HW 1

ASTR 8060

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Problem 1:

Coordinates of the stars:

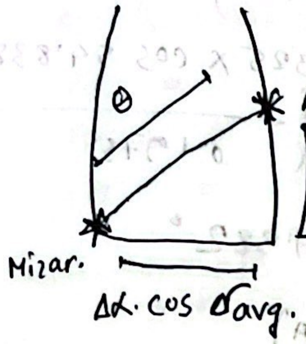
Data from Stellarium

Mizar: Dec. $\delta_m = +54^\circ\ 48'\ 22.3''$

RA, $\alpha_m = 13^h\ 24^m\ 51.3^s$

Alcor: Dec. $\delta_A = +54^\circ\ 52'\ 09''$

RA, $\alpha_A = 13^h\ 26^m\ 09^s$



θ = angular separation [In plane geometry]

δ_{avg} = Average of declination of two stars

$\Delta\delta$ = change of declination

$\Delta\alpha$ = change of RA.

so, $\theta^2 = \Delta\delta^2 + (\Delta\alpha \cos\delta_{avg})^2$ [Pythagorus theorem]

$\Delta\delta = |\delta_A - \delta_M| = (54.869 - 54.806)^\circ$

$= 0.063^\circ = 0.0011$ rad.

$\Delta\alpha = |\alpha_A - \alpha_M| = (201.538 - 201.213)^\circ$

[Small separation, so, plane geom. valid]

$= 0.325^\circ = 0.0057$ rad.

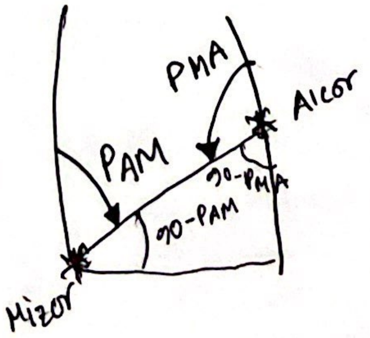
$\delta_{avg} = \dfrac{\delta_A + \delta_M}{2} = \left(\dfrac{54.869 + 54.806}{2}\right)^\circ = 54.838^\circ$

$= 0.9571$ rad

so, $\theta = \sqrt{\Delta\delta^2 + (\Delta\alpha \cos\delta_{avg})^2}$

$= \left(\sqrt{(0.063)^2 + (0.325 \times \cos 54.838^\circ)^2}\right)^\circ$

$= 0.1975^\circ = 0.0034$ rad.



PMA = Position angle of Mizar in respect to Alcor

PAM = Position angle of Alcor in respect to Mizar

$\delta_m = 54^\circ 48' 22.3''$

$= \left(\dfrac{\frac{22.3}{60} + 48}{60} + 54\right)^\circ$

$= 54.806^\circ$

$\delta_A = 54^\circ 52' 09''$

$= \left(\dfrac{\frac{09}{60} + 52}{60} + 54\right)^\circ$

$= 54.869^\circ$

$\alpha_m = 13^h\ 24^m\ 51.3^s$

$= \left(\dfrac{\frac{51.3}{60} + 24}{60} + 13\right)^h$

$= \left(\dfrac{13.414}{24} \times 360\right)^\circ$

$= 201.213^\circ$

$\alpha_A = 13^h\ 26^m\ 09^s$

$= \left(\dfrac{\frac{09}{60} + 26}{60} + 13\right)^h$

$= \left(\dfrac{13.436}{24} \times 360\right)^\circ$

$= 201.538^\circ$

So, $\frac{\cancel{\theta}}{\cancel{\Delta\alpha \cos\delta}} = \cancel{\cos}(90-$

So, $\frac{\Delta\alpha \cos\delta_{avg}}{\theta} = \cos(90 - P_{AM}) = \sin(P_{AM})$

So, $P_{AM} = \sin^{-1}\left(\frac{\Delta\alpha \cos\delta_{avg}}{\theta}\right) = \sin^{-1}\left(\frac{0.325 \times \cos 54.838}{0.1975}\right)$

$= 71.382^\circ$

Again, $\frac{\Delta\delta}{\theta} = \cos(90 - P_{MA}) = \sin(P_{MA})$

or, $P_{MA} = \sin^{-1}\left(\frac{\Delta\delta}{\theta}\right) = \sin^{-1}\left(\frac{0.063}{0.1975}\right) = \cancel{18.602}\ 108.602^\circ$ [should be between $\frac{\pi}{2}$ and π]

