From archaeoastronomy to supernovae

France – HANDS ON UNIVERSE

VOLOS 2013 July 31 , Greece

Without astronomy, man ignores one's place. Aristote

Platon and Aristote, in Athens'school,

by Raphaël, 16th century

Suzanne and Michel FAYE, Paris France ***http://science.faye.free.fr***

OUTLINE

- A presentation, with 3 topics and 2 softwares:

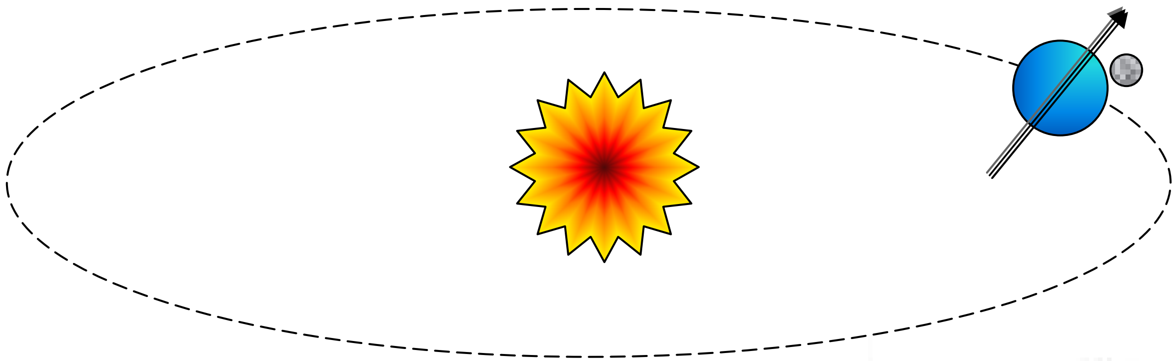
  0 . Mankind and Cosmos: 12 months / 12 phalanges/ 2 x 12 hours

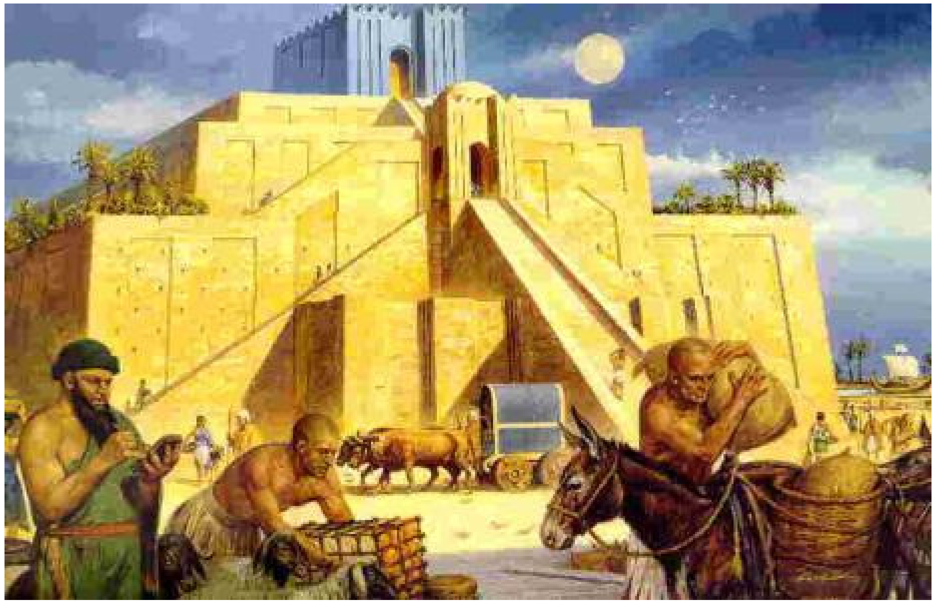
1. Archaeoastronomy with Timocharis and Hipparchus / a touch of Stellarium.
2. Archaeoastronomy of pleiades all over the world
3. Supernovae, from archaeoastronomy to black energy/ a touch of Salsa J.

- Two workshops:

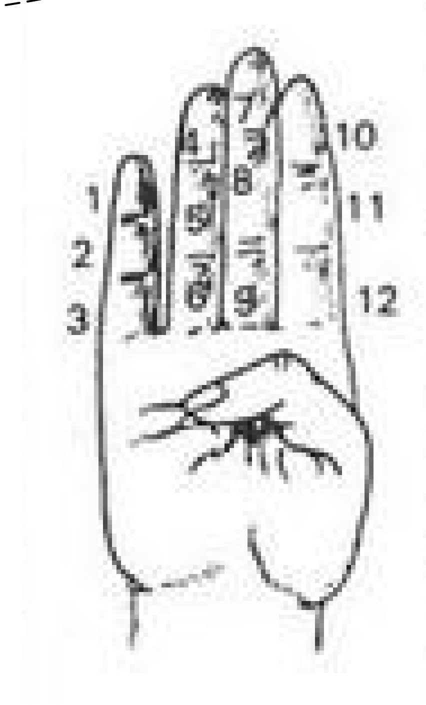
1. Precession of the equinoxes with Stellarium
2. Light curve of SN 1994 J with Salsa J

Mankind and Cosmos: 12 months / 12 phalanges/ 2 x 12 hours



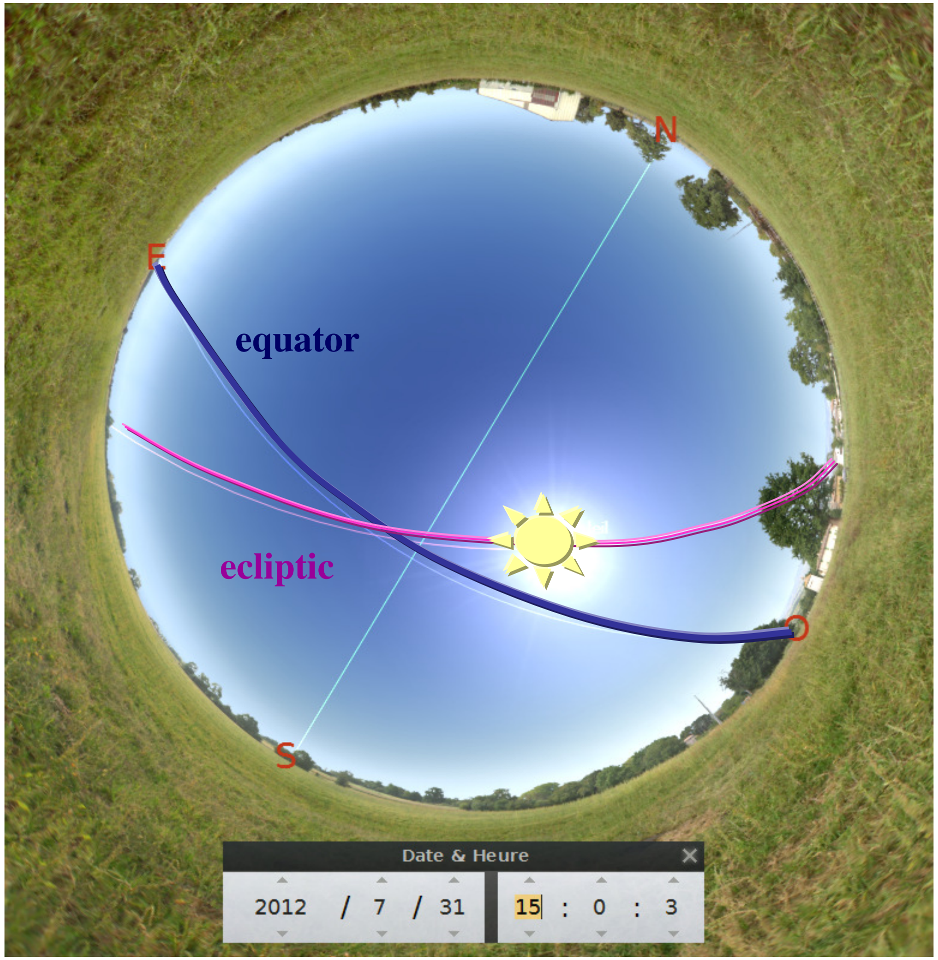


Mesopotamia (Iraq)



12 phalanges

1st step : From ancient greek astronomers to Stellarium, the precession of the equinoxes



Babylonians, Egyptians, Greek, Indians, Chinese, Japanese and all, a common inheritance:

Ecliptic: apparent path of the Sun on the celestial sphere; it is inclined about 23.5° compared to the celestial equator.

With Stellarium, you can follow the motion of the Sun along ecliptic during day, month and year.

The moments, two each year, when the Sun is at intersection of equator and ecliptic are called ***equinoxes*****;** one happens around March 21, the other around September 21. The spring equinox is called the ***vernal equinox***

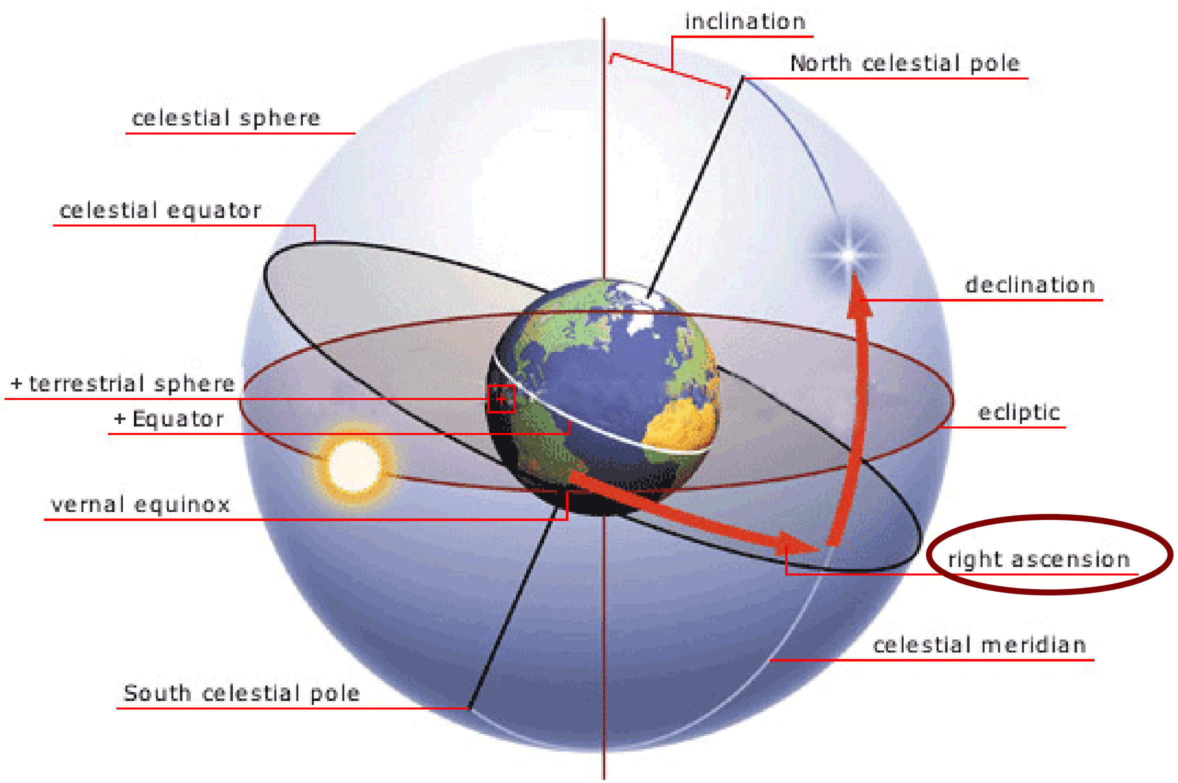
How did ancient greek astronomers measure the position of stars?

Three great ideas:

1st great idea: use vernal equinox as a **reference.**

2nd great idea: how to get vernal equinox measure? Use **lunar eclipse** (next slide)

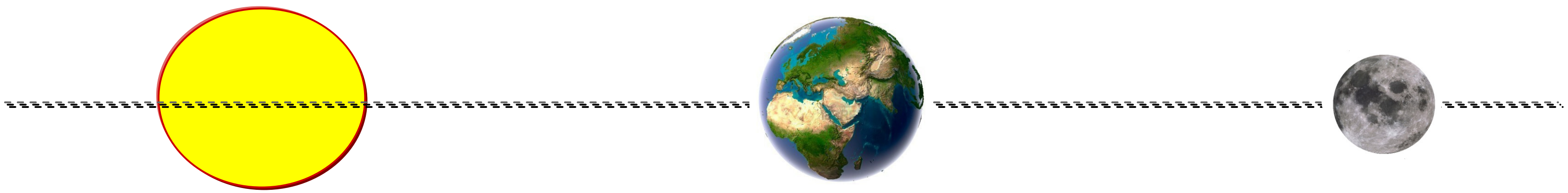
3rd great idea: when lunar eclipse is not exactly opposite to Vernal point, then evaluate the **adjustment** due to the shifting, that is **360/365 (°/day)**



So, they measure **right ascensions** of stars and moon on lunar eclipse day

Why to use lunar eclipses day?

	Timocharis	Hipparcus
When ?	283 BC./3/18 at 1h35 Equinox -283: 3/25	131 BC./1/17 at 23h32 Solstice -132: 12/23
Why ?	At lunar eclipse, Sun, Earth and Moon are on the same line	



So, we compare the right ascension of the star (RA_{star}) with the right ascension of the moon (RA_{moon}), that gives:

Near equinox: Position of a star: $RA_{star} – RA_{moon} + 180° \pm (360/365) * $ (number of days before or after equinox)

Near solstice: Position of a star: $RA_{star} – RA_{moon} \pm 90° \pm (360/365) * $ (number of days before or after solstice)

How did ancient greek discover precession of the equinoxes?

Babylonian astronomical materials

+

Ancient Greek astronomers/ *related by Ptolemy in Almagest*

Hipparchus measured **the position of Spica** and other bright stars, using a lunar eclipse to have a precise reference line (previous slide) .

Comparing his measurements with data from his predecessors, **Timocharis** (320–260 BC) and **Aristillus** (~280 BC), he concluded that Spica had moved 2° relative to the equinoxes. He concluded that the equinoxes were moving ("precessing") through the zodiac.

What is precession of the equinoxes?

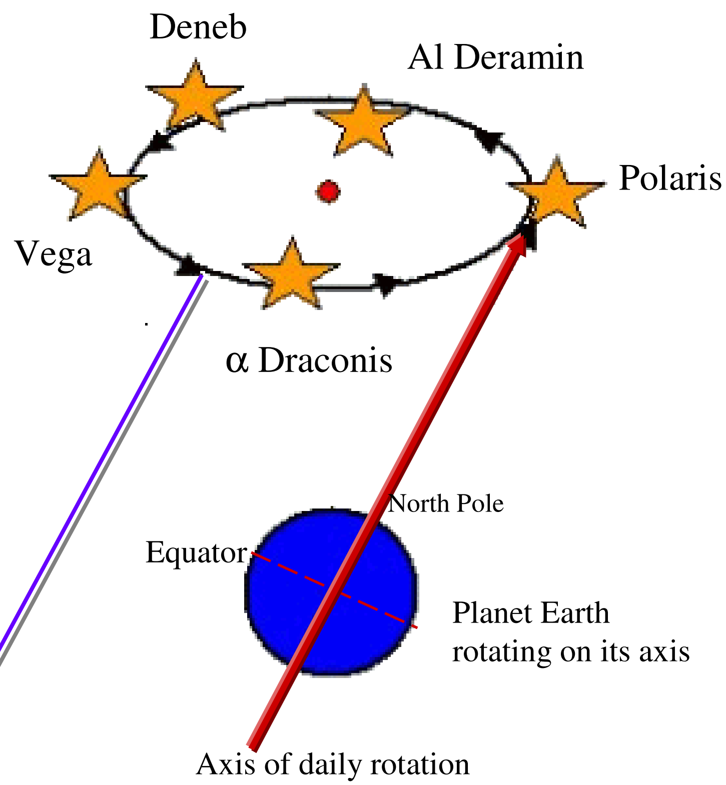
The Earth rotates once a day about its axis of rotation, this axis itself rotates very slowly (dark circle), completing a rotation in approximately 26,000 years .

So, the North Pole star changes.

Main precession, called Precession of the equinoxes,

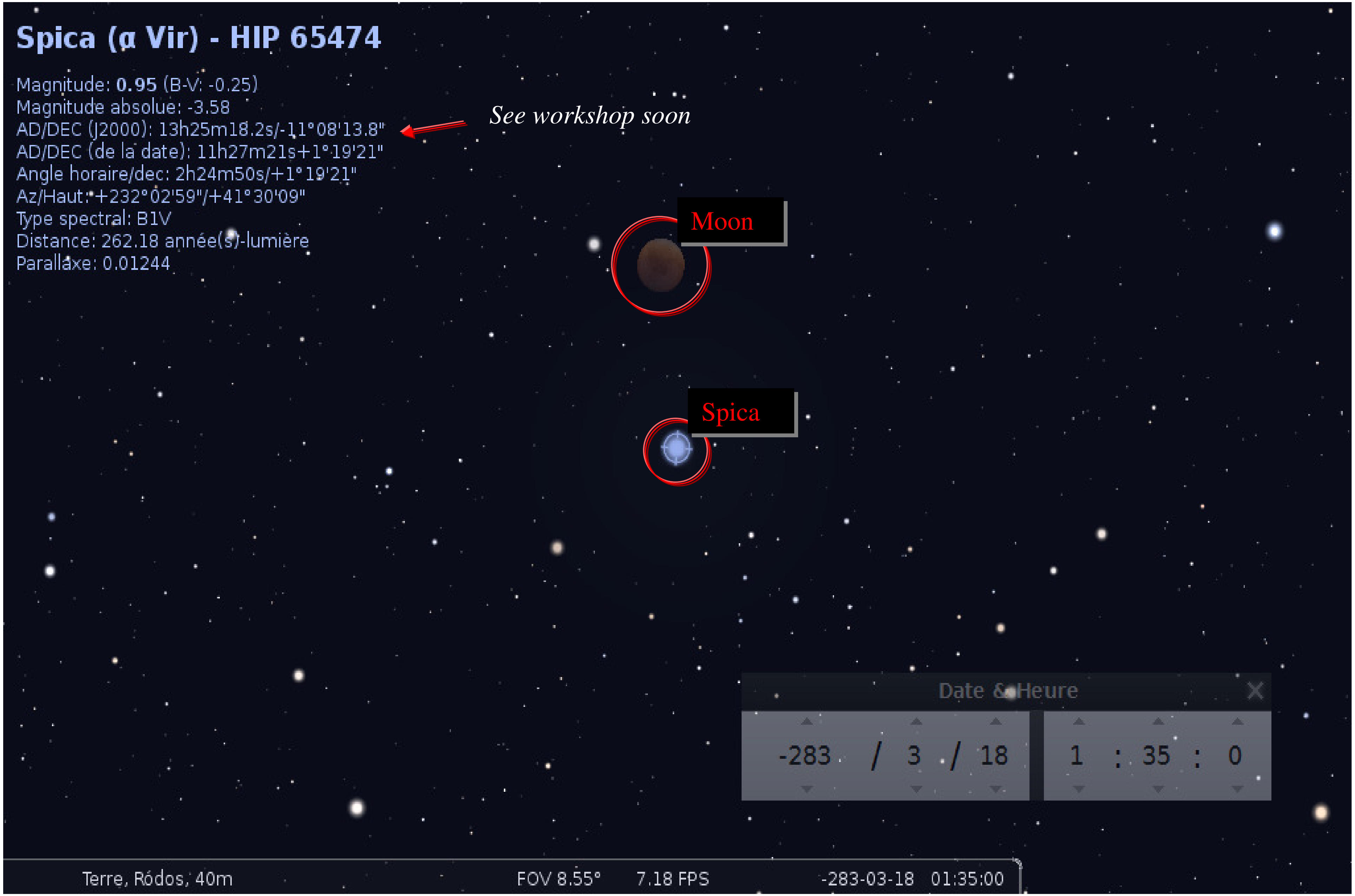
or Precession of the equator.

