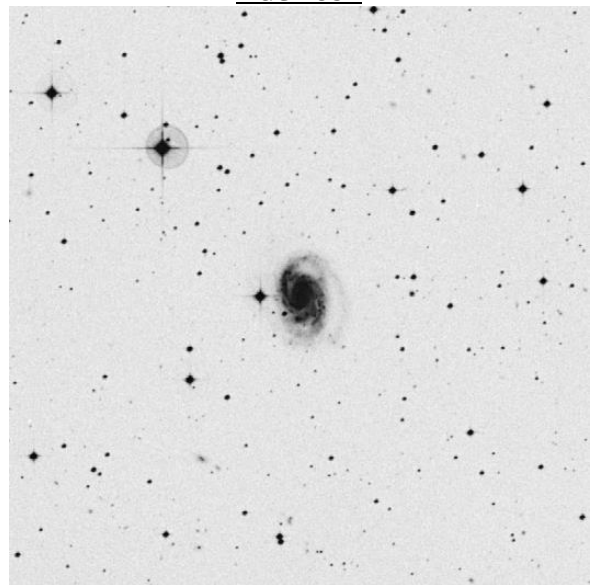
PRACTICAL AND DATA ANALYSIS QUESTION

1. The fourteen images below are obtained from Palomar Observatory Sky Survey, under NASA contract by the Space Telescope Science Institute, operated by AURA, Inc. Using the images below:
 - a. Measure the width of each galaxy in mm and fill in the measured value in Table 1. Note that the galaxies are at the centre of their image.
 - b. Note that NGC 1357 is 119.22 arcseconds wide and all the images are taken using the same camera and telescope setup. Calculate the angular width of each galaxy in arcsecond and fill in Table 1.
 - c. If all the galaxies are of the same size and have a diameter of 0.01 mega parsecs (Mpc), calculate the distances of the galaxies from Earth, r , and fill the obtained r value in Table 1.