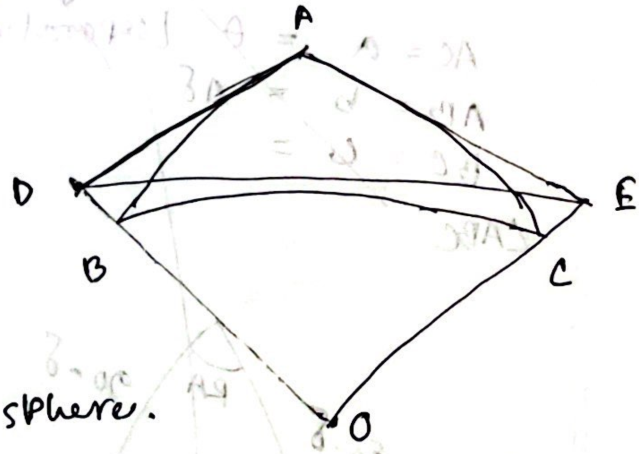
Required answer: $\theta = 0.1975^\circ$

$P_{AM} = 71.382^\circ$

$P_{MA} = \cancel{18.602^\circ}\ 108.602^\circ$

Problem 2: Deriving the law of cosine.

~~Here, A, B, C are~~ is a spherical



ABC be a spherical triangle.

Sides, $AB = c$, $BC = a$, $CA = b$ } all are in angles.

We draw tangents to A on the sphere. (DA & DE)

Then join OD and OE [The went thoug B and C].

In ΔDAE, $DE^2 = AD^2 + AE^2 - 2AD.AE\cos A$ — ① [Plane Geom. cosine formula]

In ΔDOE, $DE^2 = OD^2 + OE^2 - 2OD.OE\cos a$ — ②

So, $DE^2 = DE^2$ or, $AD^2 + AE^2 - 2AD.AE\cos A = OD^2 + OE^2 - 2OD.OE\cos a$

$\Rightarrow 2OD.OE\cos a = (OD^2 - AD^2) + (OE^2 - AE^2) + 2AD.AE\cos A$ — ③

ΔDAO is plane triangle right-angled at A. because DA is a tangent to AB at A and OA is radius.

By Pythagoras,

$OD^2 - AD^2 = AO^2$

Similarly in ΔOAE, $OE^2 - AE^2 = AO^2$

So, Eqn ③, $2OD.OE\cos a = AO^2 + AO^2 + 2AD.AE\cos A$

$\Rightarrow OD.OE\cos a = AO^2 + AD.AE.\cos A$

$\Rightarrow \cos a = \frac{OA}{OD}.\frac{OA}{OE} + \frac{AD}{OD}.\frac{AE}{OE}\cos A$

In ΔOAD. $OA/OD = \cos\angle DOA$

$AD/OD = \sin\angle \cancel{DOA}\, DOA$ | Also, $\angle DOA = c$, $\angle AOE = b$

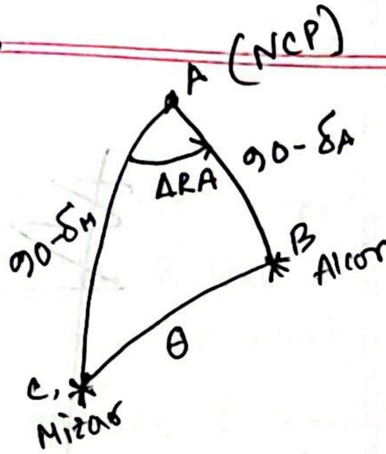
So, $OA/OE = \cos\angle AOE$

$AE/OE = \sin\angle AOE$

So, $\cos a = \cos b.\cos c + \sin b.\sin c\cos A$

Suppose, the stars are Alcor and Mizar,

If we consider the figure on the right,



We need to find out BC,

which is the angular separation.

So, $BC = \theta = a$

$AC = 90-\delta_M = b$

$AB = 90-\delta_A = c$

$\angle CAB = \Delta RA = |\alpha_M - \alpha_A| = A$

So, in the cosine formula, $\cos a = \cos b \cos c + \sin b \sin c \cos A$

It can be written as, $\cos\theta = \cos(90-\delta_M)\cos(90-\delta_A) + \sin(90-\delta_M)\sin(90-\delta_A)\cdot\cos(\alpha_M-\alpha_A)$

or, $\cos\theta = \sin\delta_M \cdot \sin\delta_A + \cos\delta_M \cdot \cos\delta_A \cdot \cos(\alpha_M - \alpha_A)$

or, $\theta = \cos^{-1}\left(\sin\delta_M \cdot \sin\delta_A + \cos\delta_M \cdot \cos\delta_A \cdot \cos(\alpha_M-\alpha_A)\right)$