It exists minor components, called Precession of the ecliptic

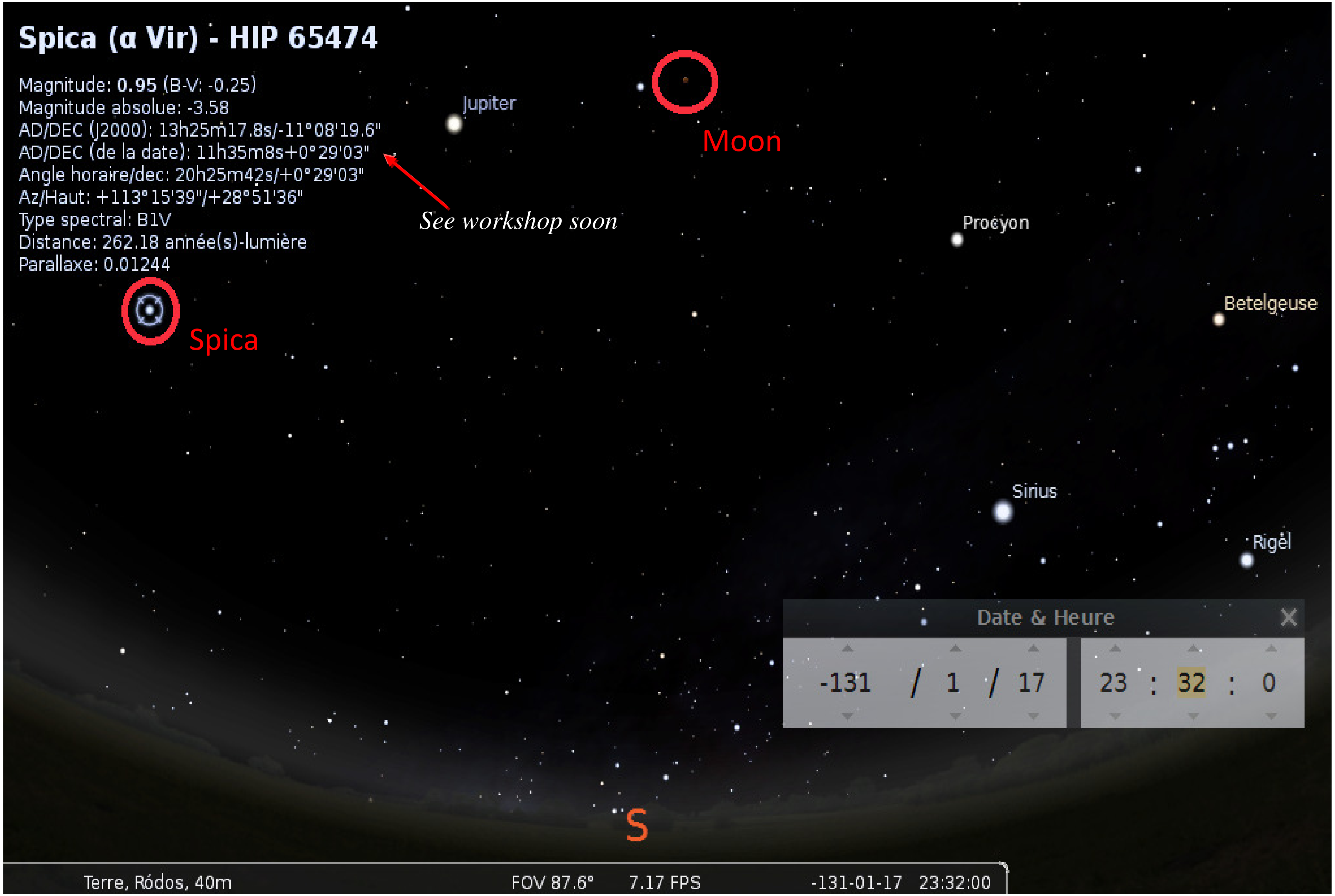


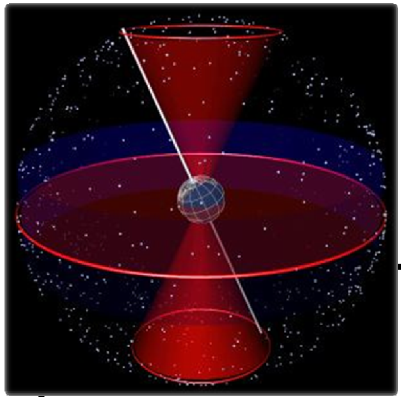
Like a spinning top or a gyroscope:

On Timocharis'footsteps with Stellarium (see workshop below)



On Hipparcus'footsteps with Stellarium (see workshop below)





Precession of equinoxes

	Timocharis	Hipparcus
When ?	283 BC./3/18	131 BC./1/17

The position of Spica changed 2 ° in (283-131)= 152 years

So, a complete rotation of the Earth axis lasts:

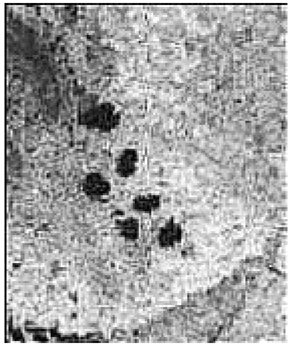
152 * 360/2 =27000 years

2nd step : From France to Easter Island, the Pleiades, Six Sisters and more in the constellation of Taurus

The Pleiades are one of the first constellations which excited the interest of the earliest star-gazers. We find Pleiades in the myths and literature of many cultures.

The division of the year according to the star phases of the Pleiades, that is their heliacal rise and fall, was accepted practice throughout the world: in Eurasia, North and South America, Indonesia …

Paleolithic European Constellations - star maps in Lascaux cave in France 17 500-13 000 B.C.



The open cluster of the Pleiades

The 6 stars and the Aurochs, markers of the equinoxes, 17300 years ago (astronomy and carbon dating)

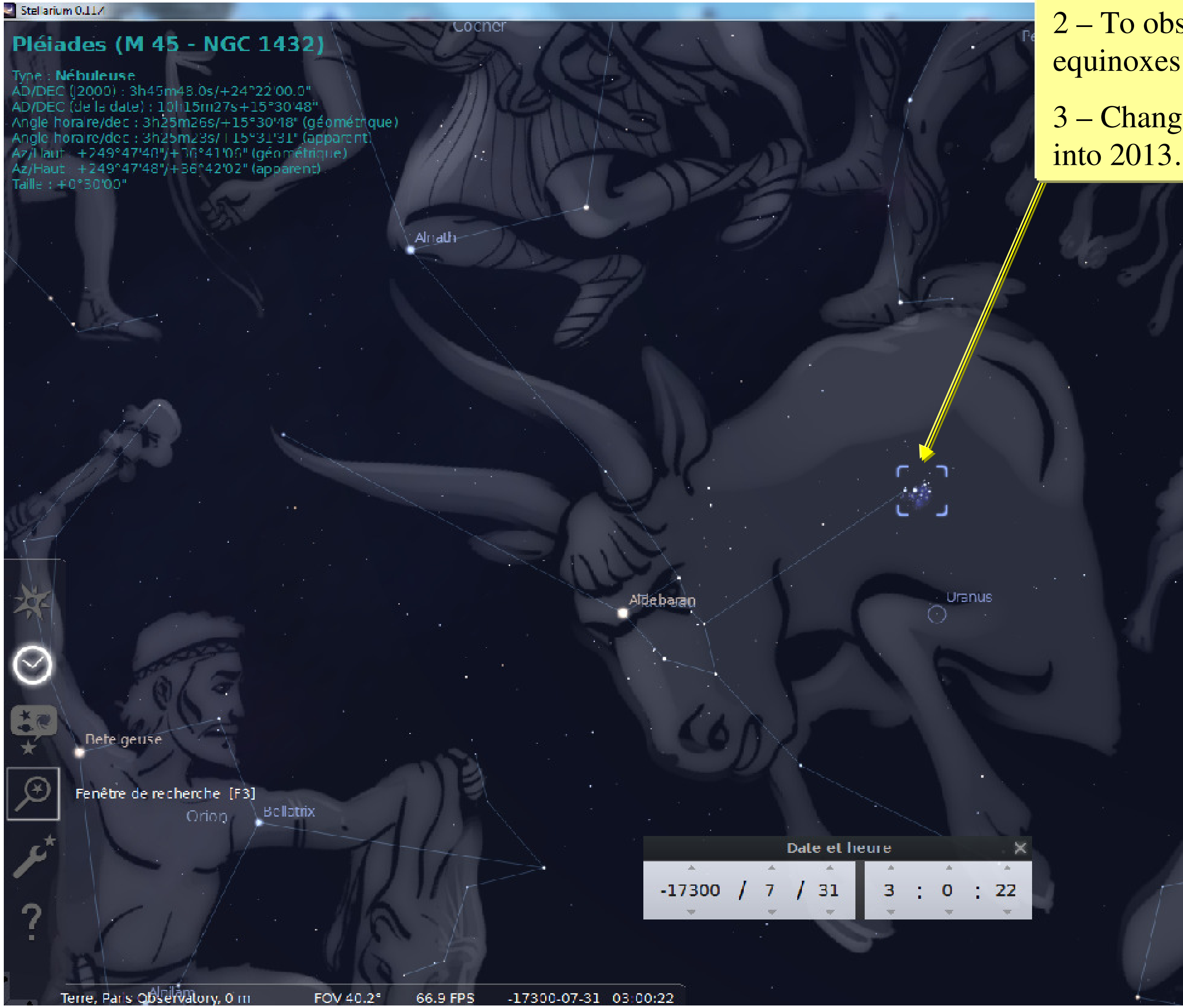
Do it yourself, with Stellarium

Ancient greek Πλειων = *Year, according to the Pleiades*

1- To Zoom

2 – To observe at equinoxes dates

3 – Change (-17300) into 2013…



The Pleiades: the celestial herd of ancient timekeepers

A myth of the Blackfoot Natives in North America throws light on the picture of the « Salle desTaureaux » in Lascaux.

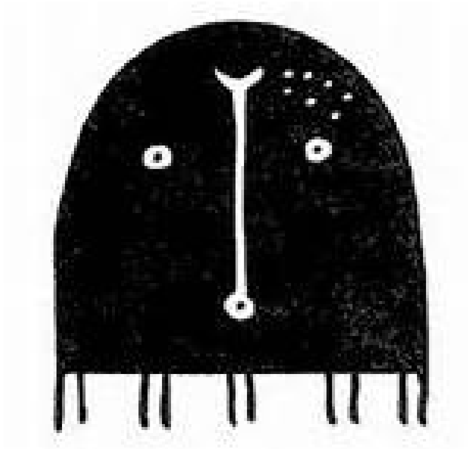
These people synchronise the star phases of the Pleiades with the changes in the coats of the buffalo (equinoxes)

Pleiades (hundred of stars, 6 to 7 particularly bright) a prominent sight , in each hemisphere, worldwide known since antiquity

30 cm , 2.2 kg

Nebra disk, Germany, 1600 BC.

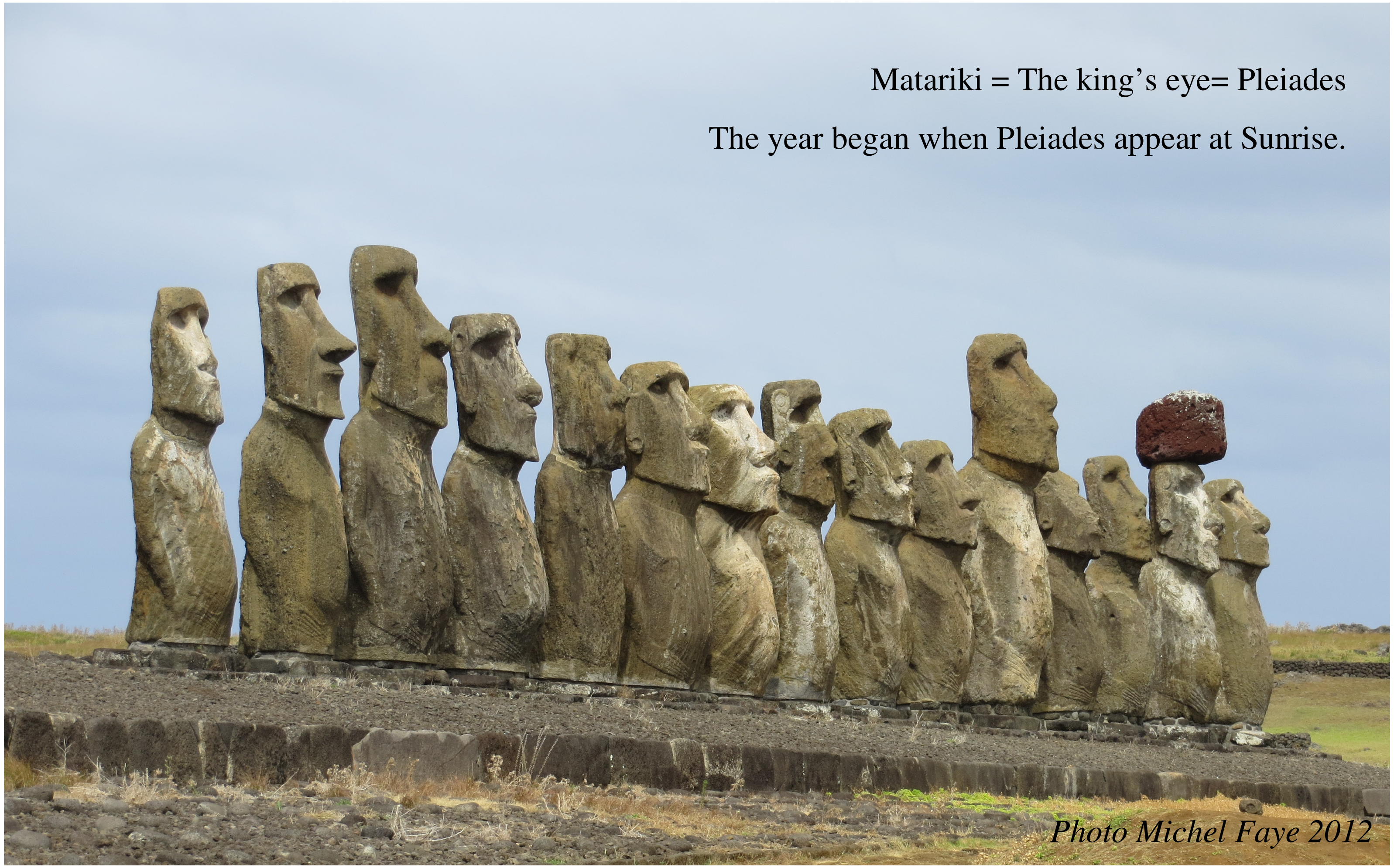
With Sun, Moon, Pléiades and arch of the Sun courses during the year.



Mask of Black God,
the Navajo sky god, a sky map.
A crescent moon on his forehead,
the sun as his nose,
the Pleiades «Sparkling Particles»
or « Flint boys » on its forehead.

