Lesson 6, 7 and 8 (Methods of astronomy and space astornomy)

2021年5月18日 11:06

Constellations

1. How many constellations are there?
2. Are the constellation names and their boundaries unambiguously defined?
3. If "yes", who defined them? How can we know that?

   The Constellation by International Astronomical Uniton (IAU)

4. Is the "Crab nebula" (05 38 56.6, -64 05 03.3, ICRS) located in the constellation Crab?
   No!

   Crab nebular with optical (DSS) and X-ray (Chandra) displayed with JUDO2 at DARTS/JAXA

Expression of the coordinates

1. Explain the two expressions to express values of the coordinates.
   Take an example Cyg X-1:
   (RA, DEC) = (19 58 21.68, 35 12 05.8) or (299.590316, 35.201606) in J2000

   Useful web-tools: SIMBAD, Coordinate Converter, JUDO2

2. What are the conversion formulae between them?

Naming of X-ray sources

1. The first celestial X-ray source, Sco X-1, was discovered in 1962. Since then, how are the X-ray sources named?

   Cyg X-1, LMC X-1, GX339-4, 1A0620-00, GS1124-68, PSR B1509-58, GRO J1655-40, MAXI J1348-630, etc.

   GX339-4 means "Galacitc X-ray source at galactic coordinates (l,b)=(339, -4)

   X-ray sources around the Galactic Center displayed with JUDO2 MAXI and Swift/BAT images, Suzaku pointing fields superposed

Precession of the equinoxes and epoch

1. Explain precession of the equinoxes and epoch.

   B1950--> based on the equinox 1950
   J2000 --> based on the equinox 2000

2. Explain the International Celestial Reference Frame (ICRF) or System (ICRS).

   Based on the Barycenter of the solar system --> We do not have to worry about presession of Earth!

3. How can we convert B1950 coordinates to J2000 (ICRF) or vice versa?
   --> Use COCO, or any converters!

Coordinate conversion

1. Explain the three astronomical coordinates, equatorial coordinates, ecliptic coordinates, and Galactic coordinates.

   Animation to explain the equatorial to galactic coordinates

2. Find (web) tools to carry our these coordinate conversions?

3. Write a simple program by yourself to carry our these coordinate conversions.

   R programs to conver Cyg X-1 equatorial coordinates to ecliptic or to galactic coordinates

Output of COCO for Cyg X-1

Target Cyg X-1 resolved by SIMBAD (local cache)

J2000		B1950		Galactic		Ecliptic	
RA	Dec	RA	Dec	L	B	Lon	Lat
19 58 21.68	35 12 05.8	19 56 28.87	35 03 54.5	71 20 06.0	03 04 00.6	313 40 24.7	54 14 44.8
299.590316	35.201606	299.120291	35.065134	71.334990	3.066836	313.673532	54.245772

Season and observability

1. We would like to observe the famous black hole binaries **Cyg X-1** (19 58 21.7, +35 12 05.8, ICRS) and **LMC X-3** (05 38 56.69, -64 05 03.3, ICRS) with ground "optical telescopes". Where and when can we observe them?
   How many times do we have the "best" observation periods (the target is near the zenith in midnight) per year?

   Once (when the source is located opposite to the Sun)

   Visibility tool by Nordic Optical Telescope

2. What if using ground "radio" telescopes?

   You may observe in day-time, so you may choose the "best" priod all-around year.
   (However, you may not observe very close to the Sun.)

3. What if using "ordinary" astronomical satellites, where the telescope is pointing perpendicular to the "fixed" solar panel? (*Sun angle* is ~90 degree)
   How many times do we have the "best" observation periods (Sun is perpendicular to the solar-panel) per year?
   Usually, twice a year, when the target is papendicular (90 degree apart) to Sun.
   If the source is close to NEP or SEP, the source is always observable.

   Cyg X-1 observation log by Suzaku
   LMC X-3 observation log by Suzaku

   Cyg X-1 obervability by HEASARC's viewing
   LMC X-3 obervability by HEASARC's viewing

4. For most astronomical satellites, where the telescope is pointing perpendicular to the "fixed" solar panel, there are two locations on the sky which are always observable. Where are they (their coordinate in the equatorial coordinates and ecliptic coordinates)?