From Problem ①, $\theta = \sqrt{(\delta_M-\delta_A)^2 + \left((\alpha_M-\alpha_A)\cdot\cos\left(\frac{\delta_M+\delta_A}{2}\right)\right)^2}$

Now, if we make plot of both of them,

Table:

δ_M	δ_A	α_M	α_A	θ_{plane}	θ_{spher}
30	31	180	175	4.4226	4.4222
30	35	180	160	17.5933	17.5580
30	40	180	145	30.3642	30.1366
30	45	180	130	42.4090	41.6534
30	50	180	115	53.6594	51.8092
30	55	180	100	64.0617	60.2753
32	-81	175	75	145.0838	123.1226
32	-85	175	~~160~~ 130	~~12.6620~~ 166.1633	~~12.8491~~ 103.1112
32	40	175	145	25.5550	25.4137

If we compare θ_{plane} and θ sphere like the graph above, we can see for larger θ (angular separation), the difference will be larger.

But when both α (RA) will be equal, or both δ (DEC) is 0, ~~or bot δ (DEC) will be 0~~, then the θ_{plane} and θ sphere will be same. These are the special cases.

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Problem 3:

The tools we are using will convert from Galactic coordinates to Equatorial coordinates. So we need the Galactic coordinates of all these points in the sky at first

Point in the sky	Galactic longitude (l)	Galactic latitude (b)
Galactic Center	$0°$	$0°$
Galactic Anticenter	$180°$	$0°$
North Pole*	$0°$	$+90°$
South Pole*	$0°$	$-90°$
Points of intersection of ecliptic and galactic plane**	$0°, 180°$	$0°$

* Longitude can be anything for North pole and South pole.

** We know that the galactic center is at sagittarius which is a zodiac, means it's also on the ecliptic. So, sagittarius should be one point. Another point should be 180° away from Sagittarius.

Now using the tools, we can find out the RA and DEC of these points:

Points in the sky	RA (α)	DEC (δ)
Galactic center	$17^h 45^m 37^s.21$	$-28^{\circ}.9361$
Galactic Anticenter	$05^h 45^m 37^s.17$	$+28^{\circ}.9361$
Gal. North Pole	$12^h 51^m 26^s.28$	$+27^{\circ}.1284$
Gal. South Pole	$00^h 51^m 26^s.27$	$-27^{\circ}.1283$
Points of intersection of ecliptic and galactic plane.	$17^h 45^m 37^s.21$	$-28^{\circ}.9361$
	$05^h 45^m 37^s.17$	$+28^{\circ}.9361$

[NASA/IPAC Extragalactic database]

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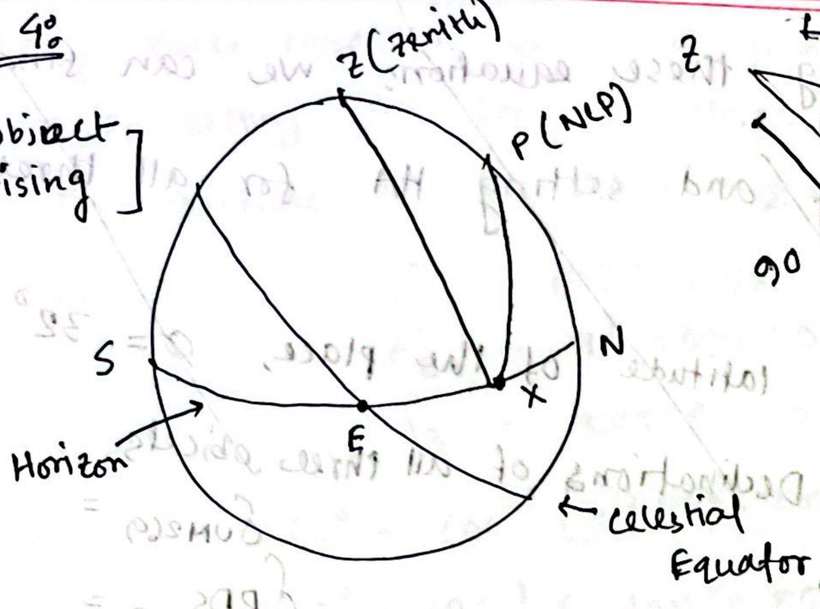
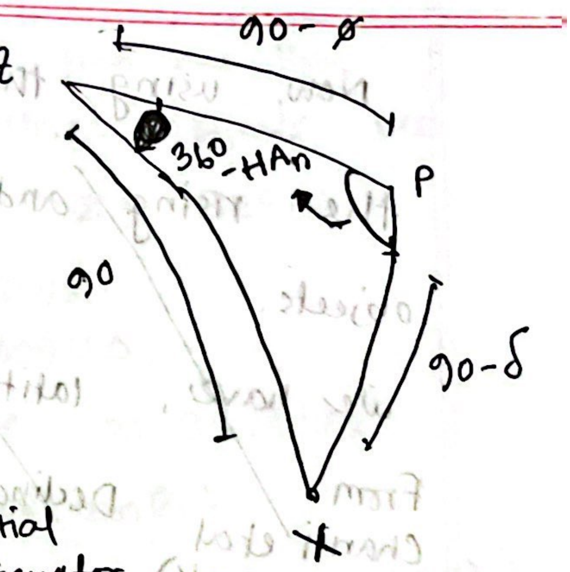
Problem 4:

[x is the object when rising]





Using cosine equation in the spherical triangle PZX,

$$\cos 90° = \cos(90-\delta)\cos(90-\phi) + \sin(90-\delta)\sin(90-\phi)\cos(360°-HA_r).$$

[solving for HA],

or,

$$\frac{\cos 90° - \cos(90-\delta)\cos(90-\phi)}{\sin(90-\delta)\sin(90-\phi)} = \cos(360°-HA_r)$$

or,

$$\frac{0 - \sin\delta\sin\phi}{\cos\delta \cdot \cos\phi} = \cos(360°-HA_r)$$

or,

$$-\tan\delta\tan\phi = \cos(360°-HA_r)$$

or,

$$360° - HA_r = \cos^{-1}(-\tan\delta\tan\phi)$$

or,

$$HA_r = 360° - \cos^{-1}(-\tan\delta\tan\phi)$$

[HA_r is the HA at the time of rising]

At the time of setting it will be,

$$HA_s = 360° - HA_r$$
$$= \cos^{-1}(-\tan\delta\tan\phi)$$

Now using these equation we can find out the rising and setting HA for all three objects. We have, the latitude of the place, $\phi = 32^\circ N$

and declinations $\delta_1 = 0.8542910$

$\delta_2 = 34.5304110$

$\delta_3 = \cancel{33.1} - 21.3277778$

So, $HAr_1 = 360^\circ - \cos^{-1}(-\tan\delta_1 \tan\phi_1)$

$= 360^\circ - \cos^{-1}(-\tan(0.8542910) \cdot \tan(32))$

$= 269.4661324^\circ$

$= 17.9644^h$

$HAs_1 = 360^\circ - 269.4661324^\circ$

$= 90.53386755^\circ$

$= 6.0356^h$

$HAr_2 = 360^\circ - \cos^{-1}(-\tan(34.5304110) \cdot \tan(32))$

$= 244.5356566$

$= 16.3024^h$

$HAs_2 = 360^\circ - 244.5556566^\circ$

$= 115.4643434$

$= 7.6976^h$

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$$HA_{r_3} = 360° - \cos^{-1}(-\tan(-21.3277778)\tan(32))$$

$$= 284.1212936°$$

$$= 18.9414^h$$

$$HA_{s_3} = 360° - 284.1212936°$$

$$= 75.87870638°$$

$$= 5.0586^h$$

We also have the right ascesion (RA) of all three objects. ~~with~~ (Chanişi et al (2016))

which are $\alpha_1 = 10.8322440° = 0.7221^h$

$\alpha_2 = 234.2429720° = 15.6162^h$

$\alpha_3 = 331.6725000° = 22.1115^h$

We know, $LST = HA + RA$ [LST is local sidereal time]

So, for UM 269,

Rising sidereal time, $LST_{r_1} = HA_{r_1} + \alpha_1$

$$= 17.9644^h + 0.7221^h$$

$$= 18.6865^h$$

Setting sidereal time, $LST_{s_1} = HA_{s_1} + \alpha_1$

$$= 6.0356^h + 0.7221^h$$

$$= 6.7577^h$$

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For PDS 808,

Rising sidereal time,

$$LST_{r_2} = HA_{r_2} + \alpha_2$$
$$= 16.3024^h + 15.6162^h$$
$$= \cancel{31.9186^h}$$
$$= 7.9186^h$$

[The time repeats after 24^h]

Setting sidereal time,

$$LST_{s_2} = HA_{s_2} + \alpha_2$$
$$= 7.6976^h + 15.6162^h$$
$$= 23.3138^h$$

For ~~PKS~~ PKS 2203-215,

Rising sidereal time,

$$LST_{r_3} = HA_{r_3} + \alpha_3$$
$$= 18.9414^h + 22.1115^h$$
$$= 17.0529^h$$

Setting sidereal time,

$$LST_{s_3} = HA_{s_3} + \alpha_3$$
$$= 5.0586^h + 22.1115^h$$
$$= 3.1701^h,$$

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We know, Local Mean Solar time (LMST)$_\odot$

$= HA_{mean\_sun} + 12^h$

comparing this with equation, $LST_\odot = HA_\odot + RA_\odot$

We get to know that $LMST = LST_\odot$ will be true when Sun's RA is 12^h.