Ahu Tongariki (Eastern Island) :

Moai are facing Matariki (Pleiades) desappearing above Rano Raraku



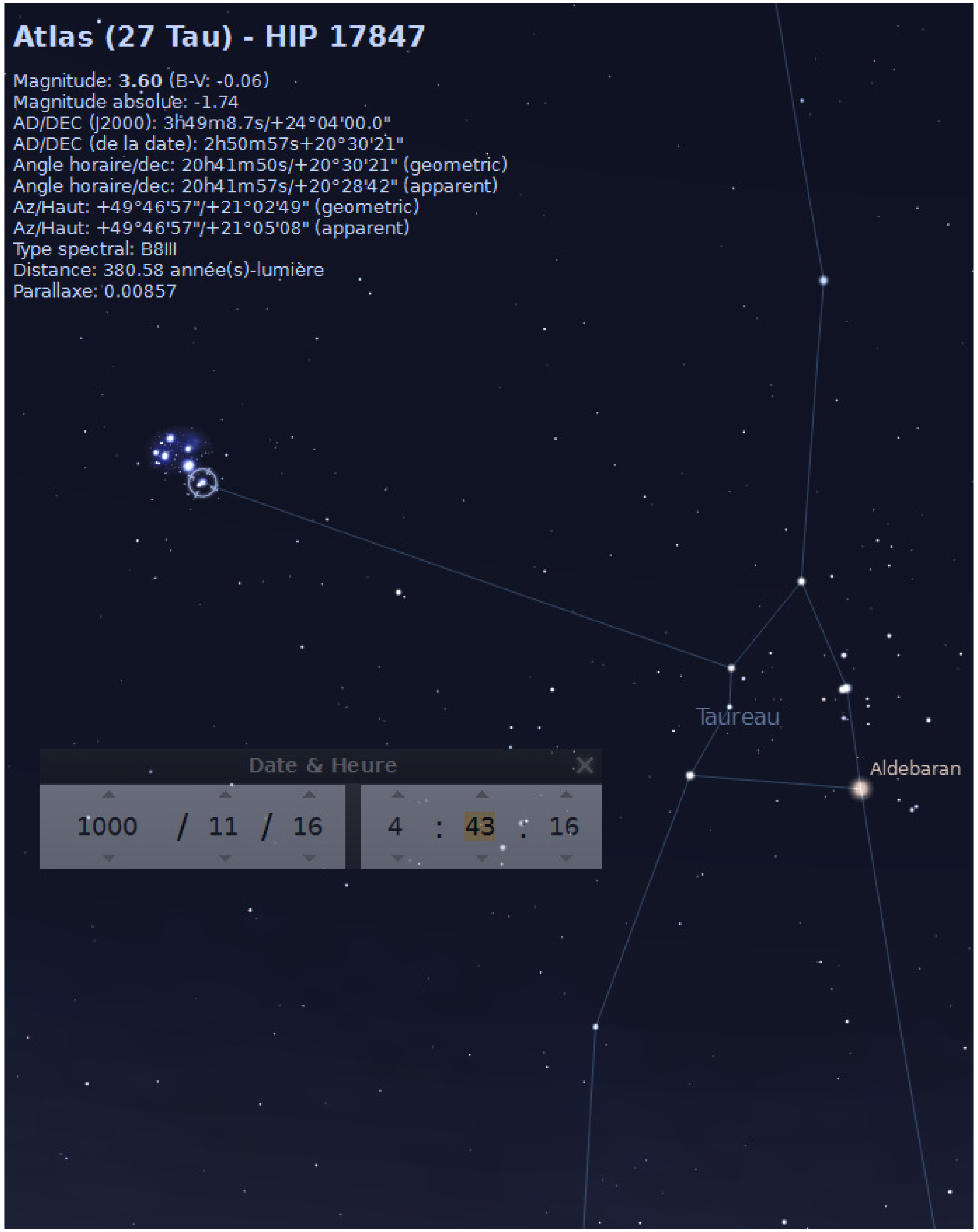
When Matariki rises (November 16th), the bountiful (making good) season, season of abundance (Hora Nui) begins / easy fishing

When Matahari falls (April 18th), the dark season (Tonga Iti) begins/end of fishing season, monthes of tribal wars begin

Eastern Island / *Pleiades rise, announcing good fishing time + Atlas, father of the Pleiades*

Above: Petroglyph as a star map, including a fishing hook.

Below: Rock with Pleiades



3rd step : From Guest Stars to black energy

What is a guest star?

Ancient astronomers took careful note of "guest stars", which suddenly appeared among the fixed stars.

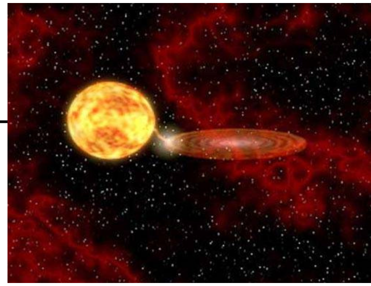
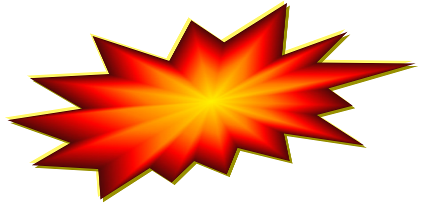
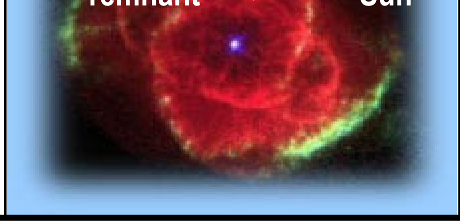
- Nova is a brightness resulting of a fusion reaction that happens on the **surface of a white dwarf** (see next slide); it is a recurring process: it burns, stops, burns again…

- **Supernova** is a **single explosion** of

Type I - White dwarf star+ companion

Type II - A massive star $M_{start} > 8M_{Sun}$

More about supernovae

Life and death of stars	Our Sun	A white darf + a companion	M > 8 M_{Sun}	
End of fusion reactions: Inside collapse Outer layers ejected	**Red Giant** 	**White dwarf swallows its companion** 	**Supernova type II** 	
Remnant	**White dwarf** **$M_{remnant}$<1,44 M_{Sun}** 	**It may give a supernova type I**	**1,4 M_{Sun} < M < 3 M_{Sun}** Neutron star with pulsar (radio emission by rotating object)	**M > 3 M_{Sun}** Black hole *≠ black holes centers of galaxies*

Chandraseckhar calculated the lower limit for white dwarf : 1,44 M_{Sun}

Schwartzschild calculated the radius of a black hole (Horizon of the black hole) $R = 2\ GM/c^2$

With SalsaJ

1 - File

Open

Discover a supernova

SNY.FTS and SNZ.FTS.

Quick photométrie:

2 - Click on the blue line

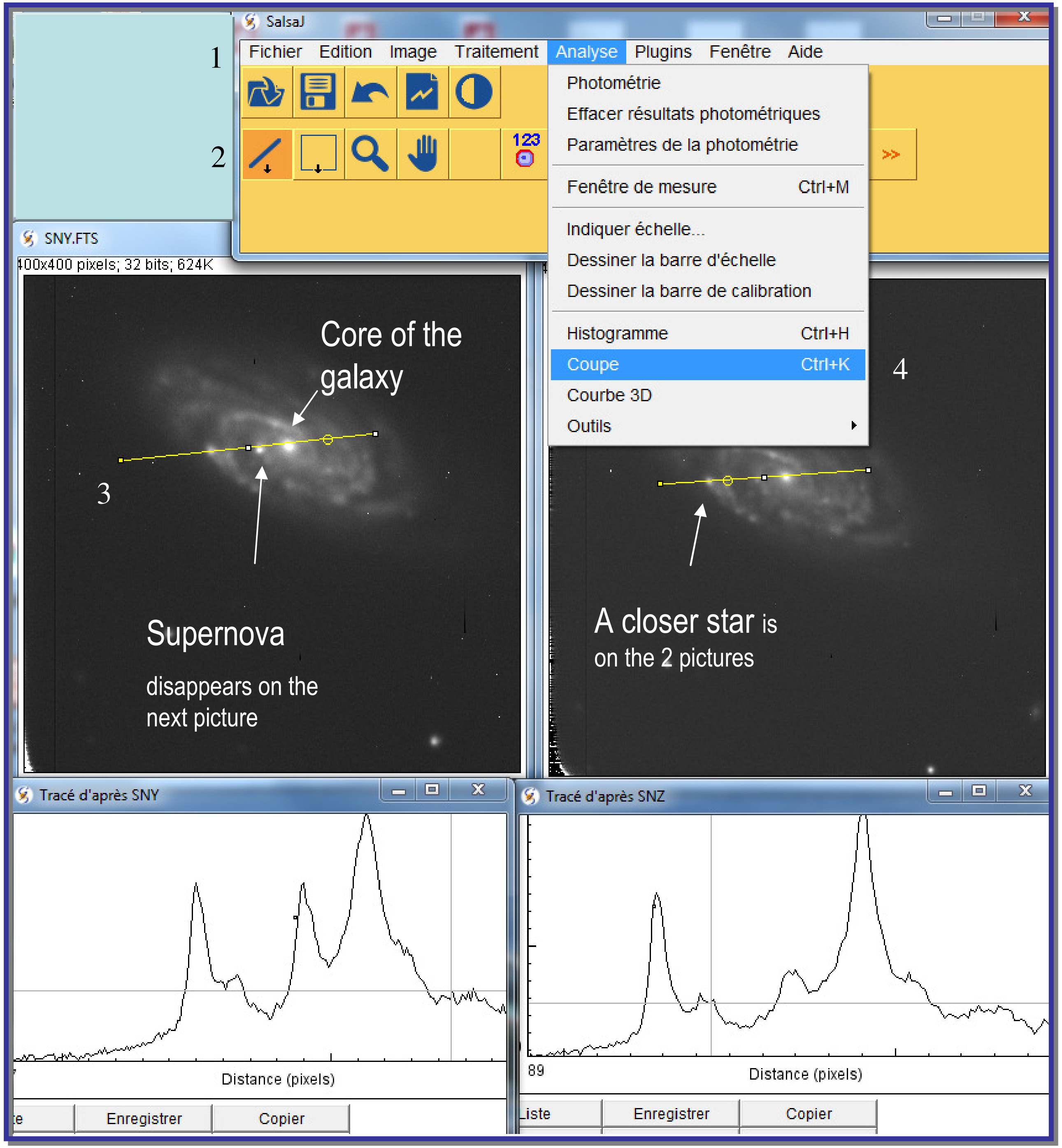
Go and draw a line along the bright objects

3 - Go to Analyse

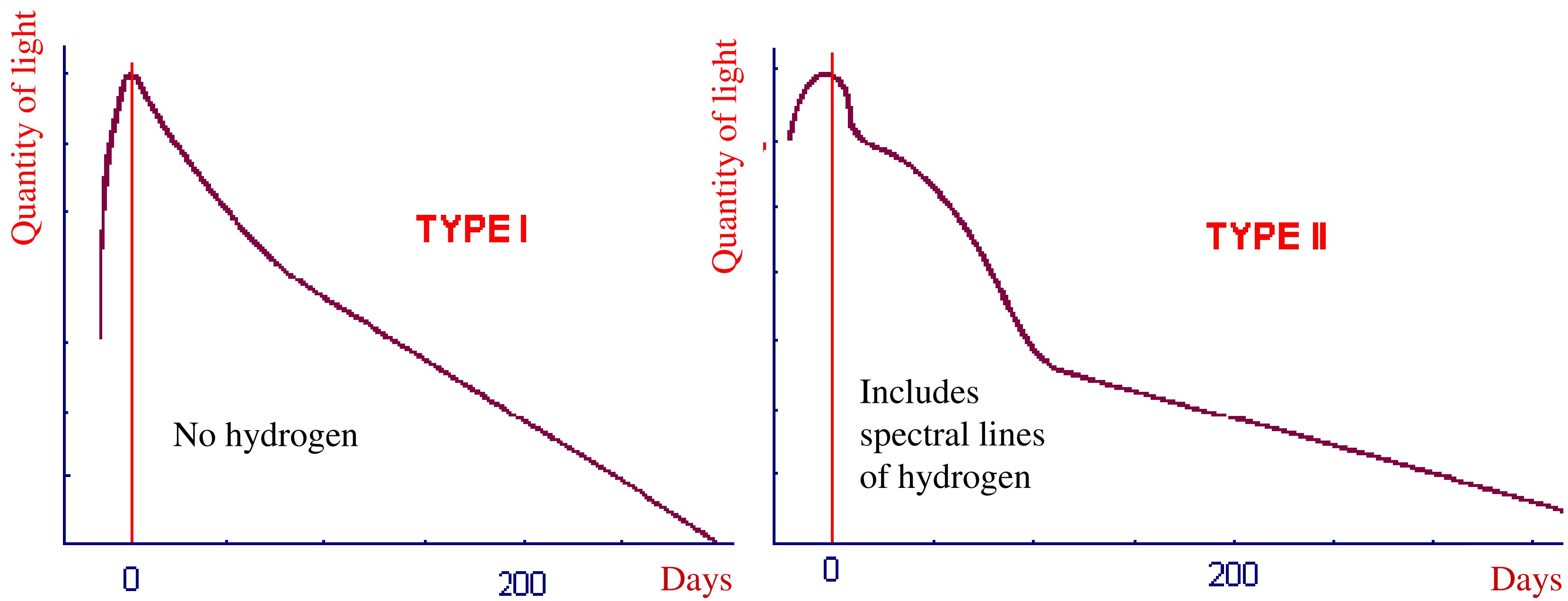
4 - Plot Profile (French Coupe)

5 – Compare the 2 profiles of light and explain.

Supernova = a single exploding star gives, during one year, as much light as the core of a galaxy.



Hydrogen or not Hydrogen



Light curves of supernovae

« Historical supernovae » + Recent ones

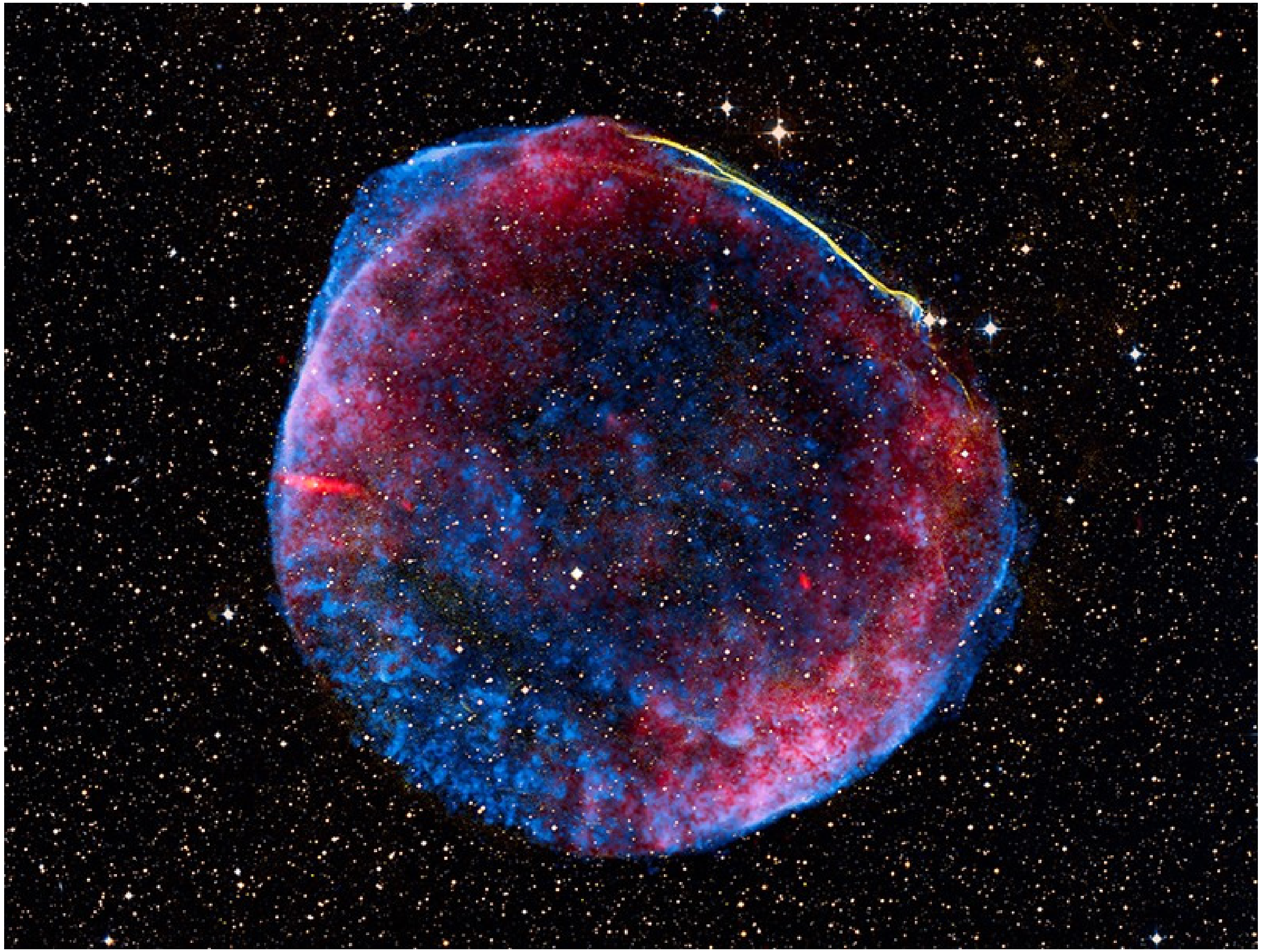
Key Word	Where?	When?	Magnitude	Months	Reported in
Chinese text	Centaurus	185	-8	20	China
Jinshu Songshu	Scorpius	393	-1	8	China, Japan
Petroglyph	Lupus	1006	- 7.5	>24	China, Japan, Europe, Arabia, North America
Schism	Taurus	1054	-5	22	China, Japan, North America
-	Cassiopeia	1181	0	6	China, Japan
Tycho Brahe	Cassiopeia	1572	-4	18	China, Corea, Europe
Kepler	Ophiucus	1604	- 2.5	12	China, Corea, Europe
Van Gogh	Whirpool galaxy	1994 / 2005/2011	- 8.4/- 14/- 13.5	-	Modern observatories
Magellan	Large Magellanic Cloud	1987	3	1	Southern hemisphere

Constellations in our Galaxy, the Milky Way

A rocky planetarium near Flagstaff, Arizona (USA)