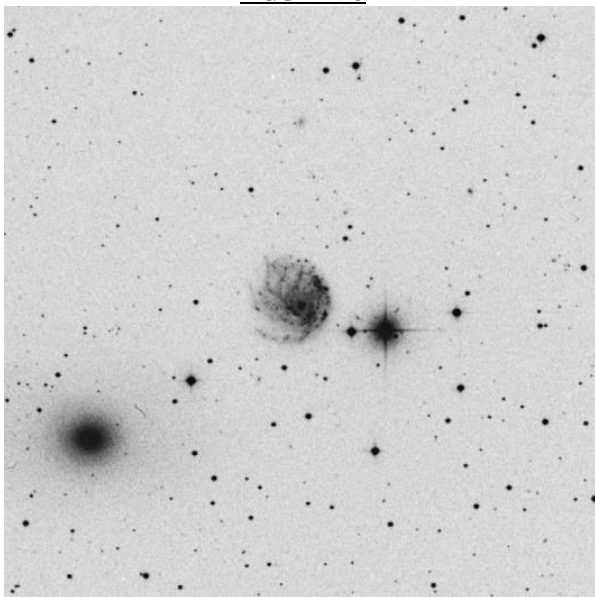
NGC 1357



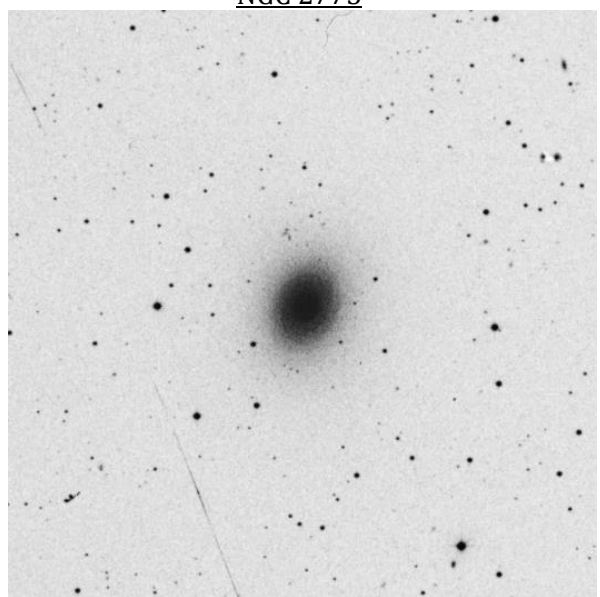
NGC 1832



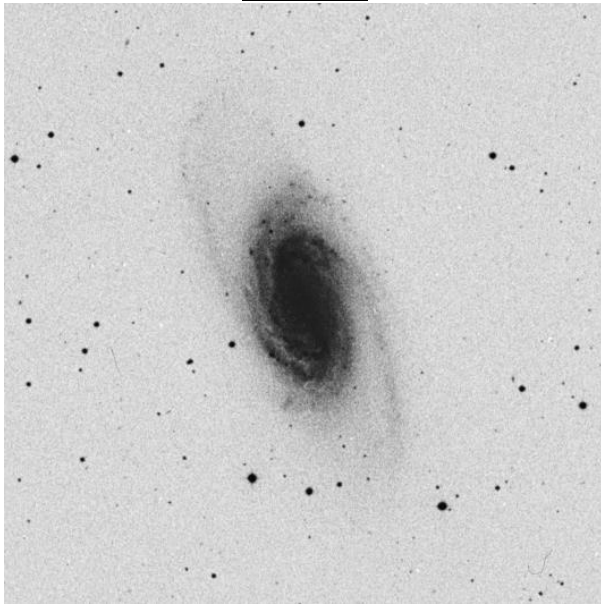
NGC 2276



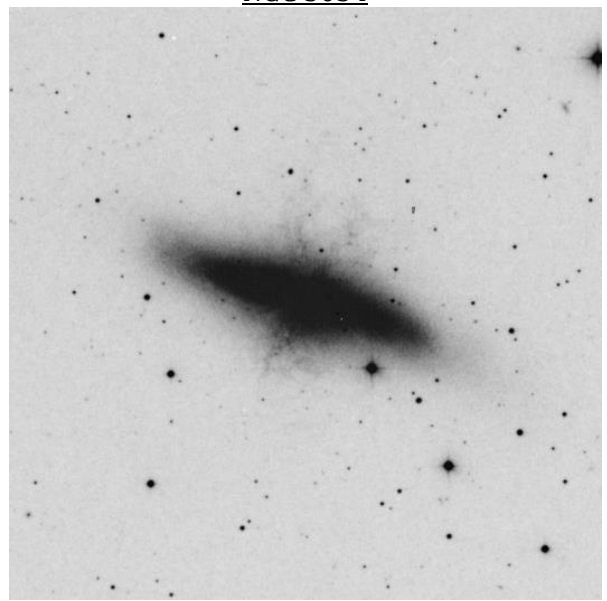