So, at September 23^{rd}, ~~12:00 AM,~~ ~~Sun's~~ local time and local sidereal time will be same.

September 1, is 22 days before, or, $(365.25 - 22) = 343.25$ days after September 23^{rd}.

So, the difference between local time and local sidereal time on September 1st will be,

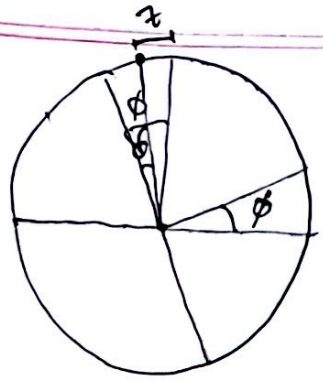
$$\left(24^h - 24^h \times \frac{343.25}{365.25}\right)$$

$$= 1.4456^h$$

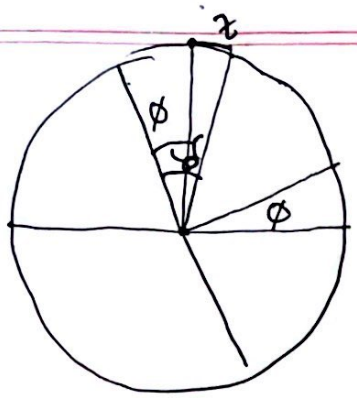
For each of the LST that we got, we need to subtract 1.4456^h to get the local time.

We can make the following table based on this.

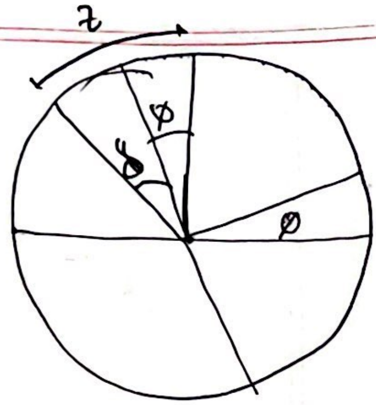
Object Name	Local Rising time	Local Setting time
UM 269	$17.2409^h = 17^h 14^m 27^s$	$5.3121^h = 5^h 18^m 44^s$
PDS 898	$6.473^h = 6^h 28^m 23^s$	$21.8682^h = 21^h 52^m 6^s$
PKS 2203-215	$15.6073^h = 15^h 36^m 26^s$	$1.7245^h = 1^h 43^m 28^s$



UM 269



~~PKS 898~~ ~~2203-215~~
PDS 898



~~PKS 2203-215~~
~~PDS~~ PKS 2203 -215

For each of the cases zenith angle $z = |\phi - \delta|$

For. UM 269, $z = |\phi - \delta| = |32 - 0.8542910|^\circ$

$= 31.145709^\circ$

Minimum Airmass $= \frac{1}{\cos z} = \frac{1}{\cos(31.145709)} = 1.1684$

For ~~PKS 2203-215~~, ~~PDS 898~~, PDS 898, $z = |\phi - \delta| = |32 - 34.5304110|^\circ$