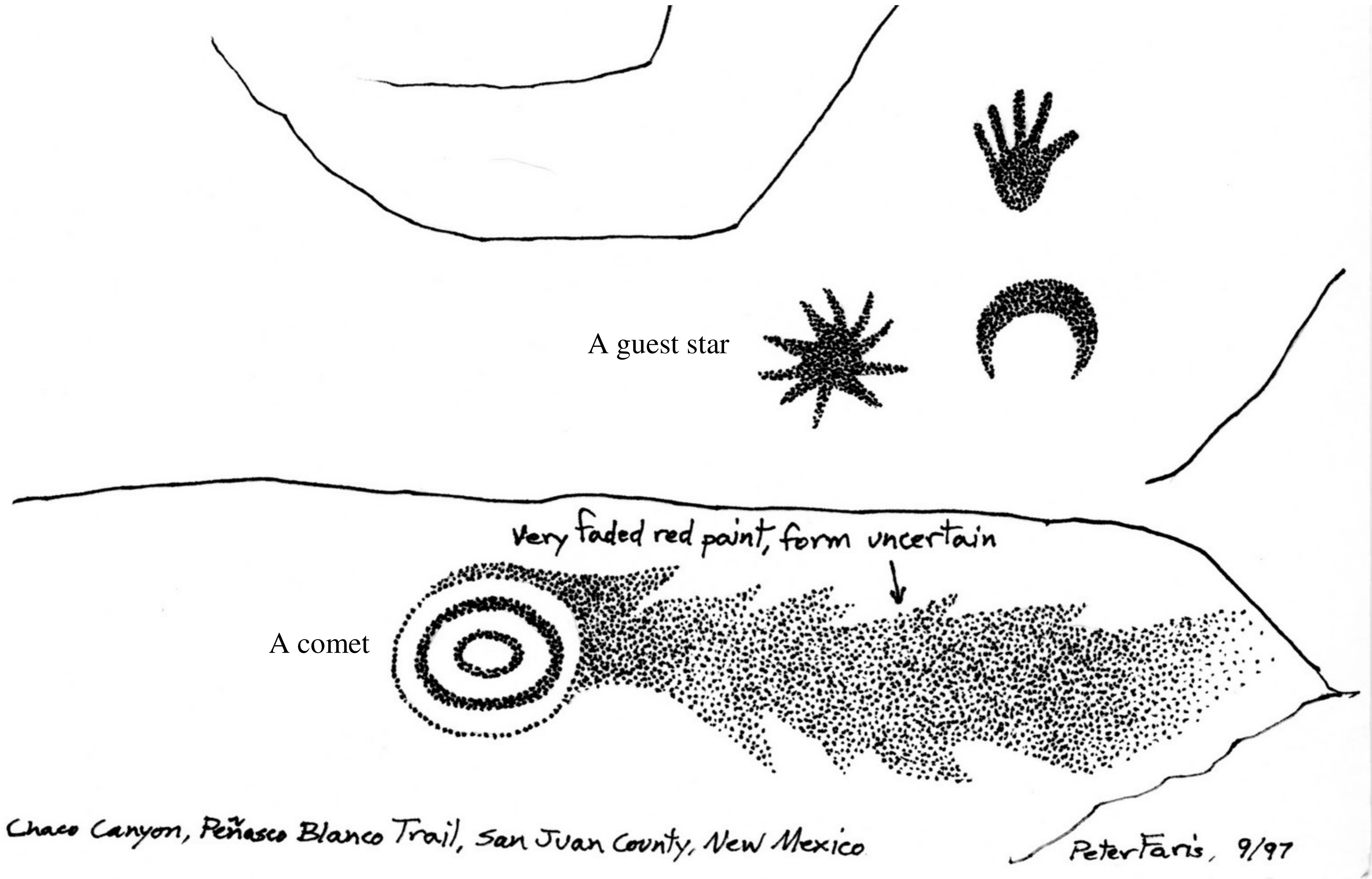
Big Deer site: a petroglyph possibly depicting the supernova of A.D. 1006(star symbol, right of center) and the constellation Scorpius (scorpion symbol, left of center).

Today: Nebula remnant from Supernova 1006

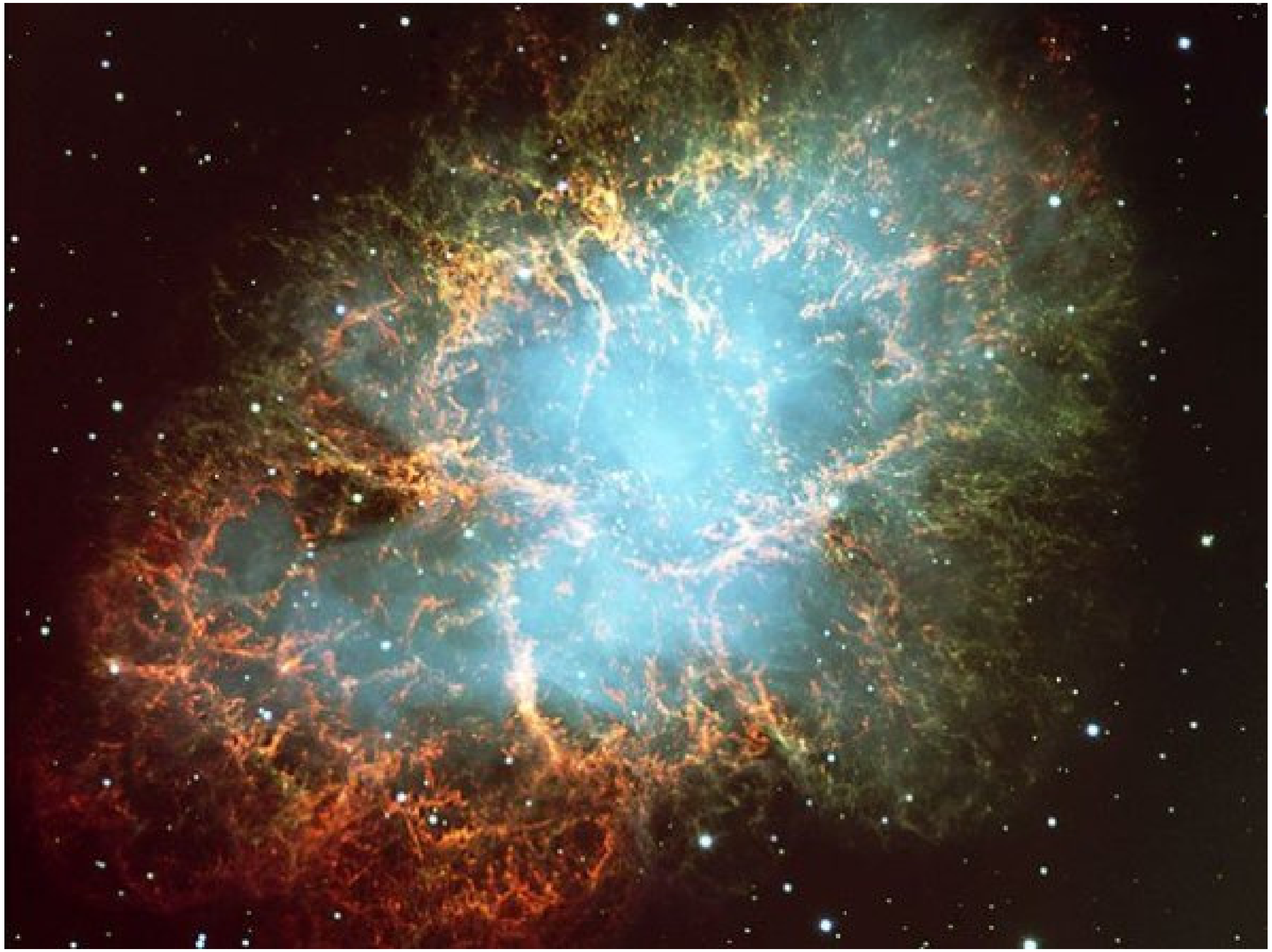


Petroglyphs in Chaco Canyon, USA : Guest Star 1054?

July 1054 ?


A guest star
A comet
Very faded red paint, form uncertain
Chaco Canyon, Peñasco Blanco Trail, San Juan County, New Mexico
Peter Faris, 9/97

A today picture of the same object : Crab Nebula



A huge star exploded, a supernova, creating prebiotic molecules,

Today, a radio emitting object (a pulsar) is still there.

You can zoom on this remnant with Stellarium.

1054: a supernova that european people refused to see?

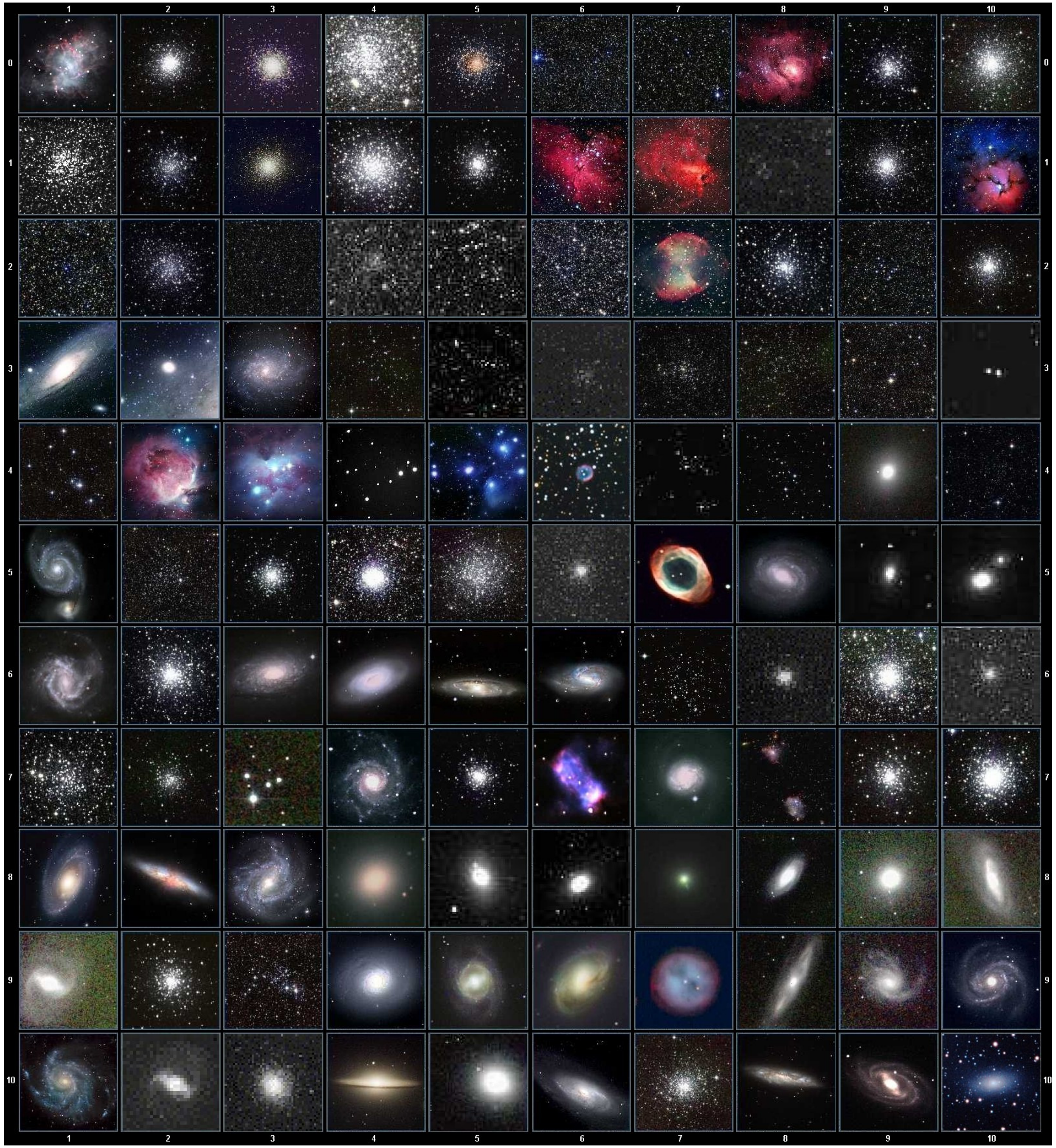
1054:The European Great Schism, a *split between Eastern Orthodoxy and Western Roman Catholicism* . That was such a shock that christian chroniclers didn't dare to add an abnormal star as a bad sign in the sky..

We know six suggested orthodox documents, but far less precise than chinese or japanese documents, or than european documents for others «historical » supernovae.

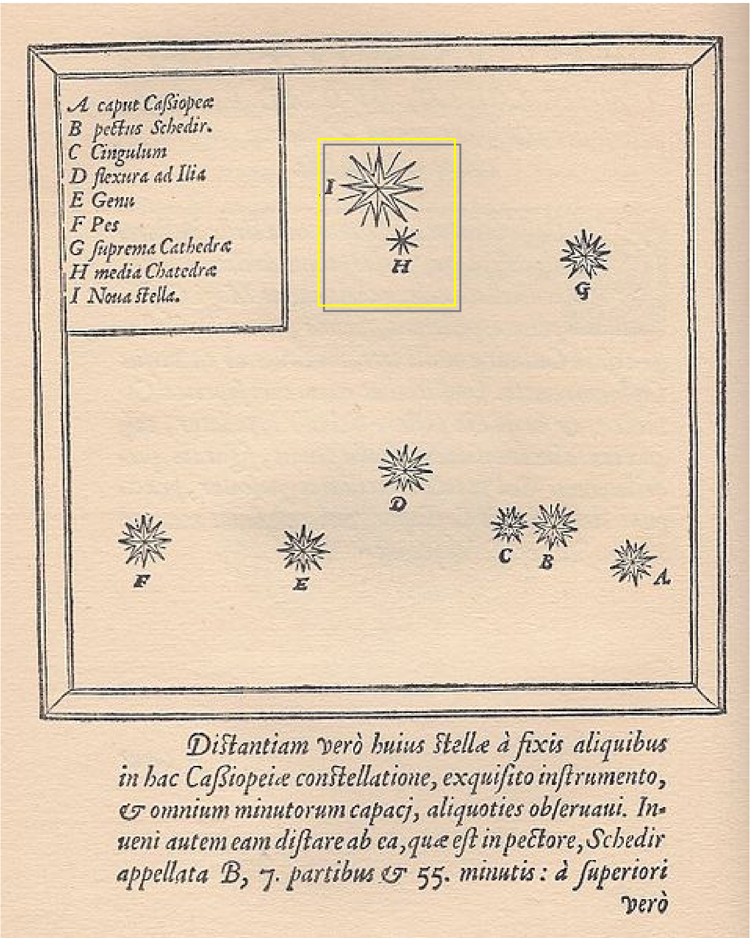
The Cronaca Rampona: *In AD 1058, Pope Stephen IX has come to the throne [...] Also in this year of Christ 1058, Henry III reigned (or lived ?) for 49 years [...] At this time, famine and death was upon the whole world. He stayed in the province of Tibur for three days in the month of June [...] At that time, a very brightly-shining star (stella clarissima) entered into the circle [or the circuit] or the new moon, in the thirteenth calends at the beginning of the night."*

Crab Nebula M1 in Messier’s catalog, 18th century

Messier had first mistaken M1 with Halley’s comet. He felt ashamed of that, then decided to list all the « non stars» objects, and so began with Crab Nebula!



SN1572 1a Tycho Brahe

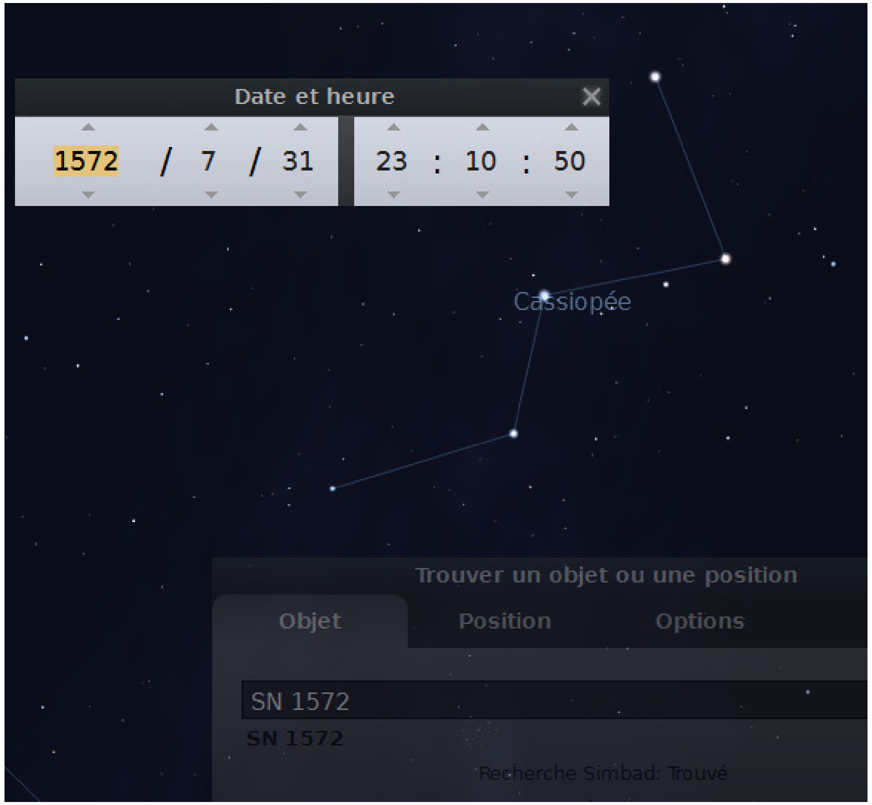


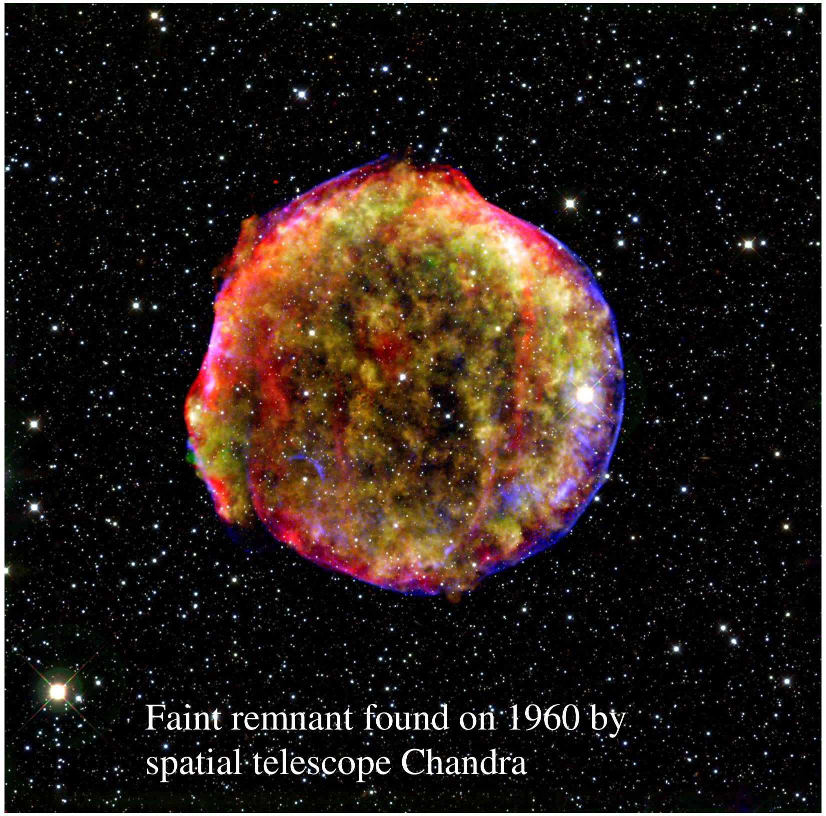
The « new star » SN 1572 is one of the most important events in the history of astronomy, because it questioned astronomers about variability of the cosmos.