NGC 2775



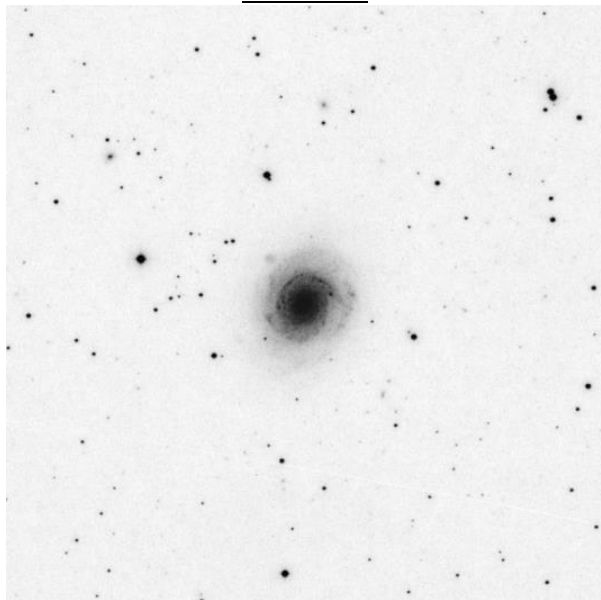
NGC 2903



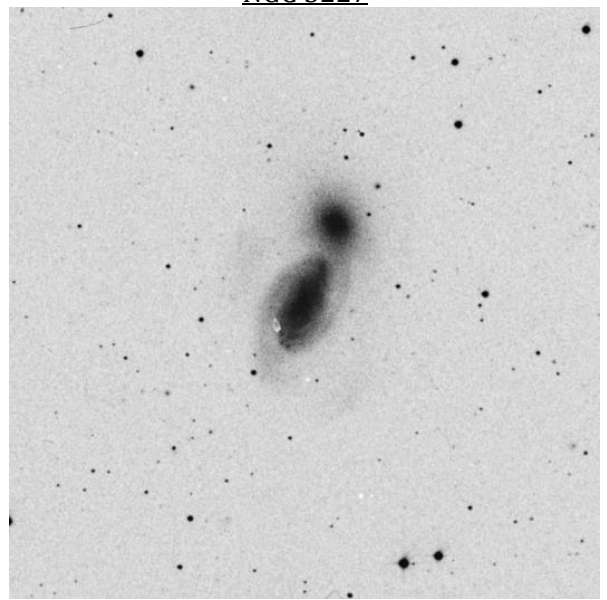
NGC 3034



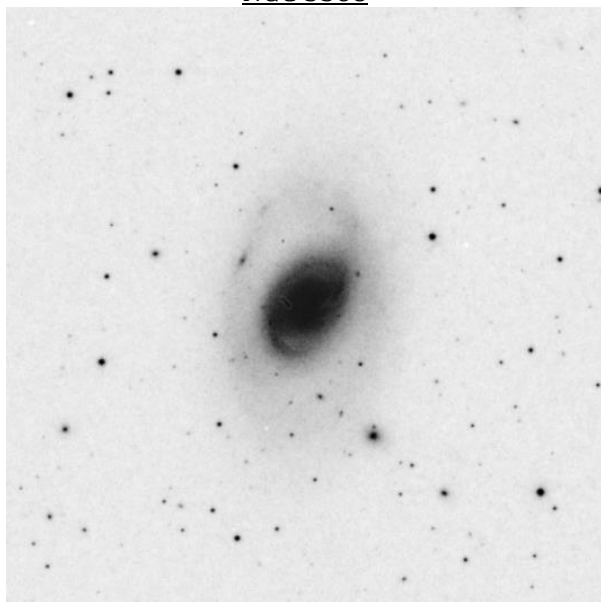
NGC 3147