$= 2.5304^\circ$

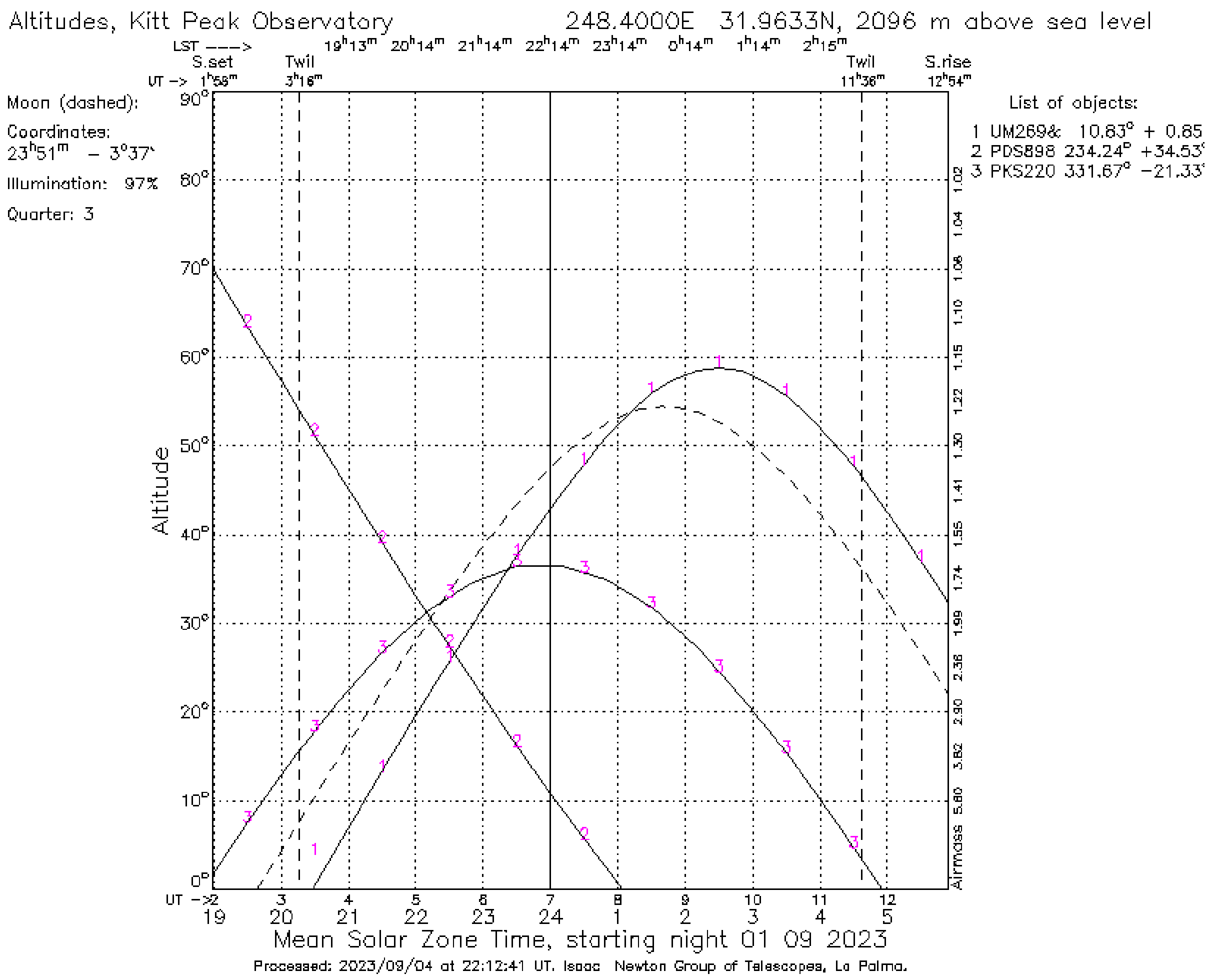
Min. airmass $= \frac{1}{\cos z} = \frac{1}{\cos(2.5304)^\circ} \approx 1$

for ~~PDS 898~~ ~~PKS 2203-215~~, PKS, 2203-215 $z = |\phi - \delta| = |32 - (-21.3277778)|$

$= 53.3277778$

Min. airmass $= 1.6744$

Problem 5:



I plotted them through the following website: http://catserver.ing.iac.es/staralt/index.php