SN 1572 is often called "Tycho's supernova", because of the extensive work *De nova et nullius aevi memoria prius visa stella* ("Concerning the Star, new and never before seen in the life or memory of anyone," published in 1573, 1602, and 1610) that contains both Tycho’s own observations and the analysis of many other observers.

In England, Queen Elizabeth called to her the mathematician and astrologerThomas Allen, "to have his advice about the new Star that appeared in the Cassiopeia to which he gave his Judgement very learnedly," the antiquary John Aubrey recorded in his memoranda a century later.

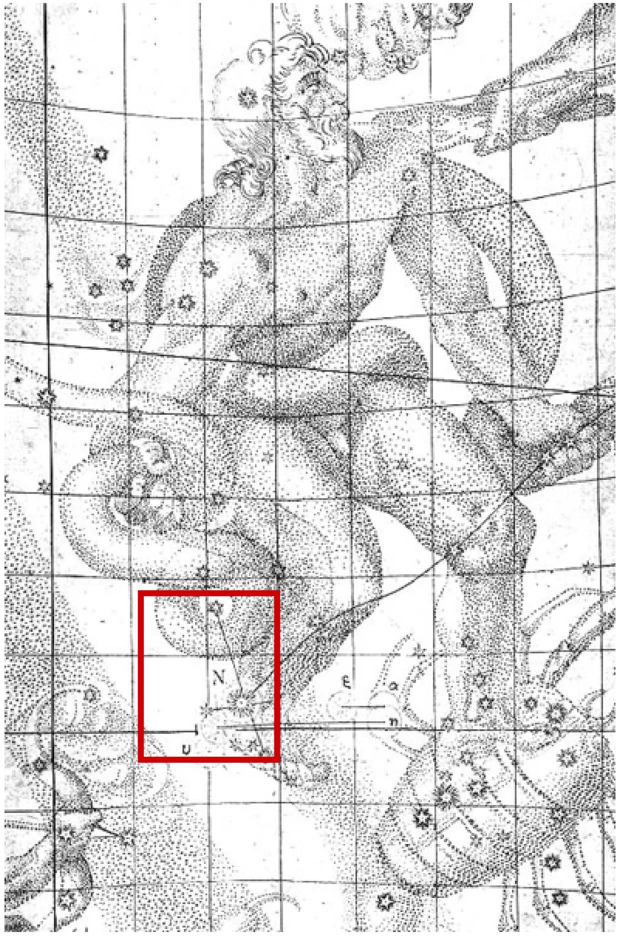
SN 1572 today / type SN 1 a : a white dwarf swallowed a companion





Faint remnant found on 1960 by spatial telescope Chandra

SN1604 1a Kepler

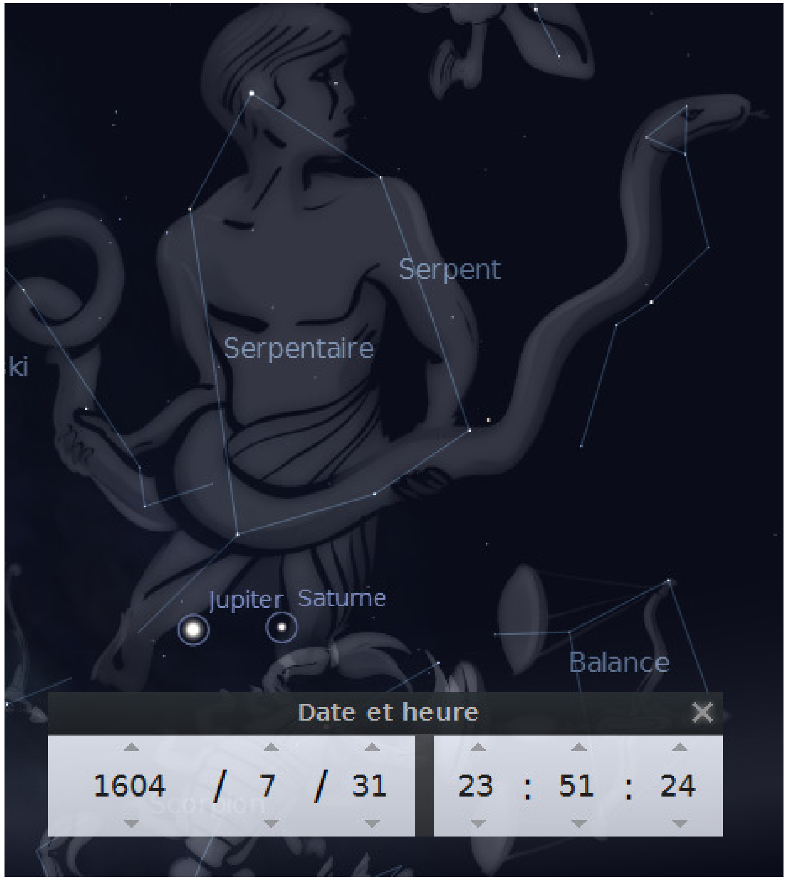


The « new star » SN 1604, also called Kepler’s supernova, is described by Kepler (letter N on the left picture).

Kepler tracked the object for an entire year and wrote a book on the subject, entitled *De Stella nova in pede Serpentarii* ("On the new star in Ophiuchus's foot", Prague 1606).
It was the second supernova to be observed in a generation (after SN 1572 seen by Tycho Brahe in Cassiopeia).

No further supernovae have since been observed with certainty in the Milky Way, though many others outside our galaxy have been seen.

SN 1604 today / type SN 1 a : a white dwarf swallowed a companion

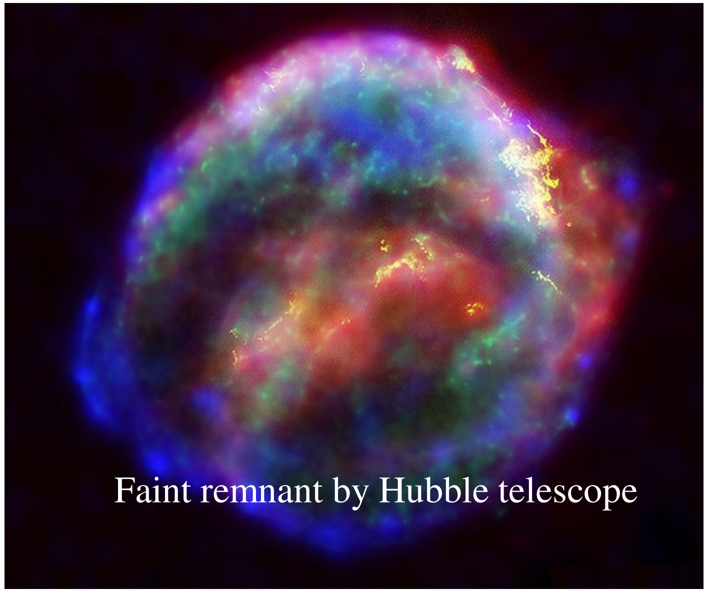


Ophiucus is Greek Ὀφιοῦχος « snake-bearer"

french *serpent* and *serpentaire*

In northern Hemisphere, Ophiucus is visible

in Summer, opposite Orion



Faint remnant by Hubble telescope

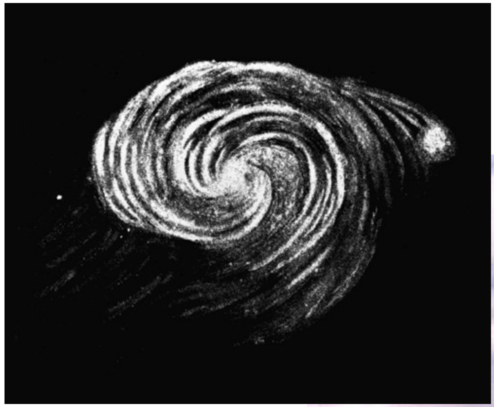
Two supernovae in M51, Whirlpool Galaxy

SN 2005cs, type II and SN 2011dh, type II

1 – Check M 51 / Whirpool Galaxy in Stellarium/ With Zoom, observe details

2 - A riddle: In what famous painting does Whirlpool Galaxy appear?

19th century: M 51(Messier Catalog) drawn by Lord Rosse



1882 : M 51 drawing published by french editor Flammarion

Flammarion, two brothers, Camille (astronomer) and Jules-Ernest (editor)

Camille and Sylvie, his first wife

Astronomie for all, his most popular book

A refracting telescope for schools

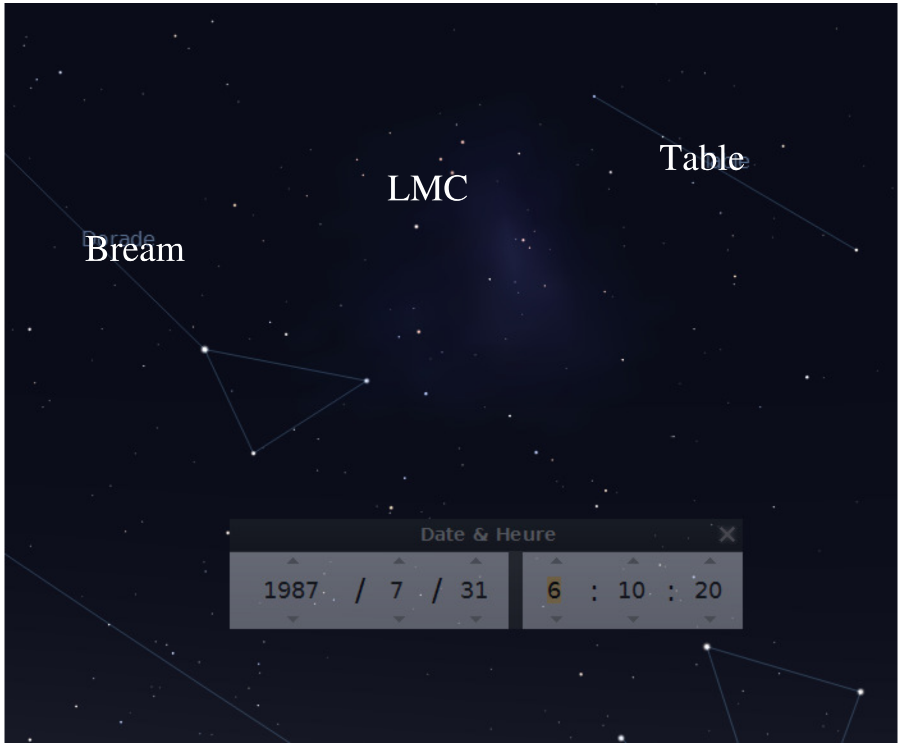
1888: M 51 painted in ***Starry Night*** by Van Gogh,

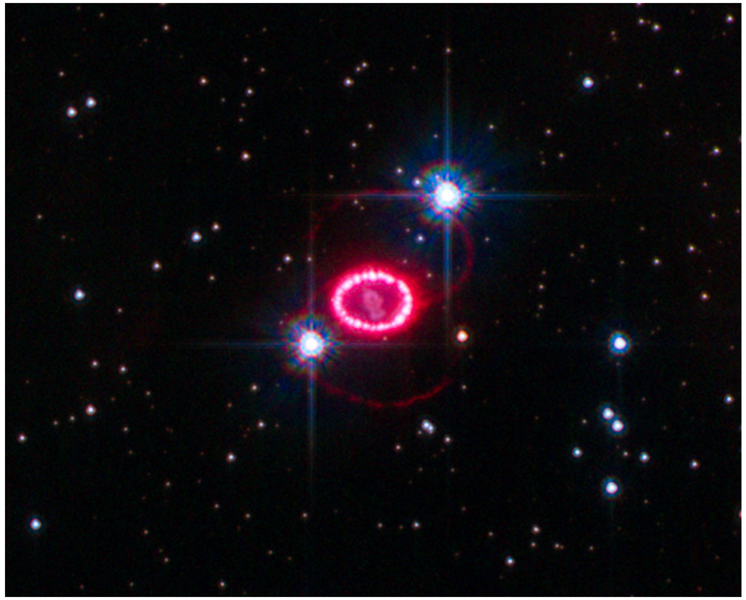
from Flammarion brothers' publication

Van Gogh read astronomy magazines.

He loved to observe stars describing lines in the sky along the night, which inspired him much in his way of painting.

Modern observatories reached hundreds of supernovae





Shock wave around SN 1987 A (Hubble Telescope), in LMC galaxy, southern hemisphere + 2 nearer stars

Large Magellanic Cloud (LMC), a dwarf galaxy satellite of the Milky Way, Southern Hemisphere

Enjoy Southern sky with Stellarium /

You can also look for archaeoastronomy with Southern Cross

Two workshops for the classroom

- **Workshop 1**: Precession of the equinoxes, with Stellarium/ Many exercices
- **Workshop 2** : Light curve of SN 1994 , in Whirpool galaxy, with Salsa J

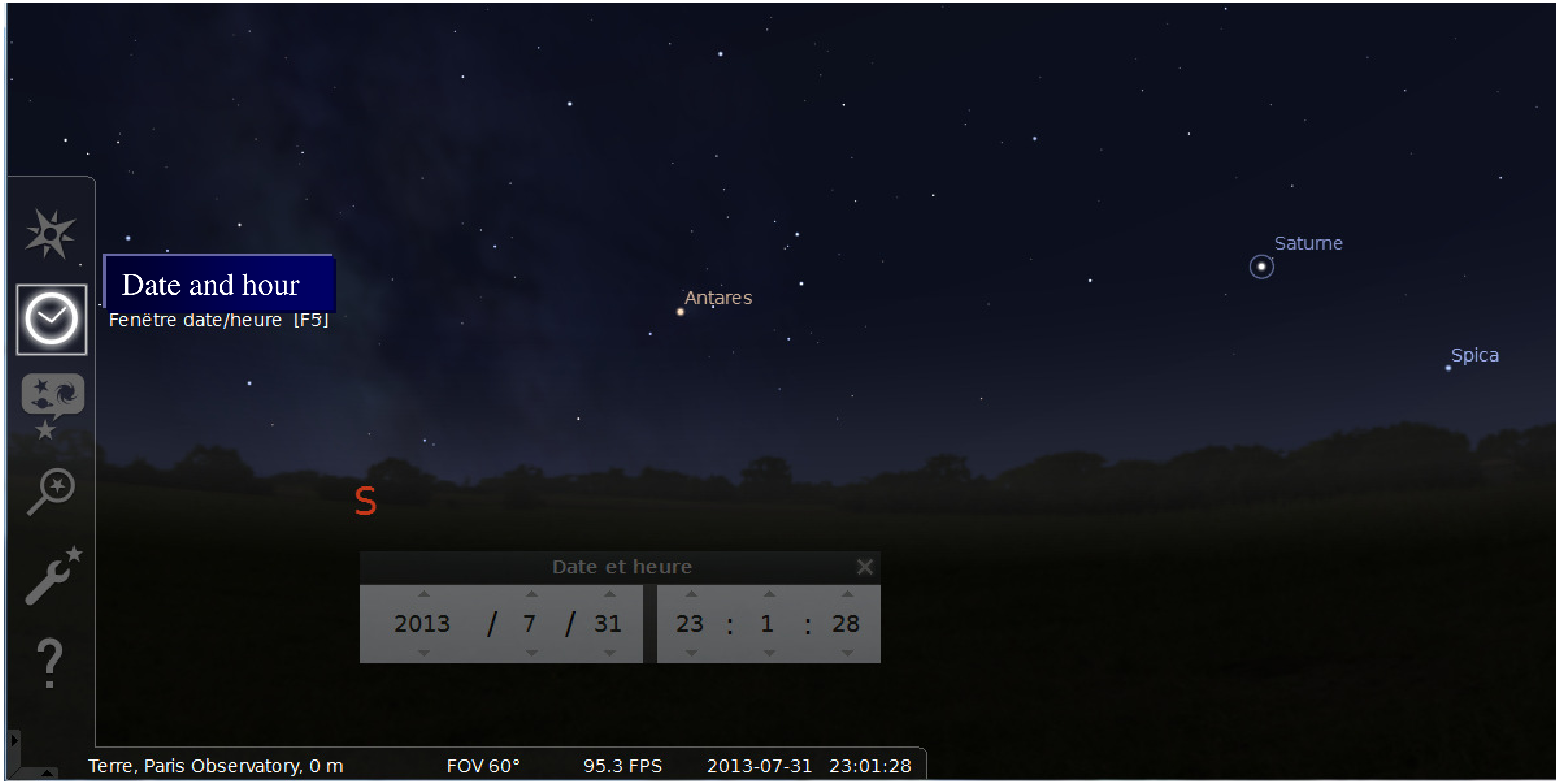
About Pleiades, our exercices are still on work

Workshop 1, with Stellarium

- **Purpose:** teaching and training the precession of the equinoxes
- **Data:** dates of lunar eclipses
- **Measures** with Stellarium 0.11.0