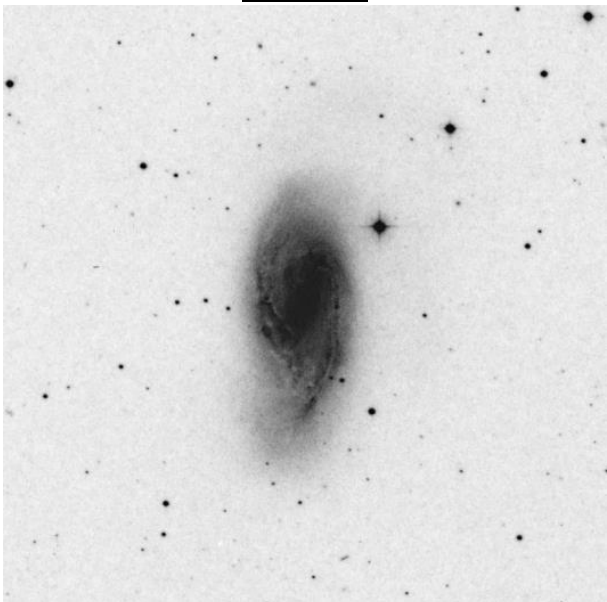
NGC 3227



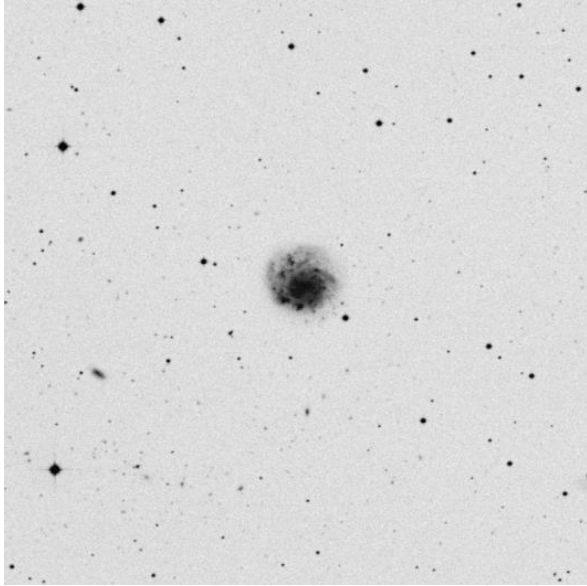
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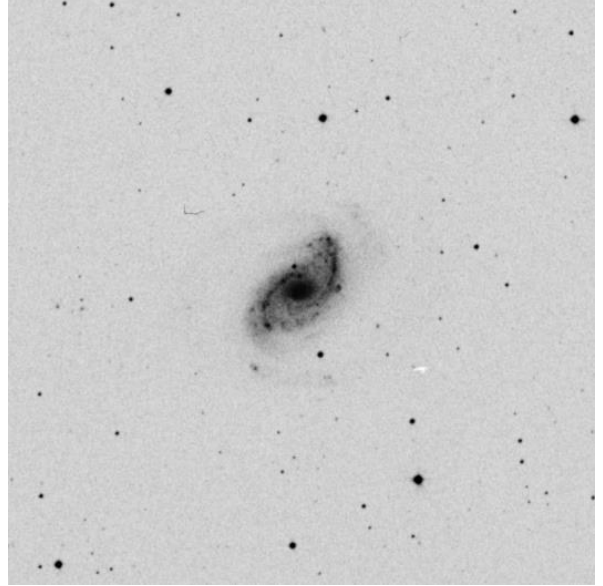
NGC 3627