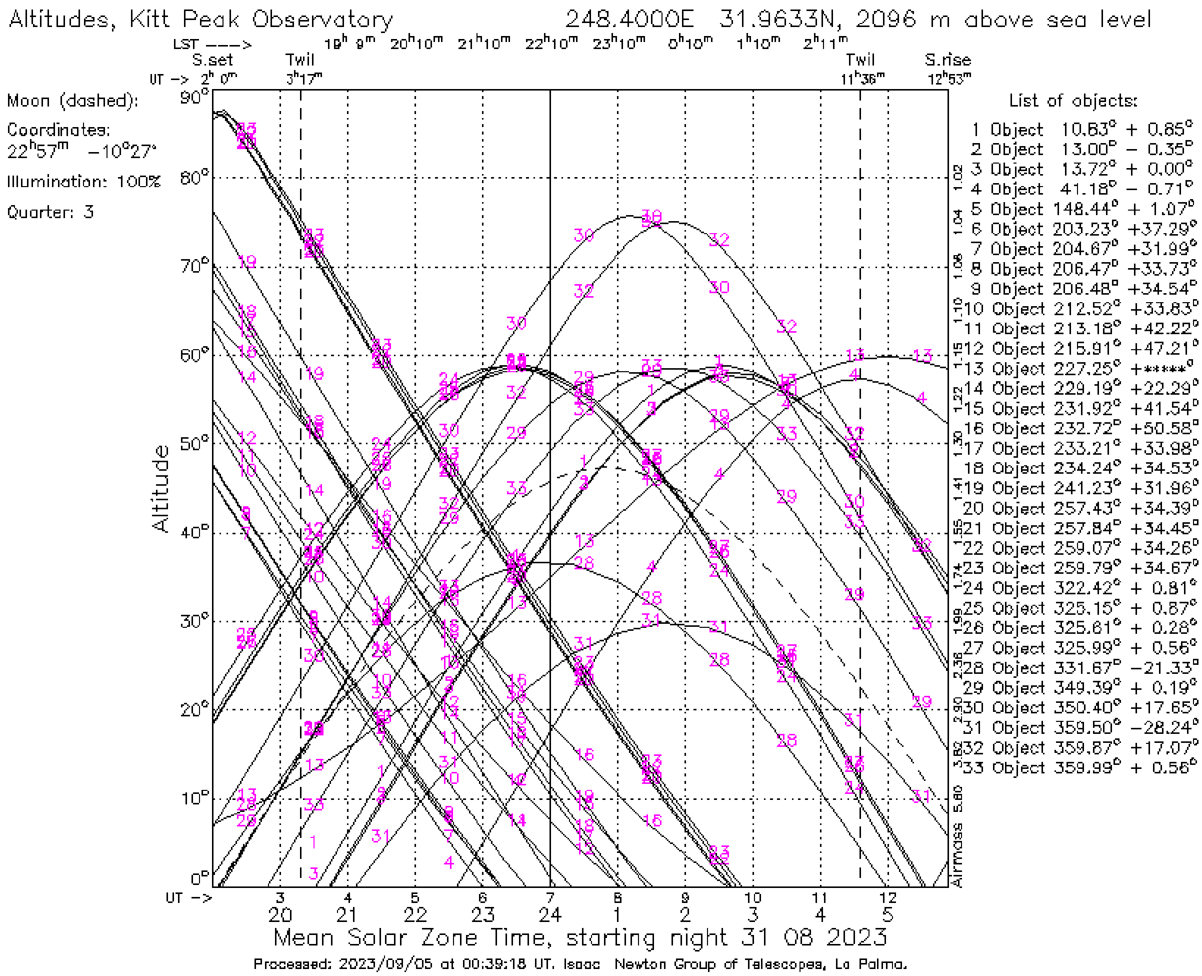
The highest air mass for all these objects will be,

UM269, X = 1.18 (I got 1.1684 in the previous problem)

PDS898, X = 1.08 (I got 1 in the previous problem)

PKS2203-215, X = 1.7 (I got 1.6744 in the previous problem)

Plot for al the bold letter objects will be as the following:



Object Name	RA	DEC	No. designated in the plot
UM 269∗	10.8322440	0.8542910	1
SDSS J005158.83-002054.1	12.9951310 ∗	-0.3483820	2
SDSS J005453.30-003258.3	13.7221040	-0.0.5495320	3
SDSS J024442.77-004223.2	41.1782445	-0.7064567	4
2QZ J095344.7+010354	148.4366915	1.0651954	5
SDSS J133254.51+371735.5	203.2271569	37.2932211	6

SDSS J133840.66+315936.4	204.6694431	31.9934505	7
SDSS J134553.57+334336.0	206.4732442	33.7266720	8
SDSS J134556.16+343224.5	206.4840056	34.5401540	9
SDSS J141004.41+334945.5	212.5184030	33.8293160	10
SDSS J141244.09+421257.6	213.1837413	42.2160210	11
SDSS J142339.44+471240.8	215.9143459	47.2113337	12
SDSS J150900.70+175114.3	227.2529518	117.8539974	13
SDSS J151646.10+221724.7	229.1921240	22.2902190	14
SDSS J152739.97+413234.6	231.9165420	41.5429560	15
SDSS J153051.79+503440.1	232.7158316	50.5778224	16
SDSS J153251.06+335852.2	233.2127605	33.9811873	17
PDS 898	234.2429720	34.5304110	18
SDSS J160454.57+315733.5	241.2273914	31.9593278	19
SDSS J170942.58+342316.2	257.4274310	34.387850	20
SDSS J171122.67+342658.9	257.8444609	34.4497191	21
SDSS J171617.49+341553.3	259.0728780	34.2648190	22
SDSS J171909.93+344001.3	259.7914157	34.6670451	23
SDSS J212939.60+004845.5	322.4150072	0.8126513	24
SDSS J214036.77+005210.1	325.1532346	0.8694920	25
SDSS J214225.29+001643.2	325.6054161	0.2786872	26
SDSS J214357.98+003349.6	325.9916181	0.5638052	27
PKS 2203-215	331.6725000	-21.3277778	28
SDSS J231733.66+001128.3	349.3902730	0.1912120	29
SDSS J232135.73+173916.5	350.3988982	17.6546025	30
2QZ J235800.2-281429	359.5011112	-28.2413889	31
SDSS J235928.99+170426.9	359.8708046	17.0741612	32
SDSS J235958.72+003345.3	359.9946880	0.5625920	33