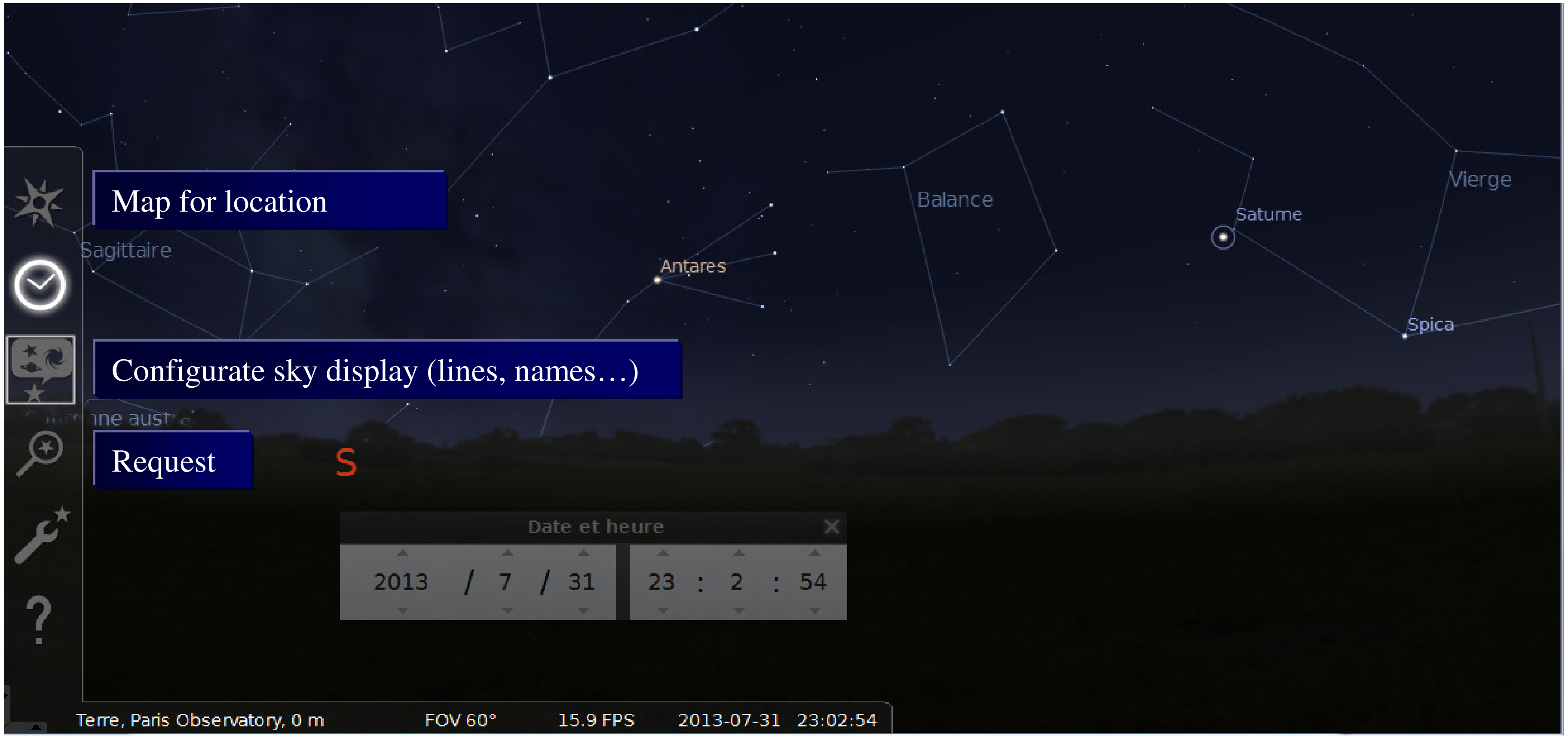
Some others versions of Stellarium contain wrong values

1st exercice: Stellarium for beginners / Version 0.11.0



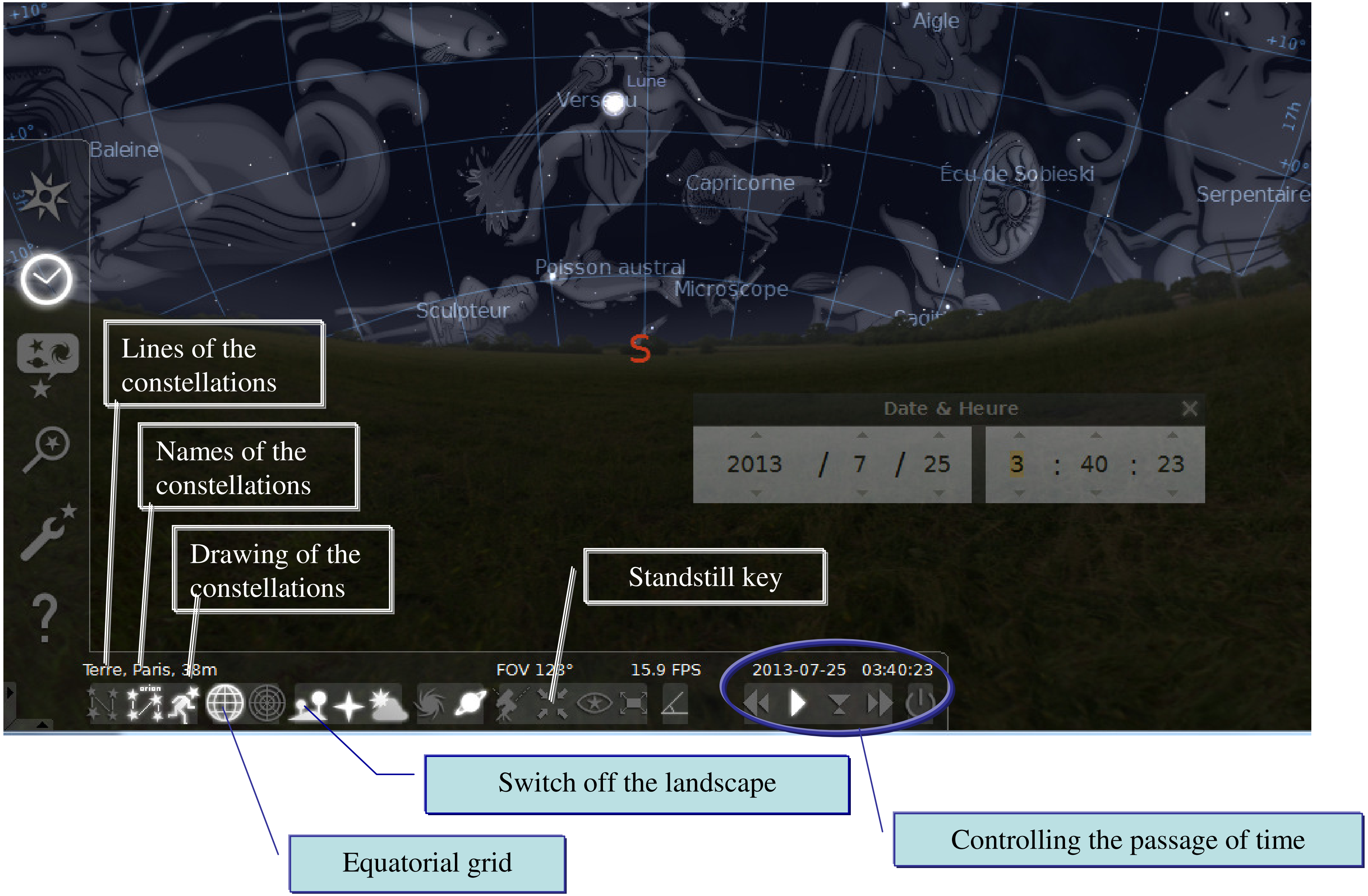
Virtual planetarium STELLARIUM (free software)

Vertical toolbar on the left



Notice : Spica (α Virgo), that we shall use for our first step as archaeoastronomers

Horizontal toolbar on the bottom



2nd exercice: Enjoying a lunar Eclipse

With Stellarium 0.11.0

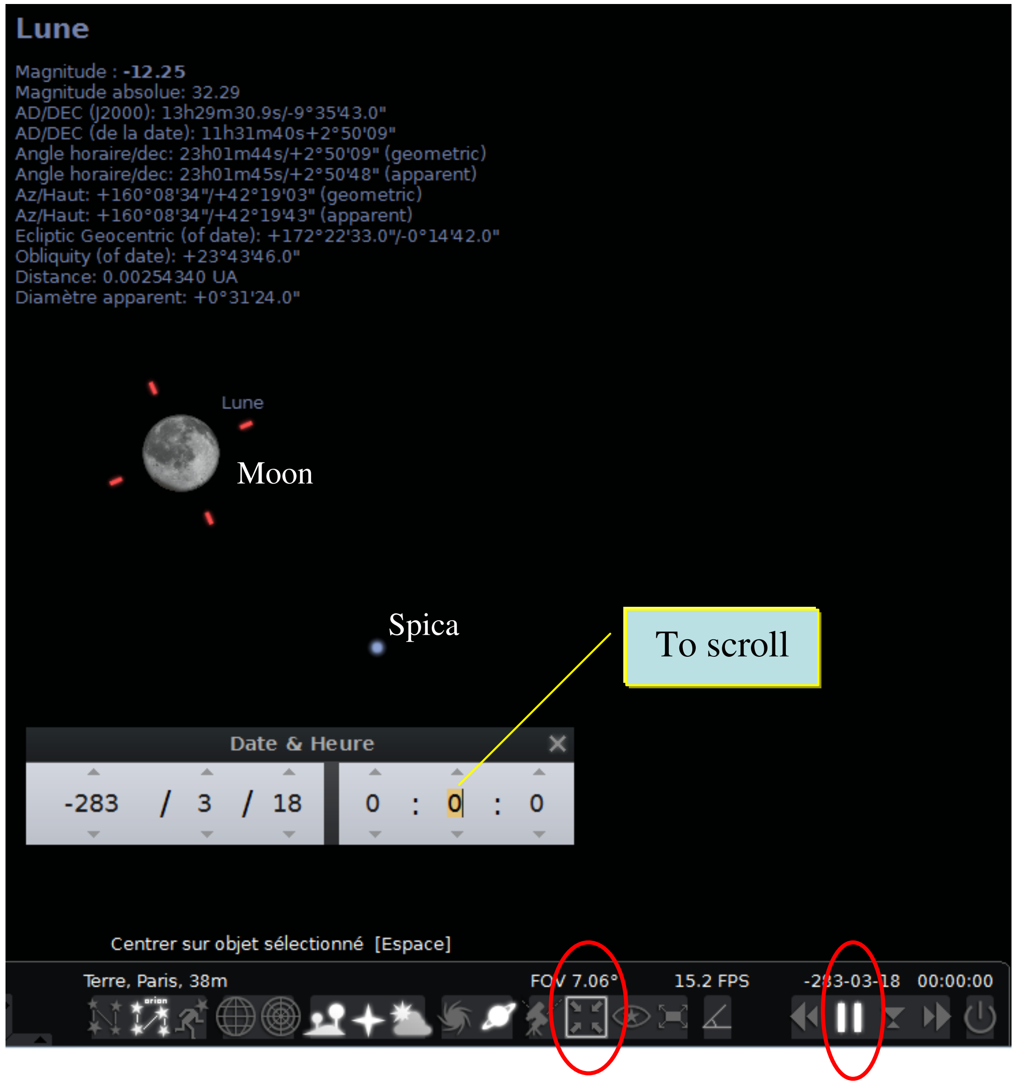
- Check -283/3/18 at 0/00/00 / **Moon**

  You get the very beginning of the solar eclipse

- Use the 2 *fixing clicks (red ellipses out against, below right)* to bring the moon to a standstill.

- Scroll minutes (yellow number) from 0 to 3h 15. *You may enjoy the whole eclipse.*

- Evaluate the hour of the full eclipse (midtime between beginning and end). *This hour is about 1h30.*



3rd exercice: Precession at a glimpse

- Open Stellarium 0.11.0
- Check any date D you like, far enough from 2000

  (< 1900 or > 2100)
- Choose any star you like, Spica, Sirius, Betelgeuse …
- Read $X_1 = RA_{star}$ (of the date) in hours
- Read X_2 = RAstar (2000= date 2000/1/1) in hours

- Period T of precession:

  T : 24 = I(2000 – D) : (X2 –X1)I

  I…I = absolute value

Any time far enough from 2000 (not to need corrections), any star gives the same precession, of course!

A quick example with Spica

Date D = 0/1/1

Angular position of Spica:

French AD = English Right Ascension RA

$X1 = RA_{Spica}$ (0/1/1) = 11h 41m 50s ≈ 11h 42m

$X2 = RA_{Spic}a$ (2000= date 2000/1/1)= 13h 25m

Period T of the precession (proportionality):

T_{years} : 24h = $(2000 – 0)_{years}$: (13h25m –11h42m)

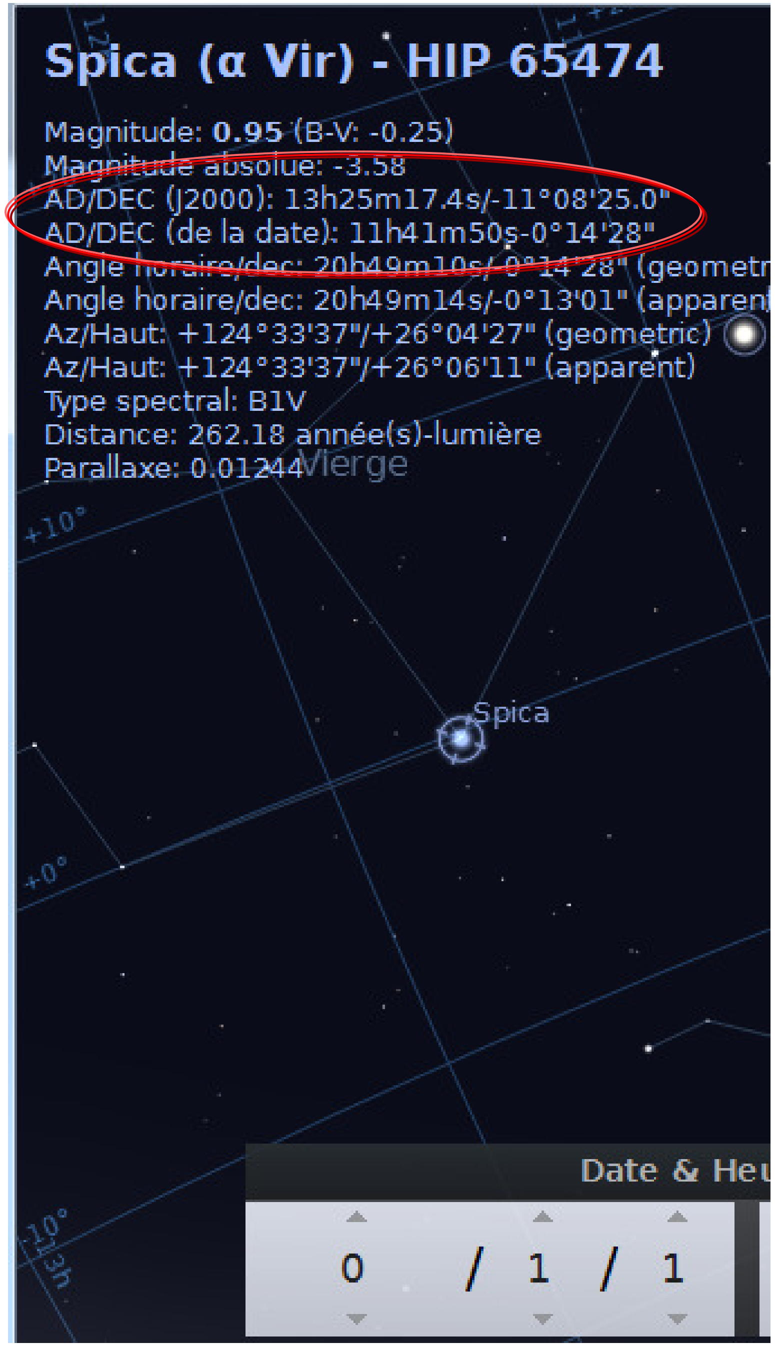
Convert in decimal hour:

13h25m – 11h 42m = 1h43m = (1+ 43/60)h = 1,72h

You can now calculate:

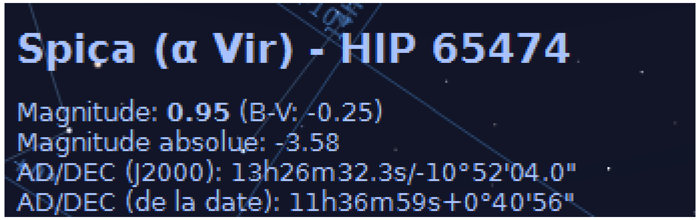
T_{years} = 24* 2000/ 1,72 = **27900 years**

The order of magnitude for T is good, let us use it to find a more accurate value.



Now, we can find the accurate value of T

- Go back in time till (2000 – 27900)= - 2**5**900 years
- Check Spica at that date; read right ascensions(RA): they differ almost 2 hours



- Use *Standstill keys*; then, change date into -2**4**900 years; RA differ one hour.
- Change date into -2**3**900 years; RA differ 6 minutes.

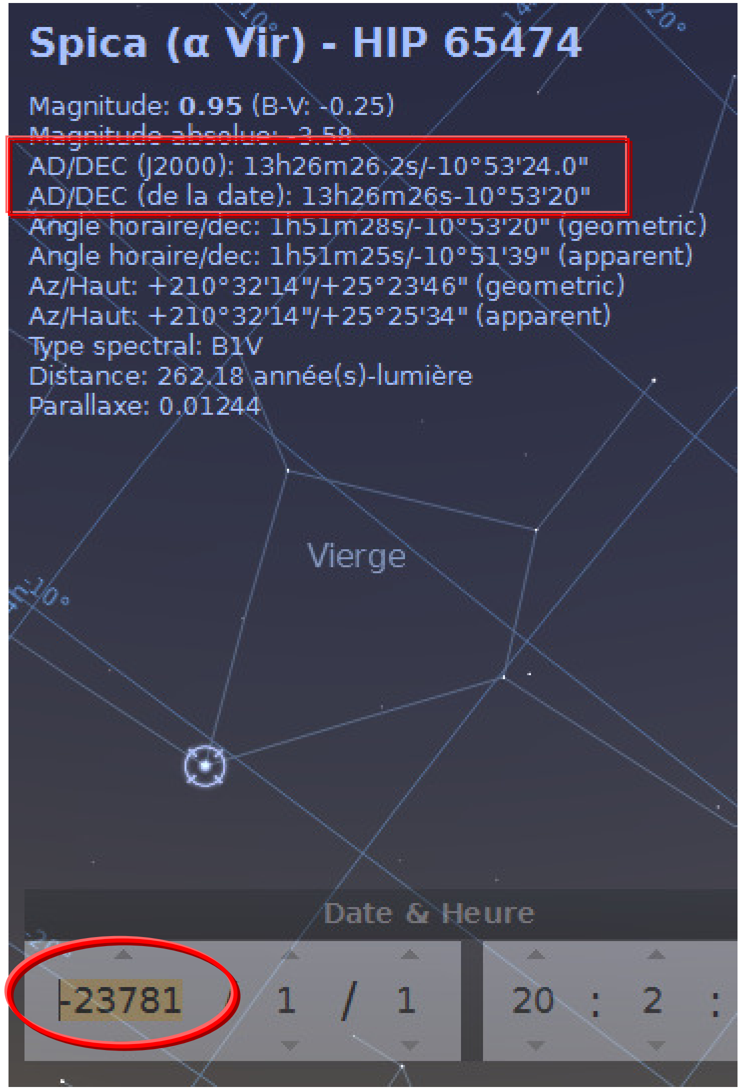
You can notice 1000 years is one hour difference.