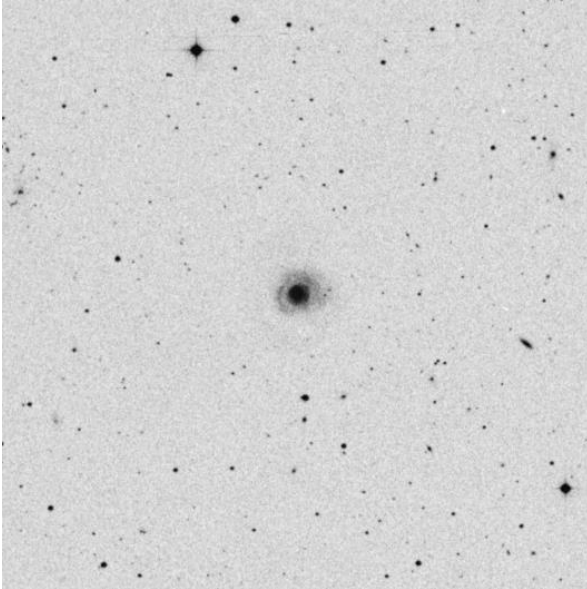
NGC 4775



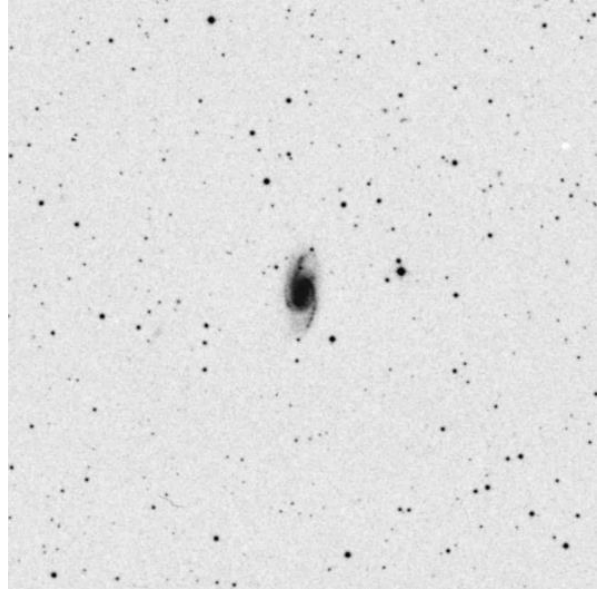
NGC 5248



NGC 5548

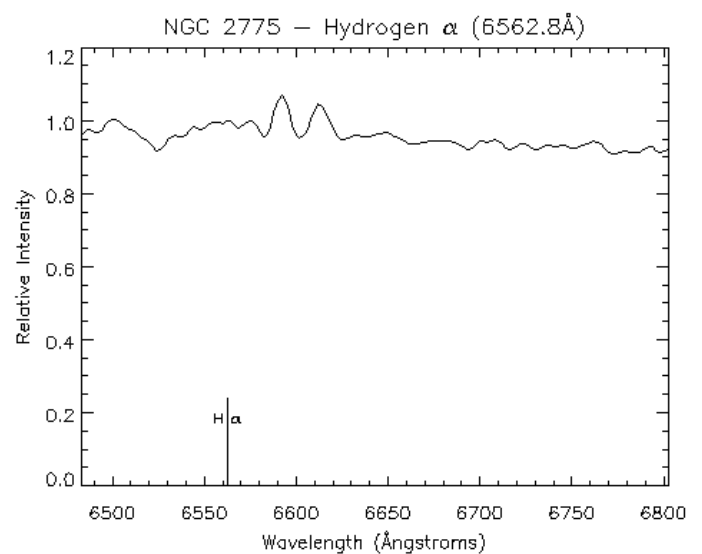
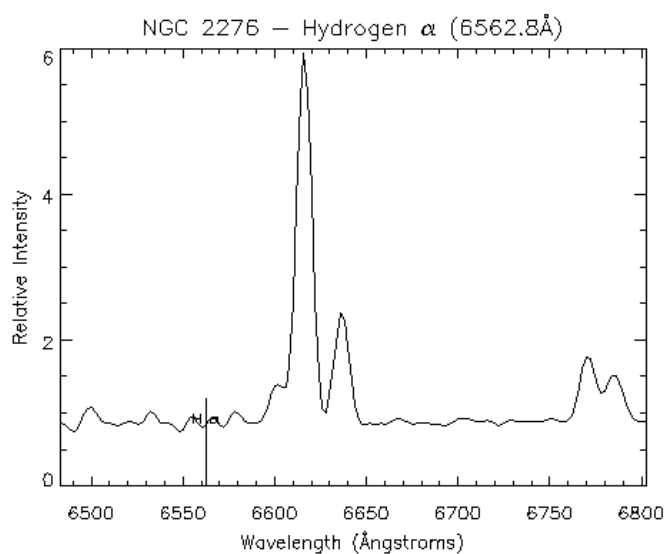
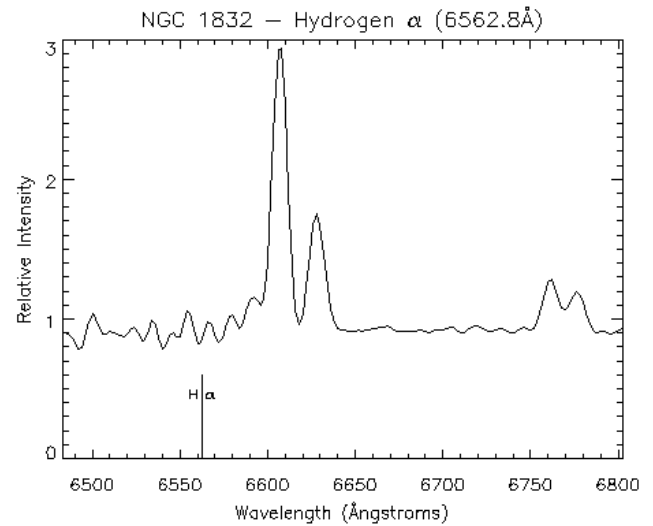
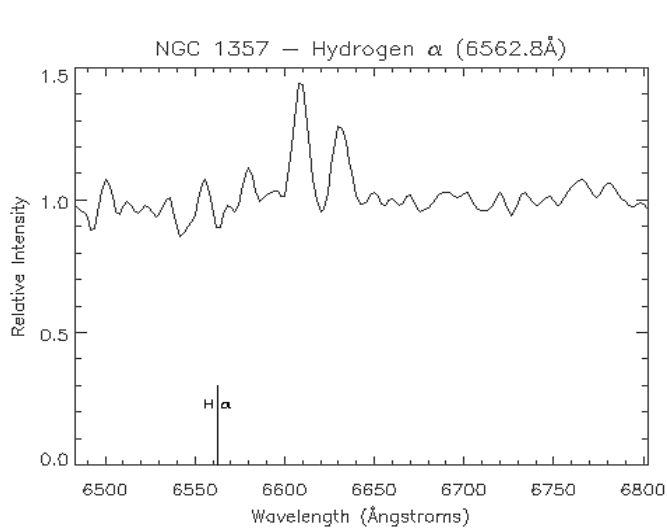