   The ASCA Slew survey

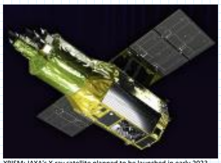
   XMM-Newton satellite slew track (in galactic coordinates)

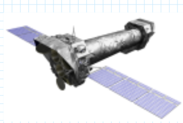
   Akari all-sky survey (from you tube)

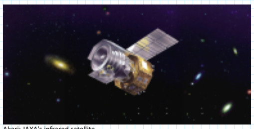
   eRosita (launched in 2019) exposure map (in equatorial coordinates)

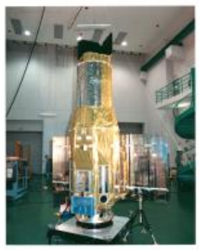
   eRosita movie by DLR (from you tube)


Suzaku: JAXA's X-ray satellite (2005-2015)
https://www.jaxa.jp/projects/sas/astro_e2/images/astro_e2_main_001.jpg


XRISM: JAXA's X-ray satellite planned to be launched in early 2023
https://xrism.isas.jaxa.jp/


XMM: ESA's X-ray satellite
https://cdn.sci.esa.int/documents/33839/35420/1567214419597-XMM-Newton_spacecraft_Al_02_625.jpg


Akari: JAXA's infrared satellite
https://www.isas.jaxa.jp/missions/files/akari_main.jpg

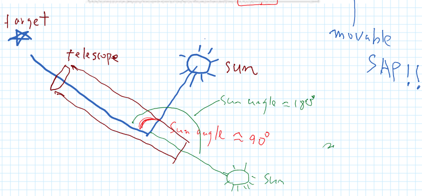

ASCA: JAXA's X-ray satellite (1993-2000)
http://www.astro.isas.jaxa.jp/asca/outline/photo/asca1.jpg

To check observability of targets, use HEASARC's "viewing" at https://heasarc.gsfc.nasa.gov/cgi-bin/Tools/viewing/viewing.pl

Viewing

Determine when or if an astronomical position can be viewed by a given space

Select one or more space telescopes:
- Chandra, allowed Sun angle range = 46.4-170
- HST, allowed Sun angle range = 60-180
- IXPE (planning), allowed Sun angle range = 65-115
- NICER, allowed Sun angle range = 45-180
- NuSTAR, allowed Sun angle range = 43-180
- Swift, allowed Sun angle range = 47-180
- XMM-Newton, allowed Sun angle range = 70-110
- XRISM, allowed Sun angle range = 60-120



Satellite Attitudes and observing targets

Below, we consider astronomical satellites where the spin axis is Z-axis and the solar-panel is toward Y-axis, and the telescope is along the Z-axis, which is toward the observing target.

The "Euler angles" to describe the satellite attitude are defined as sequential rotation around Z,Y,Z axis, (ϕ, θ, ψ).

1. Express the 3D rotation matrix using the Euler angles (ϕ, θ, ψ).

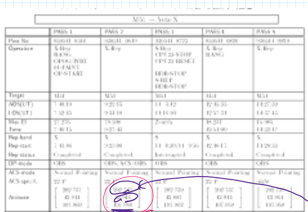
$$(\mathbf{e}_1'', \mathbf{e}_2'', \mathbf{e}_3'') = (\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3) \begin{pmatrix} \cos\phi & -\sin\phi & 0 \\ \sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{pmatrix} \begin{pmatrix} \cos\psi & -\sin\psi & 0 \\ \sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (4.41)$$

$$= (\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3) \begin{pmatrix} \cos\phi\cos\theta\cos\psi - \sin\phi\sin\psi & -\sin\phi\cos\psi - \cos\phi\cos\theta\sin\psi & \cos\phi\sin\theta \\ \sin\phi\cos\theta\cos\psi + \cos\phi\sin\psi & \cos\phi\cos\psi - \sin\phi\cos\theta\sin\psi & \sin\phi\sin\theta \\ -\sin\theta\cos\psi & \sin\theta\sin\psi & \cos\theta \end{pmatrix} \quad (4.42)$$

2. Explain the relationship between the Euler angles and the satellite attitude

3. Explain the relationship between the first two Euler angles (ϕ, θ) and the equatorial coordinates of the observing target (α, δ).