- Scroll on the year number , increasing till

RA of the date = RA (2000) [out against right, **red rectangle**].

So the precession period T is exactly [out against right, **red ellipse**]:

T = 2000 – (-23781) = **25 781 years**



4th exercice: The roundabout of stars

We shall work for example with Polaris (α Minor in the Little Bear)

With Stellarium

1- Choose Equatorial grid

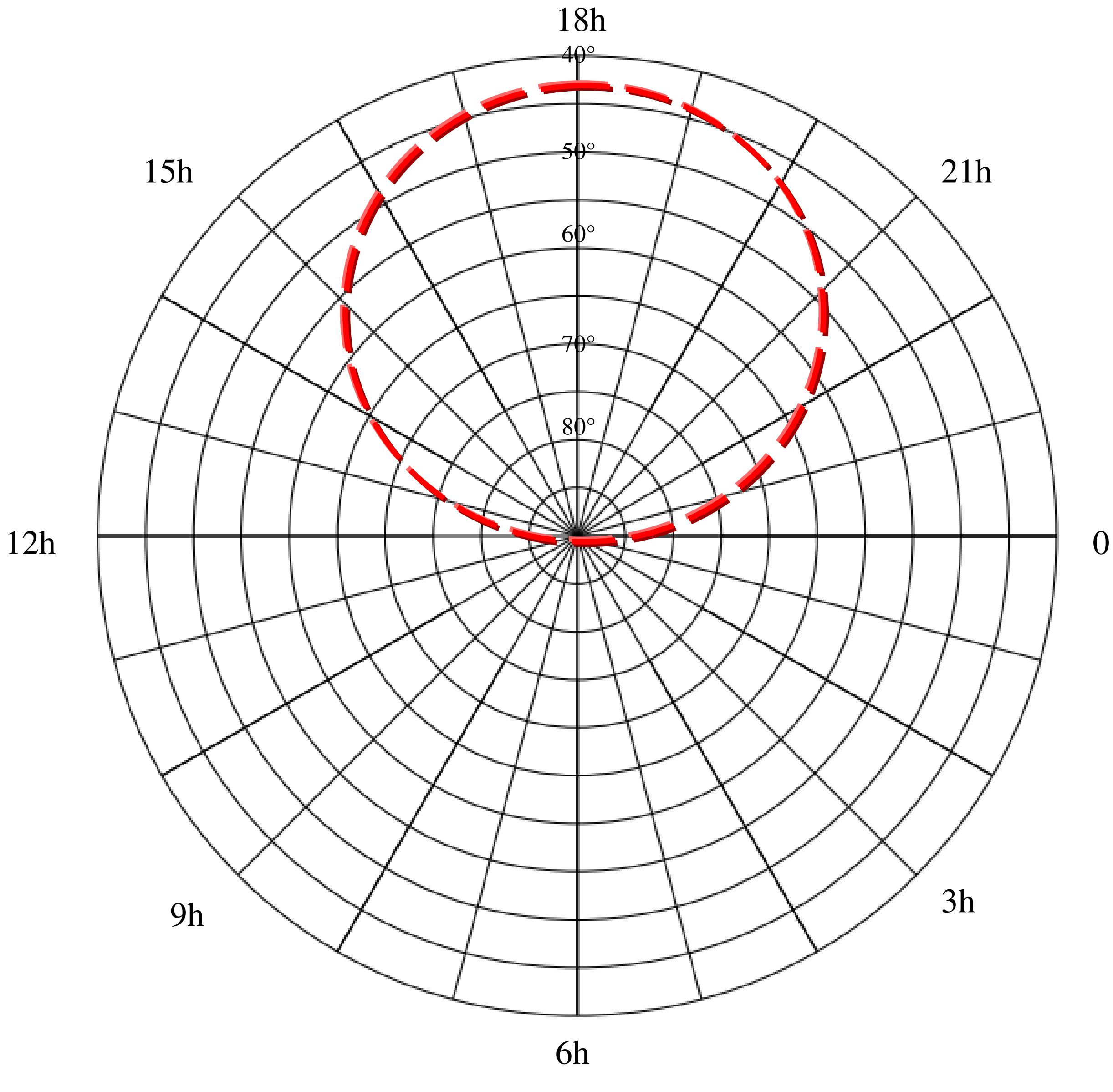
2 – Choose today 2013/7/31

3 – Choose Polaris

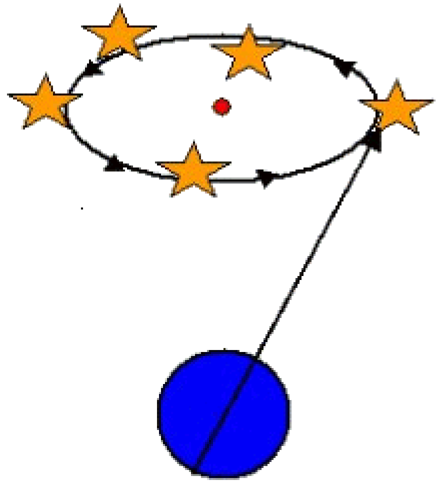
4 - Identify RA/DEC of Polaris and report on the grid. You get the North pole.

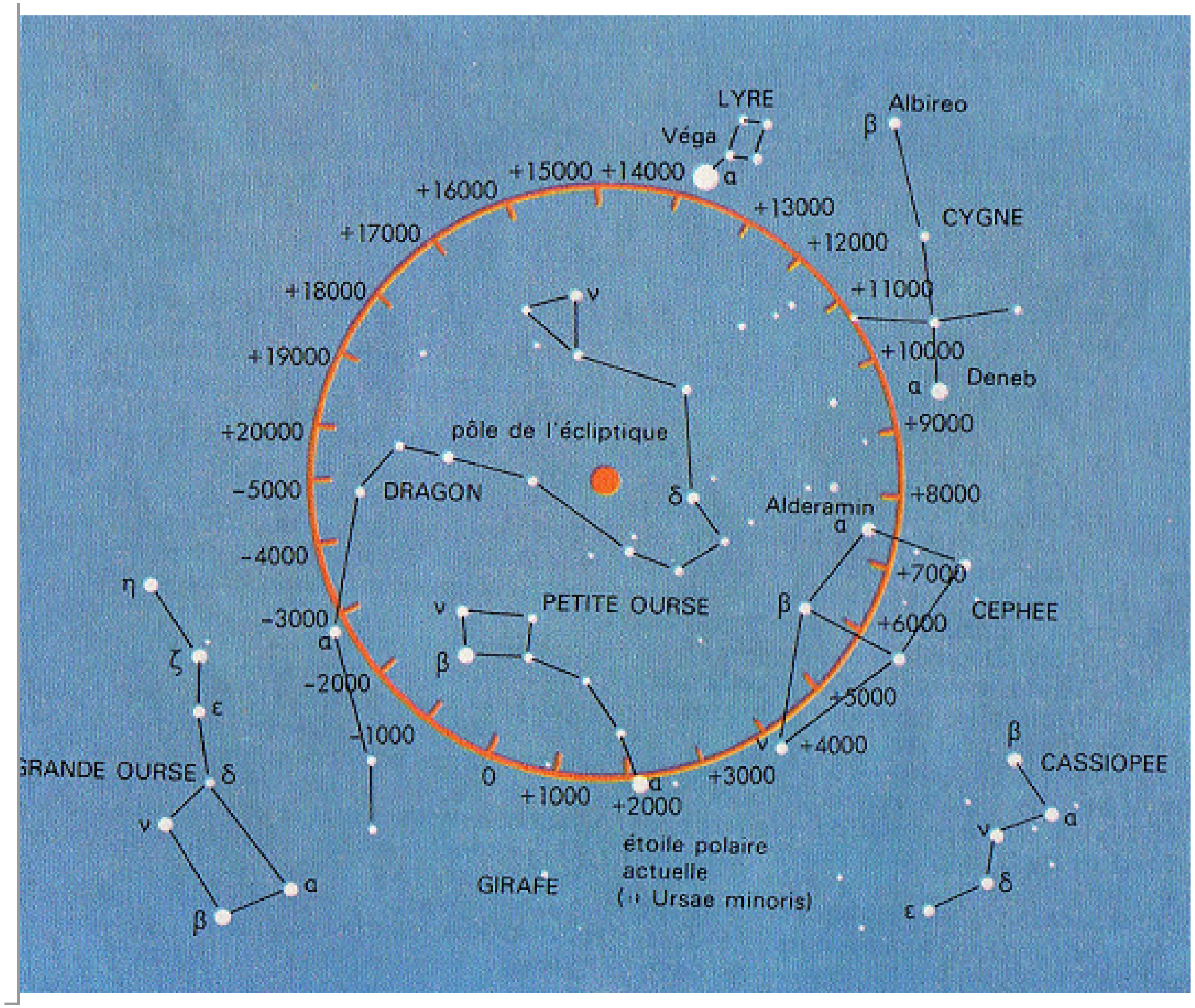
5 – Do it again every millenia (from -24 000 to 2000 for example).

You get the **apparent trajectory of Polaris.**



North Pole through millenia





What are the stars at North Pole along a period of precession:

Check for example:

-1000; - 2800; + 2000; +7500; +10200

5th exercice: On Timocharis and Hipparchus'footsteps

Ancient greek calculations (angles were measured with astrolabe):

1 – The angle between **Spica and Moon** (Right Ascension or RA/ french AD read in Stellarium)

2 – The angle between **Spica and Sun** (Right Ascension or RA/ french AD read in Stellarium)

3 – The shift S due to the **apparent motion of the Sun** ; near Equinox, S = 360/365 (°/day)= 0,9863°/day

Timocharis'measure 283 BC.	Hipparcus'measure 131 BC.
March 18th, 1h35m that is ≈ 7 days before Spring Equinox Apparent velocity of Sun: 360/365 (°/day)	January 17th, 23h32m that is ≈ 26 days after Winter Solstice Apparent velocity of Sun: 1,062 °/day
$RA_{spica\text{-}lune}$ = 5m = - 1,25° $RA_{Spica\text{-}Sun}$ = 180° - 1,25° = 178,75° RA_{Spica} = 179,67° – Shift of 7 days before Equinoxe	$RA_{spica\text{-}lune}$ = 3h45m = 56,25° $RA_{Spica\text{-}Sun}$ = 180° + 56,25° – 90°= 146,25° RA_{Spica} = 146,25° + Shift of 26 days after Solstice
$X_1 = RA_{Spica}$ = 178,75- 7*360/365 = 171,85°	$X_2 = RA_{Spica}$ = 146,25 + 26*1,062= 173,86°

$X_2 - X_1$ = 173,86 – 171,85 = 1,99 ≈ 2 °

⇒T: 360° = [-131 – (-283)] : [(173,86 – 171,85)°] => T = 360*152:2 = 27360 years

We can keep: T ≈ 27000 years ☺ ☺ ☺

A table to imagine new exercices…

	Date	Time	RA_{Moon}	RA_{Moon} 2000	RA_{Star}	RA_{Star} 2000	Period of the Precession
Spica Timocharis							
Spica Hipparchus							
Spica today							
Sirius today							
Polaris today							

RA = Right Ascension

Workshop 2, with Salsa J

- **Purpose:** to draw the light curve of a supernova

- **Data: File SUPERNOVA_ LIGHT_CURVE**

  12 images of M51, SN1994I, which is a SN 1a supernova

  You may check image information in Salsa J/ Date in Image/ Information

- **Technique seen previously**: Draw a line and Plot Profile

  To be precise, zoom before practising

With SalsaJ

1 - File / Open / Supernovae/ SUPERNOVA_LIGHT_CURVE / SNIMG1.FTS

2 – Click Image/ Information

You get :

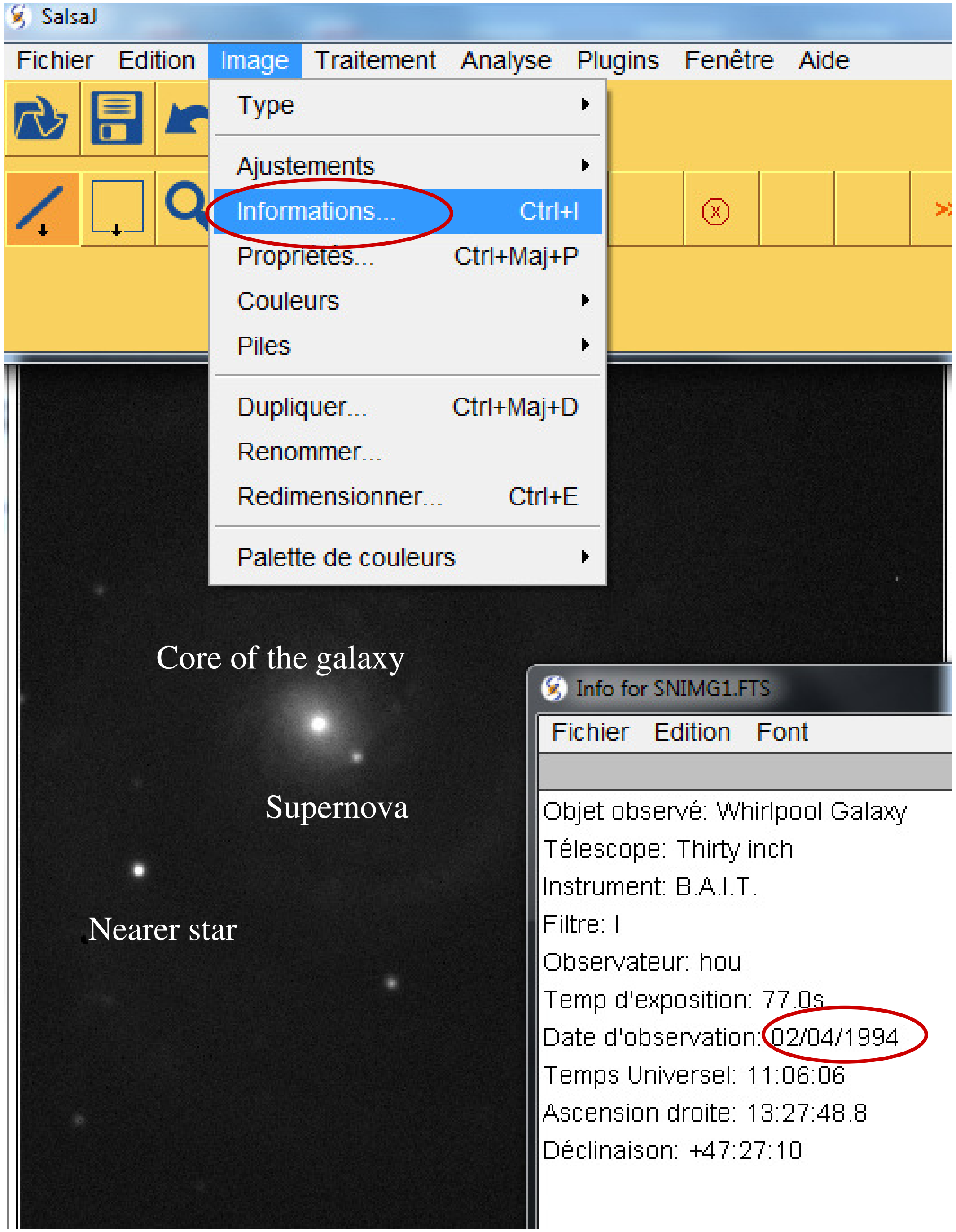
- the name of the object
- the observing day: 02/04/1994

and some others informations.

3- Open the 12 images and detect the «guest » star.

4 - Plot profiles (see next slide) and measure brightnesses.