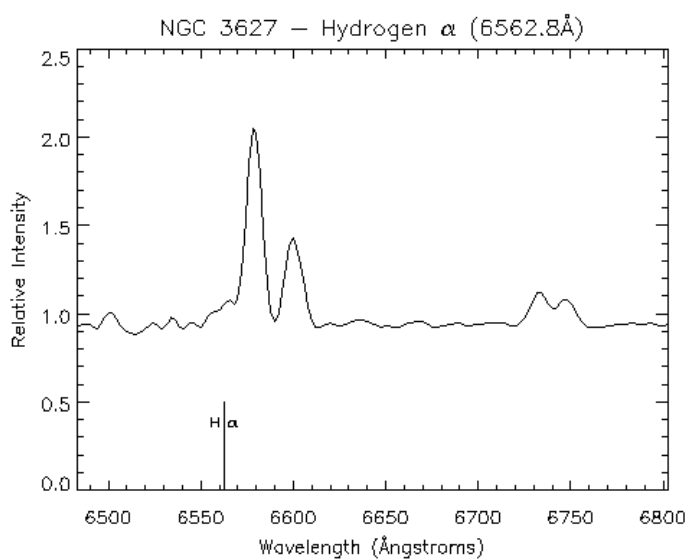
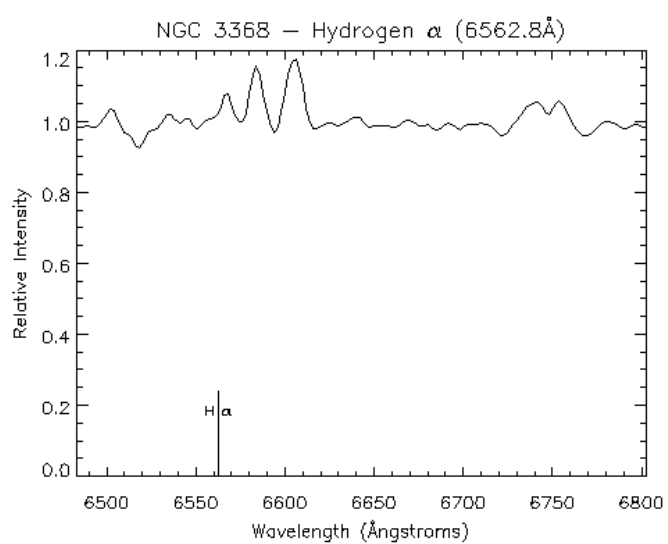
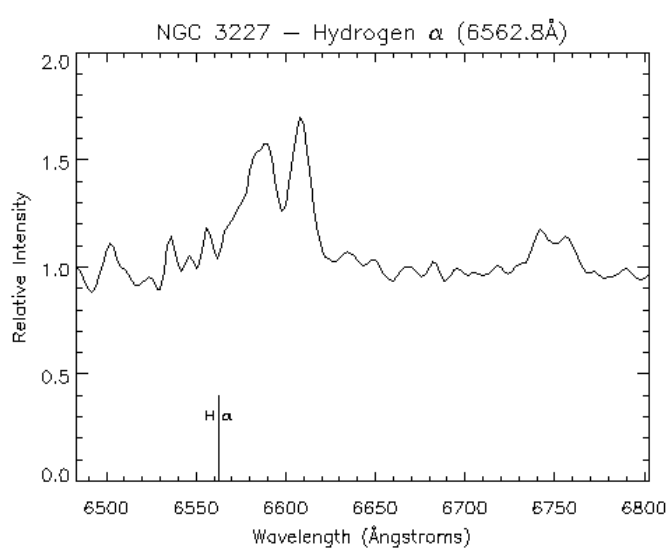