ASCA observation report on 1993/05/11 (https://data.darts.isas.jaxa.jp/pub/asca/isas_reports/0080_930511.ps)



Object Name or Coordinates: M51
(e.g., Cyg X-1 or 101.295, -16.699 or 6
Input Coordinate System: J2000
Name Resolvers: GRB, then SIMBAD else VizieR (Sesame), then NED
Use local caches
Special Equinox:
Find Target/Convert Coordinates | Reset

Target M51 resolved by SIMBAD (local cache)

J2000		B1950		Galactic		Ecliptic	
RA	Dec	RA	Dec	L	B	Lon	Lat
13 29 52.70	47 11 42.9	13 27 46.32	47 27 10.6	104 51 06.7	68 33 38.5	175 07 26.0	50 56 07.3
202.469575	47.195258	201.943004	47.452940	104.851863	68.560732	175.123876	50.935355

4. Explain the relationship between the third Euler angle and the "roll-angle" of the observation. (See the power-point file to illustrate the relationship)

5. North Ecliptic Pole (NEP) and South Ecliptic Pole (SEP) are observable all around the year. What are the Euler angles to observe NEP and SEP in Sprint equinox, Summer solstice, Autumn equinox and Winter solstice.

	NEP (270, 66.6)	SEP (90, -66.6)
Spring	(270, 23.4, 0)	(90, 156.6, 180)
Summer	(270, 23.4, 90)	(90, 156.6, 90)
Autumn	(270, 23.4, 180)	(90, 156.6, 0)
Winter	(270, 23.4, 270)	(90, 156.6, 270)

6. The Suzaku satellites observed the NEP region several times at different seasons. Using JUDO2, see how the roll-angle changes with seasons.

Satellite attitudes and quaternion (q-parameters)

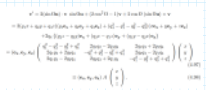
Look at an example of the ASCA satellite attitude file (on the right-hand side), where four numbers are given every 0.5 sec.

1. Calculate the "norm" of these four numbers. What are these numbers?

   Unit quaternion (単位四元数)

2. Explain that the unit-quaternion describe rotation in the three dimensional space. (see my lecture note in 2016, section 4.4)

3. Derive the relationship between the 3D rotation matrix and quaternion



4. What is the merit of using quaternion to describe satellite attitudes (or any 3D rotations) instead of Euler angles?

   The rotation axis and angle are directly given from quaternion.

5. Carry out a single rotation around a rotation axis from equatorial coordinate to Galactic coordinate using quaternion?

   Amination to illustrate the Euler rotations
   Animation to illustrate the single rotation

6. How can we perform satellite maneuver from the attitude described by the quaternion "p" to the one described by "q"?

   The new quaternion "qp^-1" gives the maneuver from "p" to "q", defining the rotation axis and the rotation angle.

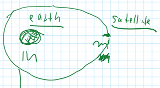
   Animation to illustrate the satellite attitude maneuver from "p" to" q"?

7. How can we "average" two satellite attitudes?

   Carry out a half rotation around that axis.

An example of ASCA attitude file, taken from https://data.darts.isas.jaxa.jp/pub/asca/asca_rev2/10010100/aux/fa930407_0233.0414.gz

TIME	QPARAM
8.303602855937183E+06	-4.214137818602299E-01
	-3.671628422241615E-01
	-6.068271680427795E-01
	5.651218097661020E-01
8.303603355954587E+06	-4.214115784132074E-01
	-3.671743574955190E-01
	-6.068260876402793E-01
	5.651171313420200E-01
8.303603855931759E+06	-4.214093076125627E-01
	-3.671826415753114E-01
	-6.068261489914747E-01
	5.651133763090849E-01
8.303604355949163E+06	-4.214079773178000E-01
	-3.671884697731878E-01
	-6.068265887438722E-01
	5.651101091929086E-01



Two body problem

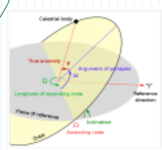
Satellite orbits, orbital six parameters, Two Line Elements (TLE)

Solve!

1. What are the orbital "six parameters"? Explain the meaning of each parameter.

   1 Semimajor axis (a)
   2 Eccentricity (e)
   3 Inclination (i)
   4 Longitude of the ascending node (Ω)
   5 Argument of periapsis (ω)
   6 True anomaly at the Epoch

   3D diagram to explain the satellite orbits in my home page;
   to demonstrate difference of Inclination orbit.html
   to demonstrate difference of Longitude of the ascending node orbit2.html



See Wikipedia for explanation

2. Where are the Two Line Elements (TLE)? Where can we find them?

   Go to NORAD!
   https://www.celestrak.com/NORAD/elements/

   See Wikipedia for explanation

   A nice explanation in Japanese by Isana-san

   Orbits of major high-energy satellites (thanks to Isana-san)