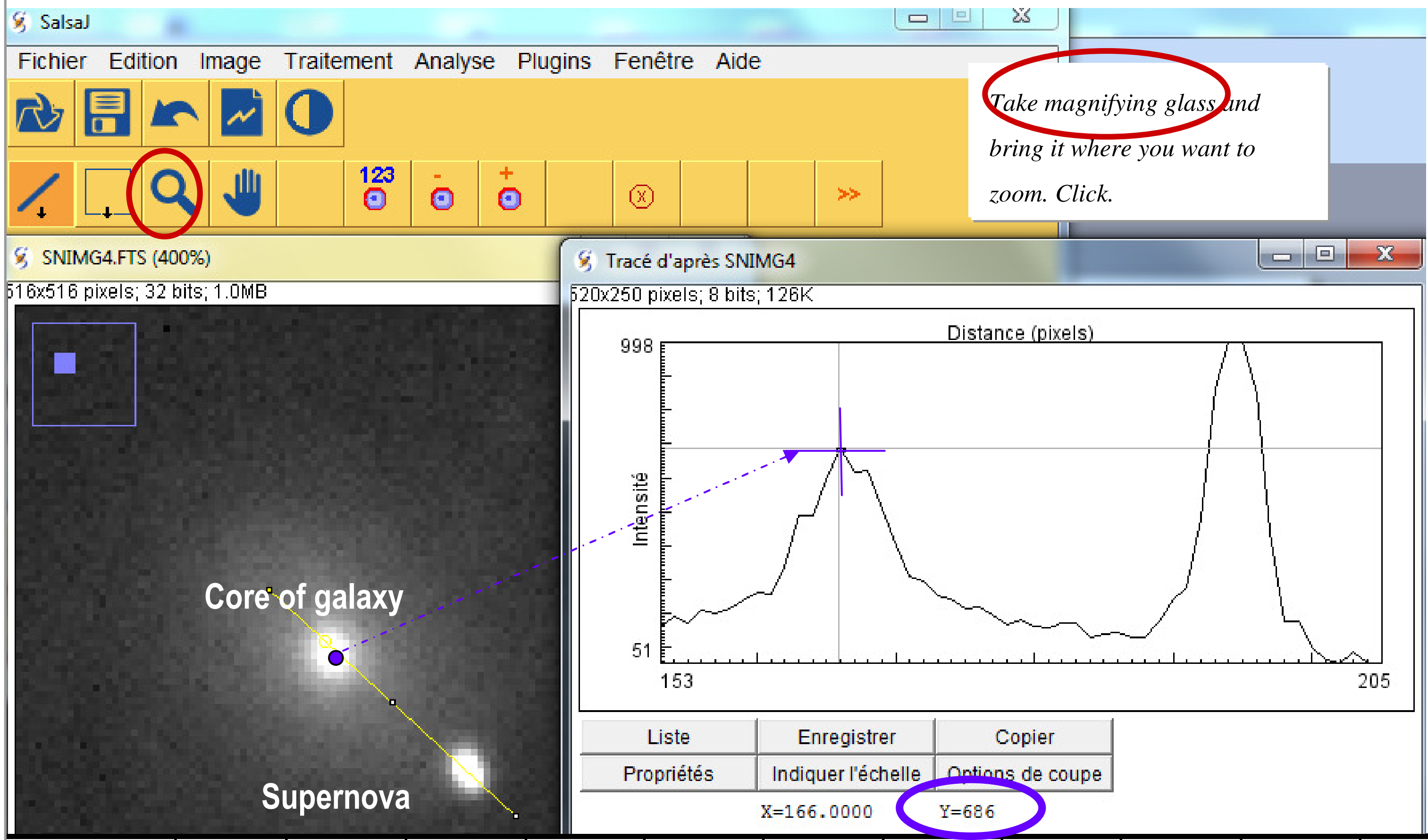
5 - Draw the light curve : ratio Supernova/ Core according to date



1- Open 12 images SUPERNOVA_LIGHT_CURVES (12 images/ Read dates in Image Info)

2 – Automatic photometry is not precise enough; open and enlarge every image**(zoom)**

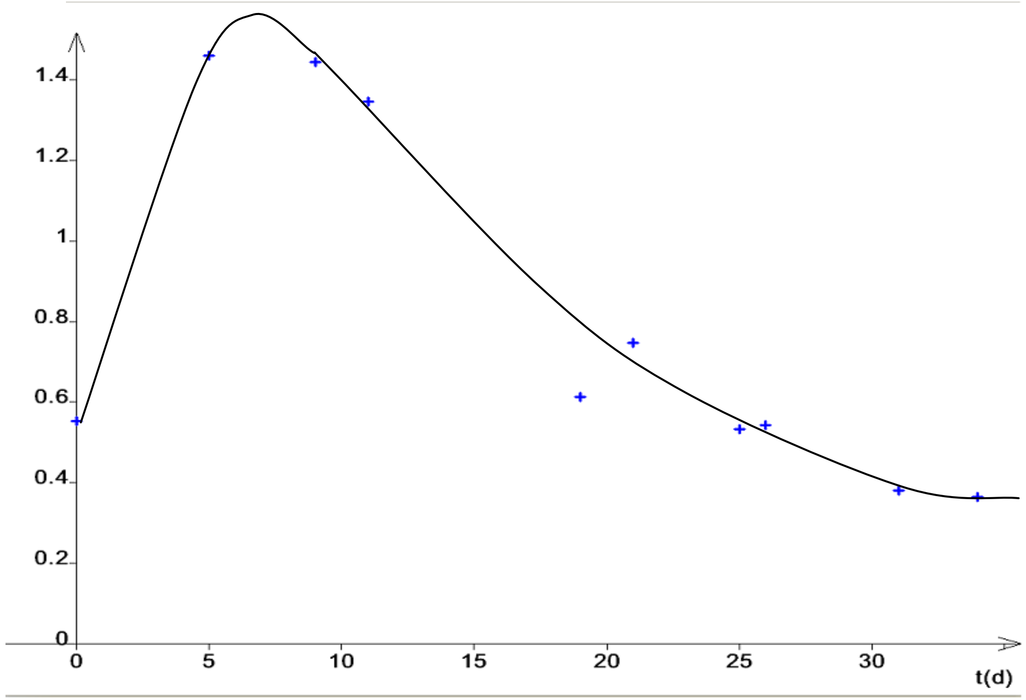
3 - **Analyse /Plot Profile**, follow the line with the mouse, read intensities on the curve.



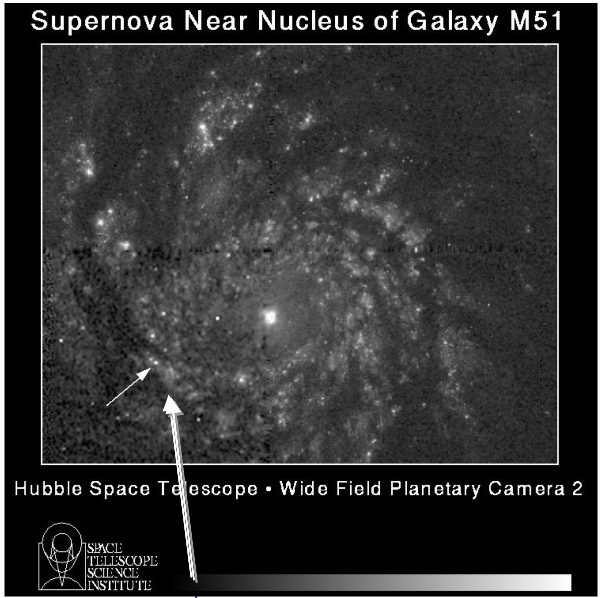
Date (Image Info)	0	5	9	11	12	19	20	21	25	26	31	34
Core of the galaxy (Brightness)	393	561	1457	686	765	1117	1116	1181	1237	1060	916	1115
Supernova(Brightness)	217	819	2103	923	823	665	913	883	658	576	349	407
Supernova/Core	0.552	1.460	1.443	1.345	1.076	0.595	0.818	0.748	0.532	0.543	0.381	0.365

Draw the light curve of supernova SN 1994 I according to date
(making reference to the core of the galaxy)

Ordinate = Brightness of the supernova/ Brightness of the core of the galaxy



Date



SN 1994I in galaxy M 51 Whirpool galaxy

Type 1a supernovae are very regular => standard candles to measure distances of galaxies

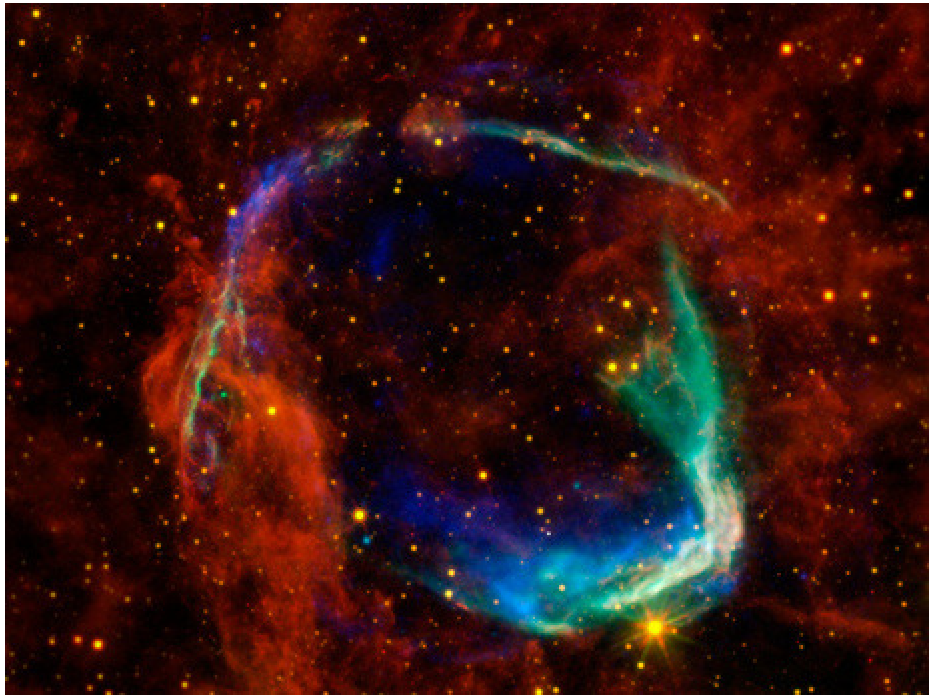
=> We receive Light emitted/ $(4 \pi d^2)$=> we can calculate the distance d of the galaxy

2011: Exploring Supernovae Leads To Physics Nobel Prize

The Supernova Cosmology Project, directed by Saul Perlmutter, including Carl Pennypacker, founder of Hands-on-Universe.

The High-Z Supernovae Search Team, directed by Brian Schmidt ,

They studied distant Type Ia supernovae. By looking at the brightness and color of light coming from these supernovae, the scientists were able to figure out that the Universe has expanded faster in the past 5 billion years instead of slowing down, as it was before that.



See key-word ***Dark energy*** (or black energy)

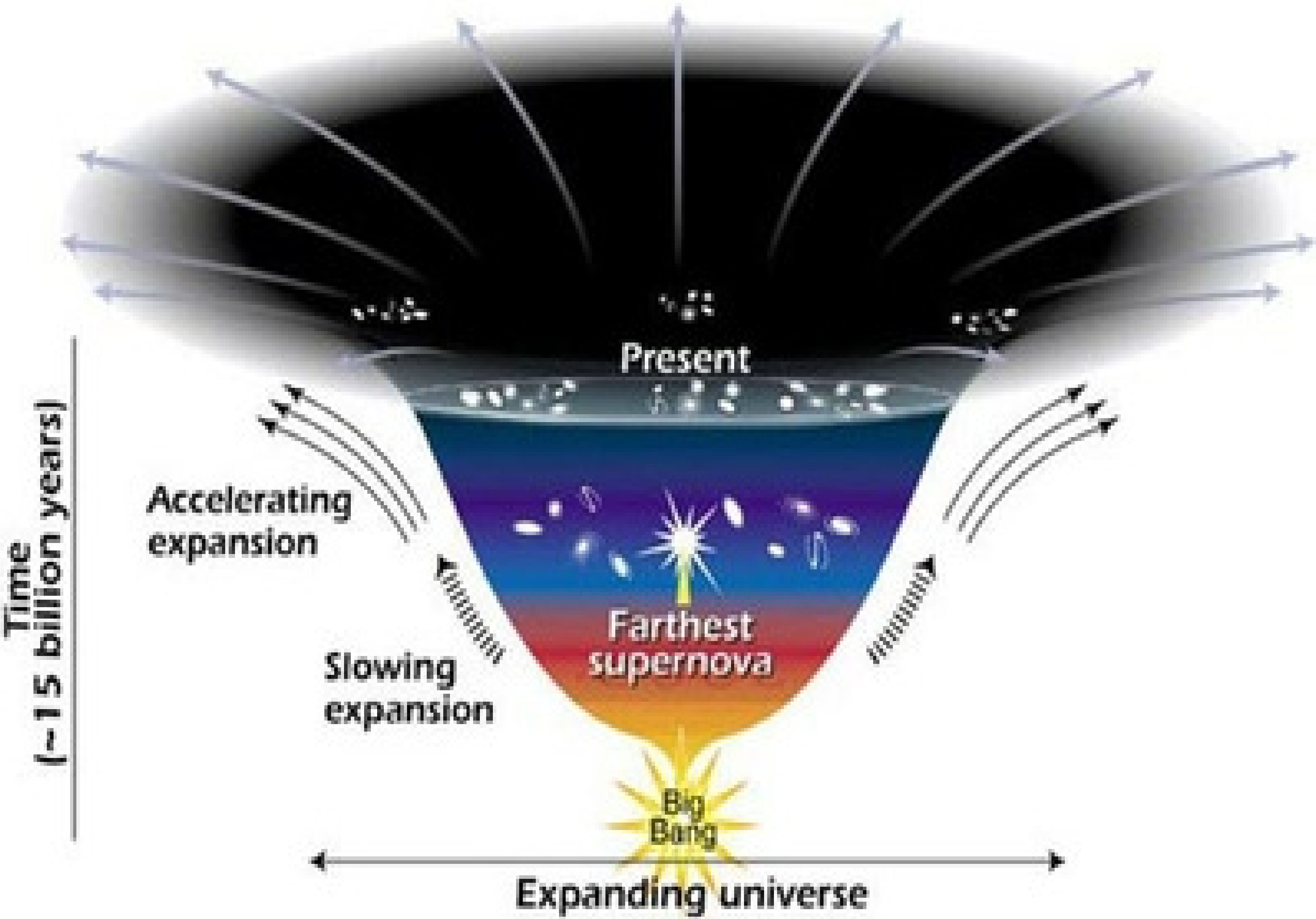
Dark energy, a sort of anti-gravitation energy

Far galaxies: distance measured with SN1a is different from distance estimated with Hubble law. It sounds like an abnormal redshift

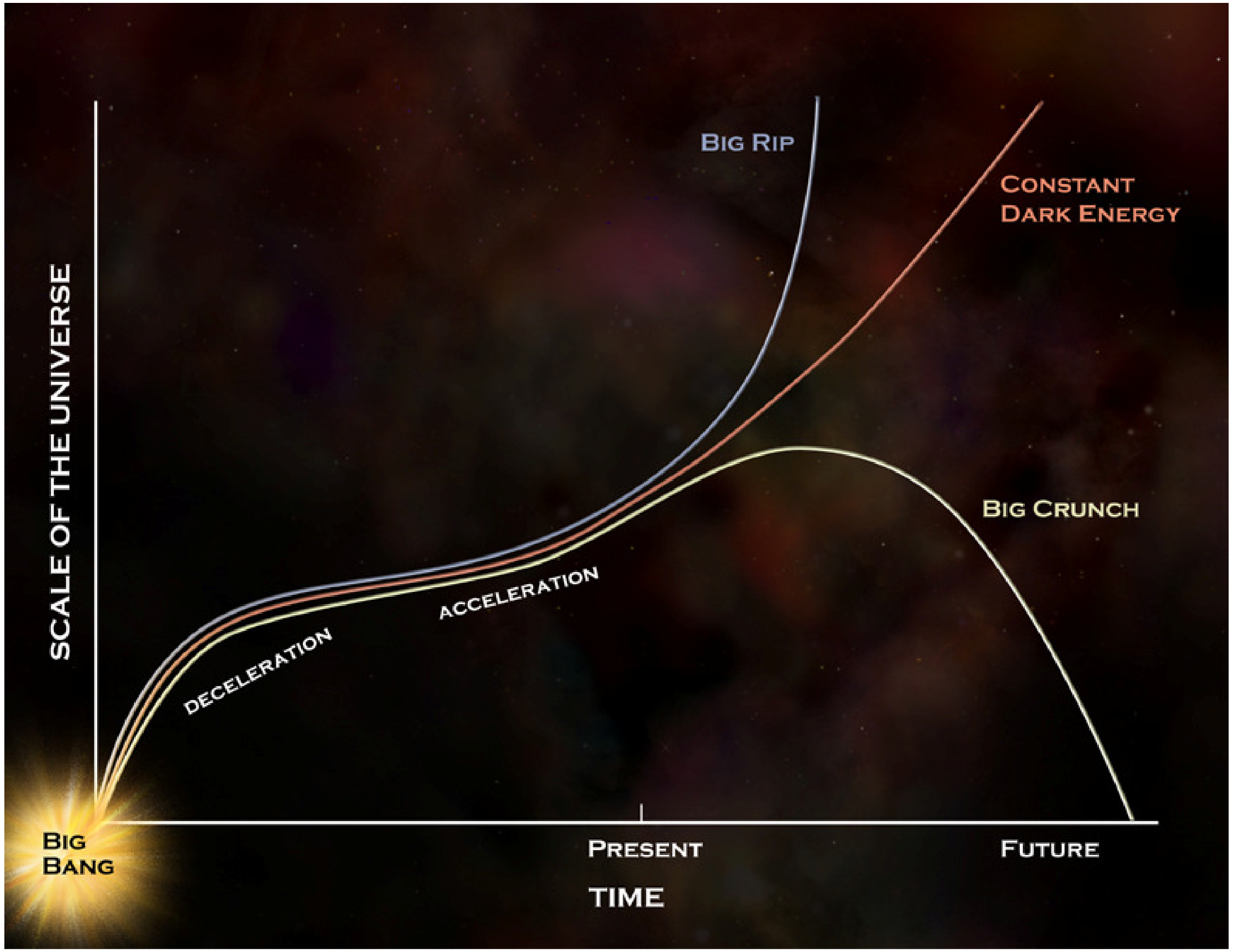
As if an unknown potential energy was modifying the expansion of the universe

So Hubble constant is not so constant!

A sort of anti-gravitation energy is modifying expansion, so Hubble constant is not so constant!

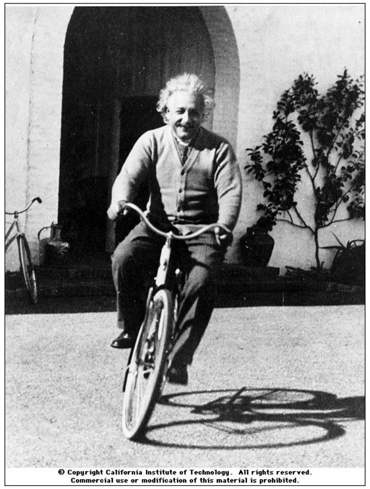


Dark energy and the future of our Universe



The Puzzle: Supernovae SN1a, give abnormal redshifts

The clue: 2 potential energies



Normal gravity :

for a spherical homogenous Universe,

$$E_{P1} = - 16\, \pi^2\, \rho^2\, G\, R^5/15$$

Dark energy, looking like anti-gravitation

$$dE_{P2} = \Lambda\, c^2 r^2\, dm \text{ et } dm = 4\, \pi\, \rho\, r^2\, dr \Rightarrow E_{P2} = 4\, \Lambda\, \pi\, \rho\, c^2\, R^5/15$$

Total potential energy is null if $\Lambda = 4\, \pi\, \rho\, G/3\, c^2$, which is **the cosmologic constant that Einstein had imagined** (his Λ was $4\, \pi\, \rho\, G/c^2$) and said it nonsense!

With France-Hands On Universe, archaeoastronomy as a window, and CCD as an eye ...

Draw your own timeline ☺

Some of Michel Faye's students, near VLT (Very Large Telescope, Chile)

Thank you for your attention