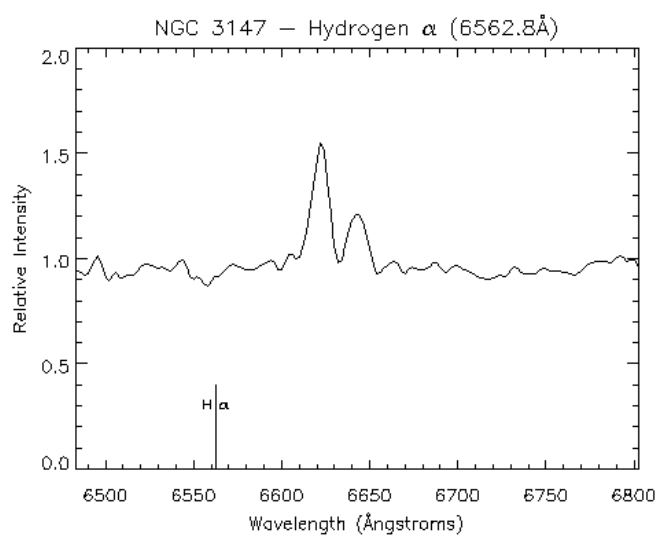
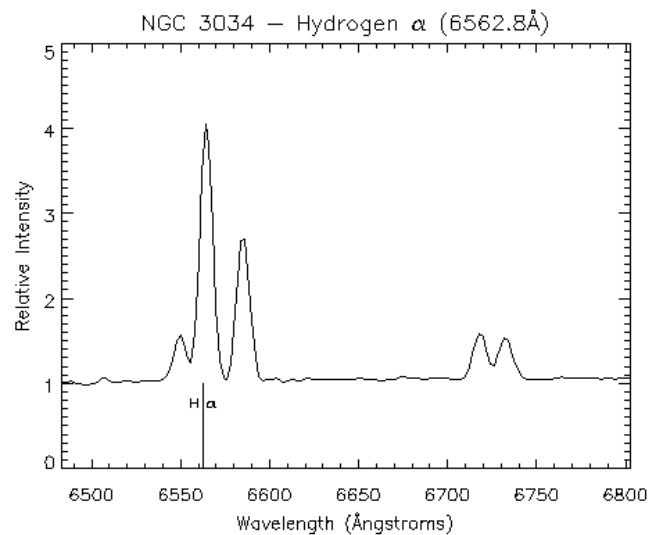
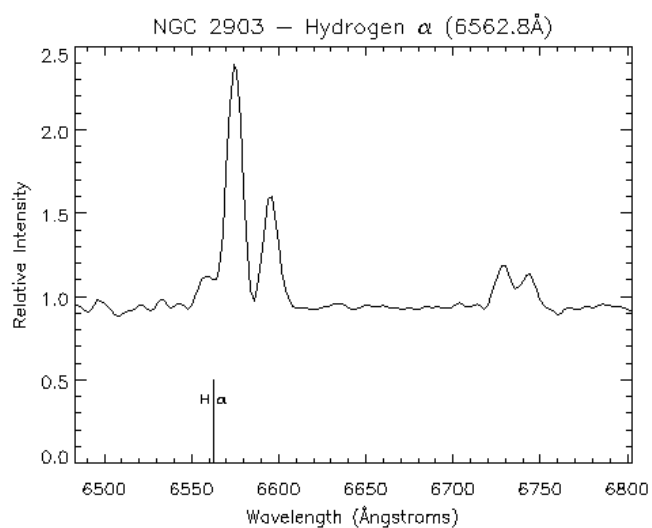
NGC 6181