   Orbits of ASTRO-H (Hitomi) and its debris

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SUZAKU (ASTRO-EII)
1 28773U 05025A   21151.54108102  .00001204  00000-0  52851-4 0  9992
2 28773  31.3813 272.0277 0004320 113.3039 246.8063 15.18391444876891
```

https://celestrak.com/satcat/tle.php?CATNR=28773

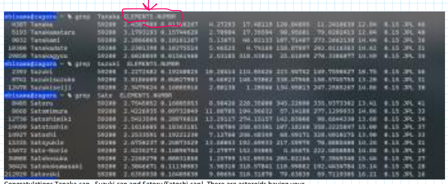
Orbits and astronomical objects

1. Where can we find orbital elements of solar planets and asteroids?

   Go to JPL to obtain the orbital six parameters (six parameters) for planets or for asteroids and comets

2. Find orbital elements of your familiar/favorite asteroids.

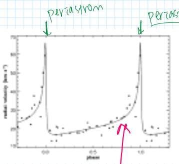
3. Are there asteroids which have your name?



Congratulations Tanaka-san, Suzuki-san and Satoru/Satoshi-san! There are asteroids having your names!

4. Give some examples of binary stars where elliptical orbits affect their emission?

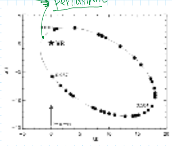
WR140



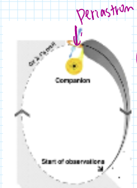
WR 140 orbit movie by STScI

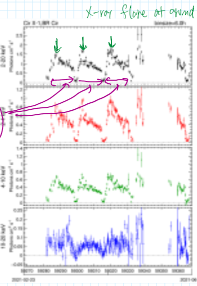
WR140 simulation movie by Okazaki-san

Figure from https://www.aanda.org/articles/aa/pdf/2001/35/aah2722.pdf



Cir X-1

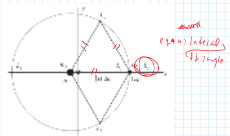




http://pysalt.salt.ac.za/meetings/salt_science_2012/session4/Cir%20X-1%20Talk.pdf
MAXI Cir X-1 page at RIKEN

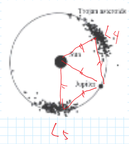
The circular restricted three-body problem and the Lagrange points

1. Explain the circular restricted three-body problem and the Lagrange points



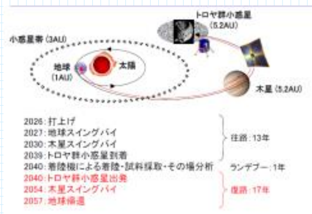
Figures taken from https://www.jstage.jst.go.jp/article/jsee/62/2/62_2_73/_pdf/-char/ja

2. What are the "Trojan asteroids"?



3. Do we have a plan to reach and study Trojan asteroids?

Yes! OKEANOS project



https://jaxa.repo.nii.ac.jp/?action=repository_uri&item_id=8195&file_id=31&file_no=1&nc_session=dq36iq3np1maobutng1cto2qq6

4. Consider the Sun-Earth L2 point. Let's put the Solar mass M1, Earth mass M2, their distance a, and the distance between the earth and the L2 is r.
What will be the equation of the motion at L2?

5. Solve the equation of motion, and estimate the distance between the earth and L2.

$r \simeq 0.01a$

Equation of motion @L2:

$$\frac{G(M_1+M_2)}{a^3}\left(r+\frac{M_1}{M_1+M_2}a\right) = \frac{GM_1}{(a+r)^2} + \frac{GM_2}{r^2}$$

$$3\left(\frac{r}{a}\right)^3 = \frac{M_2}{M_1}$$

$$r = a\left(\frac{M_2}{3M_1}\right)^{\frac{1}{3}} \doteqdot 10^{-2}a$$

Satellite orbits around the L2 point

1. Give several examples of the science satellites (space crafts) which are launched to Sun-Earth L2 point?

   Planck orbit

   Nancy Grace Roman Space Telescope orbit

   LiteBird (Hazumi-san's presentation at 2020 SPIE) Explanation of the orbit staring at about 5:40

2. What will be the orbit like around L2? How does it called?

   Lissajous orbit.

   Hunting for Dark Energy - eRosita X-Ray Telescope
   JWST orbit (nice movie and explanation!)