Problem 6:

Acronym	Full Name	Location	Aperture Size	Wavelength range or Photometric band	Website link
Nu-STAR	Nuclear Spectroscopic Telescope Array	Outer space	0.064 meters	X-ray	https://www.nustar.caltech.edu/
Chandra	Chandra X-ray Observatory	Outer space	0.10 meters	X-ray	https://chandra.harvard.edu/
HST	Hubble Space Telescope	Outer space	2.4 meters	Near IR, Visible light, Ultraviolet	https://www.nasa.gov/mission_pages/hubble/main/index.htm
Gemini	Gemini Observatory (Gemini North & Gemini South)	Hawaii & Chile	8.1 meters (aperture for both telescopes)	Optical, Near IR	https://www.gemini.edu/
SOAR	Southern Astrophysical Research Telescope	Chile	4.1 meters	Near IR, Visible	https://noirlab.edu/science/programs/ctio/telescopes/soar-telescope
LCO	Las Cumbres Observatory	Varies (HQ in California)	Varies for different telescopes	Near IR, Visible, Near UV	https://lco.global/
Spitzer	Spitzer Space Telescope	Outer space	0.85 m (aperture)	IR	https://www.spitzer.caltech.edu/
JWST	James Webb Space Telescope	Outer Space (Second Lagrange Point L2)	6.5 meter (aperture)	Orange to mid IR	https://webb.nasa.gov/
ALMA	Atacama Large Millimeter Array	Atacama desert, Chile	Array of 66 radio antennas	Millimeter and submillimeter wavelengths	https://www.almaobservatory.org/en/home/
NOEMA	Northern Extended Millimeter Array	France Alps	Array of 10 radio antennas	Millimeter and submillimeter wavelengths	https://iram-institute.org/observatories/noema/
VLBA	Very Long Baseline Array	Multiple locations is USA	Array of 10 radio antennas	Radio	https://science.nrao.edu/facilities/vlba
VLA	Very Large Array	Socorro, New Mexico, USA	Array of 27 radio antennas	Radio	https://science.nrao.edu/facilities/vla

Problem 7:

<u>The Kitt Peak Direct Imaging Manual:</u>

This manual is invaluable for astronomers using the Kitt Peak telescopes for direct imaging observations. It provides detailed instructions on instrument setup, data acquisition, and data reduction specific to these telescopes. The manual covers topics such as telescope and instrument descriptions, observing procedures, calibration, data reduction, and examples of typical observations.

<u>Photometric Standards: Landolt, 1992, AJ, 104, 340:</u>

Landolt's photometric standards paper is essential for astronomers conducting photometric observations. It provides a comprehensive list of standard stars with known magnitudes in various photometric bands. The paper includes tables of standard stars with their equatorial coordinates, magnitudes, and color indices in the UBVRI photometric systems. These standards serve as a reference for calibrating astronomical photometric observations.

<u>A User's Guide to Stellar CCD Photometry with IRAF: Massey & Davis, 1992:</u>

This paper is essential for astronomers using IRAF (Image Reduction and Analysis Facility) for CCD photometry. It offers a step-by-step walkthrough of CCD data reduction and photometry processes. The paper covers topics such as data acquisition, data reduction, aperture photometry, PSF-fitting photometry, and calibration. It provides practical examples and IRAF scripts.

<u>A User's Guide to CCD Reductions with IRA: Massey, 1997:</u>

This guide complements the previous one and is also crucial for astronomers using IRAF for CCD data reduction. It delves deeper into the reduction techniques and IRAF procedures. The paper provides detailed explanations of CCD data reduction processes, including bias subtraction, flat-fielding, image alignment, and calibration. It includes IRAF commands and scripts for each step.

Additional Papers:

<u>"Astronomy Principles and Practices" byAE Roy, and D Clarke:</u>

This book offers a broad overview of observational techniques in astronomy. Chapter 6, 7, 8 are the most import one to review coordinate systems, spherical trigonometry, and astronomical time systems.

<u>The Astronomical Almanac:</u>

This annually updated publication provides essential astronomical data, including positions of celestial objects, rising and setting times, and lunar information. It's a handy reference for planning observations.