2. The spectrum data below for the same set of galaxies as in Question 1 are obtained by Robert C. Kennicutt Jr. of the University of Arizona, and are published in The Astrophysical Journal Supplement Series, volume 79, pages 255-284, 1992. Using the data:

- From the spectrum of each galaxy, fill in the observed wavelength of H α (rest wavelength at 6562.8 Å) emission in Table 1.
- Calculate the redshift, z , for each galaxy and fill in the z value in Table 1.
- Based on the value of the z , calculate the radial velocity, v of each galaxy and fill in the v value in Table 1.
- From the values in Table 1, plot a graph of radial velocity v (km/s) against distance from Earth, r (Mpc) on the given graph paper.
- From the plotted graph, what do you get for the Hubble Constant (in units of km/s/Mpc)?
- From the value obtained for the Hubble Constant, calculate the age of the Universe (yr).





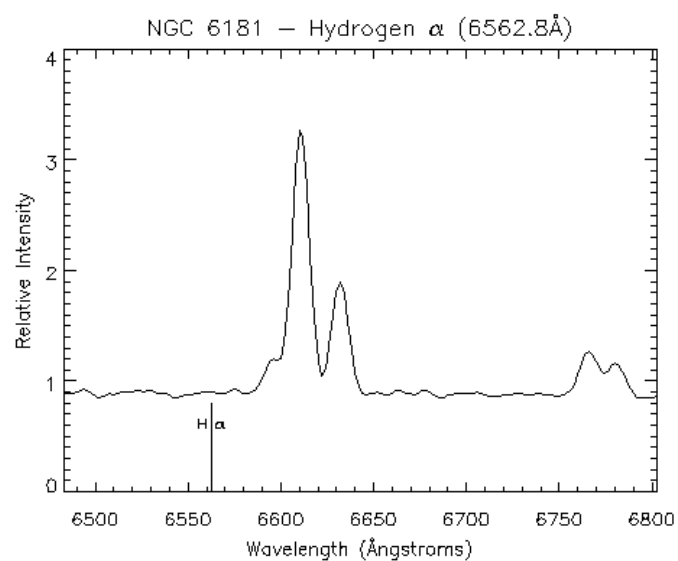
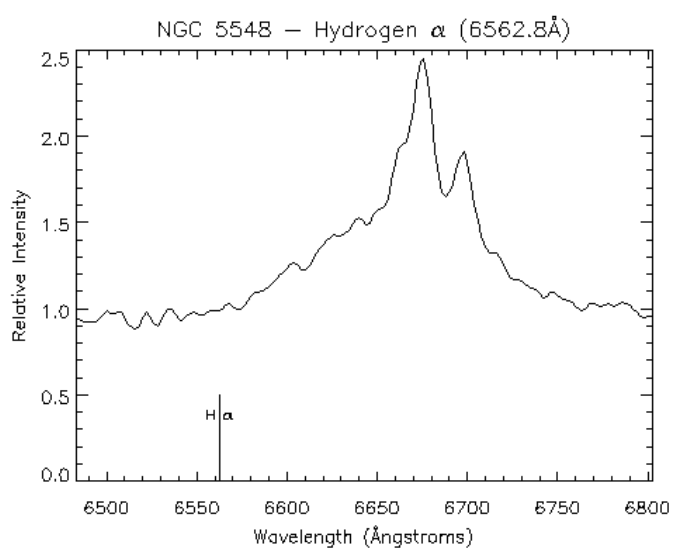
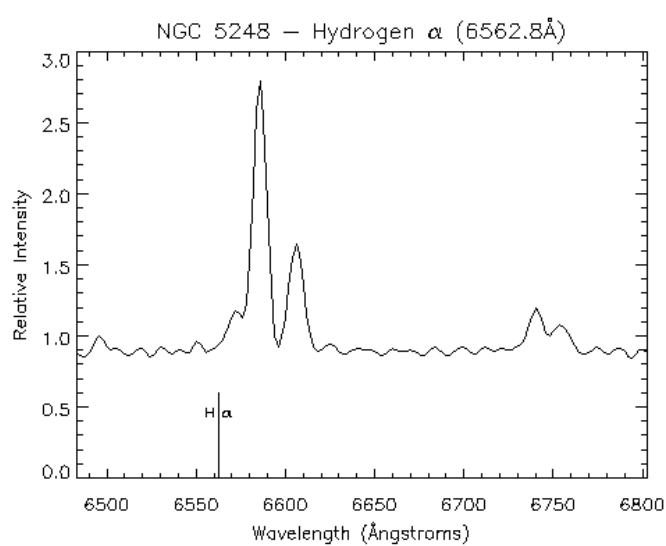
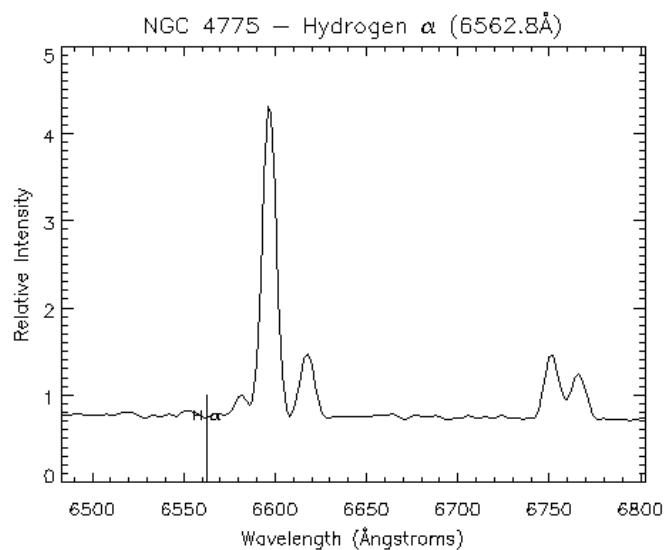


Table 1: Measured results

Galaxy	Width (mm)	Angular Width (arcsecond)	Distance from Earth, r (Mpc)	Observed H α wavelength, $\lambda_{H\alpha}$ (Å)	Redshift z	Radial velocity v (km/s)
NGC 1357		119.221				
NGC 1832						
NGC 2276						
NGC 2775						
NGC 2903						
NGC 3034						
NGC 3147						
NGC 3227						
NGC 3368						
NGC 3627						
NGC 4775						
NGC 5248						
NGC 5548						
NGC 6181						