Stellarium Simulation for Research and Outreach

Georg Zotti

Archaeological Prospection and Virtual Archaeology



Education and Heritage in the Era of Big Data in Astronomy

The first steps on the IAU 2020-2030 Strategic Plan

IAUS367: Dec. 9, 2020



- Stellarium
 - The perfect learning/teaching/outreach tool?
 - Some facts
- Virtual Archaeoastronomy
 - Architecture, landscapes, and skyscapes
 - OUTREACH: 100m² of skyscape in an archaeological exhibition
- Some further highlights
- Skycultures

Stellarium Desktop Planetarium

- Multiplatform
- Pretty sky simulation



- diverse projections (stereographic, cylindrical, etc.)
- Exchangeable constellation patterns (star myths)
- photo horizons
 - **Plugin-extendable**
- Open-source community project
 → ADD YOUR CORRECTIONS



- **Given Started in Summer of 2000 by Fabien Chéreau**
- □ First team active until ~2012
- About 10 major contributors
- Currently 2-4 active developers
 - Alexander Wolf (Maintainer; Barnaul, Russia)
 - Georg Zotti (Vienna, Austria)
 - Fabien Chéreau
 - Guillaume Chéreau



- □ 18.500 commits by 186 contributors
- 928.558 lines of code
- □ 93 languages 339 translators on **transifex**
- □ 575 financial supporters
- Quarterly releases, about 400.000 to 700.000 downloads each







Make your community sustainable.

Community Effort: Translation

transifex Dashboard Teams < stellarium English (en)	Reports Search Strings → German (de) ✓		Stellarium V Volte Providence Provi	transifex
4613 All ▼ Filters Q reviewed:no	54 38 Untranslated Unreviewed	< 0	TRANSLATED BY GZOTTI, 4 MONTHS AGO. &New Folder	 93 languages 15 without
1828				translators
&New Folder	&Neuer Ordner		&Neuer Ordner	
Show &hidden files	Zeige &verborgene Dateien			Join the team!
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 Orbits thickness in pixels 2015 	Strichstärke für Orbits, Pixels		Added by gzotti in Stellarium / stellarium, 4 months ago	
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Voices from https://sourceforge.net/projects/stellarium/reviews

zandtelchiola ***** Brilliant piece of software	Posted 07/28/201 ★★★★ This program is not just amazing, it's inspiring! It not only let's me explore the night sky, even if it's rainy outside or to find
william079516 ★★★★★ This project is wonderful.	Posted 11/14/2014 regression of the process. It's accurate Posted 11/14/2014 regression of the procession of th
★★★★★ Stellarium is a real gem. F	jplummerie ★★★★★ This is one of my favorite open source projects. It is very pedantic program in terms of Celestial Mechanics, and it is very beautiful in terms of GUI.
zistoire ★★★★ Amazing sim realist.	1 user found this review helpful. Was This Helpful? Reply Flag as Spam Posted 04/18/2014 ulation of the atmosphere. I was stunned by the lunar eclipse on 15 March 2014. The moon was freaking

Was This Helpful?

Reply

The Night Sky is alive!

Astronomical Cultural Heritage



Astronomical Cultural Heritage

TWANight.org

Anthony Ayiomamiti

Astronomical Cultural Heritage



Why do we have to Simulate the Sky?

- Site accessibility
 - not required to disturb the site
- The past sky cannot be observed!
 - Earth's precession
 - Stellar proper motion
 - Light pollution
- Speed-up research
 - allows observations during a full year within minutes



Requirements of Astronomical Accuracy for Historical Application

ΔT (earth rotation): over 30 models Precession/Obliquity: IAU 2006, Vondrák et al. 2011/12 Nutation: IAU 2000B Planet positions: - VSOP87 (recommended: -4000 ... +8000) - JPL DE430/DE431 Accurate planet positions -13.000...+17.000 **Accurate Lunar Physical Ephemeris** TODO (Lunar Rotation) and planet axes

TODO Fix mismatch with Lunar occultations (aberration)

1515-05-20 05:15:00

Landscapes and Horizons in Stellarium 0.20



Landscapes and Horizons in Stellarium 0.20





Andrew Smith: Horizon - http://agksmith.net/horizon/default.html

can export Stellarium Landscapes (SRTM 90m and 30m based; others: TBD).



Landscapes and Horizons in Stellarium 0.20

G. Zotti: Make Stellarium panoramas from Google Earth https://homepage.univie.ac.at/Georg.Zotti/php/panoCam.php

One Horizon for Each Viewpoint



Therefore... 3D Models in Stellarium!

Using Virtual Reconstructions in Stellarium's Scenery3D Plugin:

TIN export/convert

Landscape model from

- GIS (ArcGIS, QGIS, ...)
- Sketchup Pro (Trimble)

Building/feature model from

- Modellers (CAD, 3D Studio, Maya, Blender, ...)
- Laserscan models
- Image-Based Models (Photoscan, SfM-MVS, ...)
- etc.



Chichen Itza: El Castillo equinox "snake" phenomenon



Stellarium simulation for same day, 2009-03-21



"Snake Shadow" (Wikimedia)

Model from Google 3D Gallery



Immediate experience

-2011	1	- 7 -	1	13	17	 25	-	32



Immediate experience Interactive exploration

Hadrian's Villa, Tivoli: "Antinoeion"



Astronomical Cultural Heritage: Chankillo, Peru



Made from LiDAR data courtesy Clive Ruggles & Ivan Ghezzi

Astronomical Cultural Heritage: Chankillo, Peru

Made from LiDAR data courtesy Clive Ruggles & Ivan Ghezzi

Astronomical Cultural Heritage: Chankillo, Peru



Made from LiDAR data courtesy Clive Ruggles & Ivan Ghezzi

Stellarium 0.17 & Scenery3D: Laser Scan



Combine with Unity Game Engine

G. Zotti et al. Serious Gaming for Virtual Archaeoastronomy Studies in Digital Heritage, 4(1):51–74, 2020 DOI:10.14434/sdh.v4i1.31041

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Ecliptic of Date

Seasonally Mutable Terrain (grass color/snow)

G. Zotti et al. Serious Gaming for Virtual Archaeoastronomy Studies in Digital Heritage, 4(1):51–74, 2020 DOI:10.14434/sdh.v4i1.31041

OUTREACH: The Skyscape Planetarium

- Exhibition in the MAMUZ Museum for Prehistory, Mistelbach (Austria) 2016-17.
- Stonehenge Horseshoe in 1:1 replica stones
- 25x4m curved screen, 5 projectors
- Scripted show (~20 minutes)
- Archaeoastronomical details explained with simulated sky

G. Zotti, F. Schaukowitsch, M. Wimmer: The Skyscape Planetarium. In Culture and Cosmos, vol.21 269–281, 2017. https://www.cultureandcosmos.org/pdfs/21/CCv21_17Zotti.pdf

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Remote Control Web Interface

- Stellarium as web server
- Replicates most GUI settings
- Avoids user interface on big screen
- Allows external communication and starting shows at preprogrammed times
- Optional:
 Operator uses web browser
 - on PC
 - simple 7" Tablet

Stollarium romote	control	
in controls Selection Sky DSO	Landscape Starlore Actions and scripts Location	Projection
Time	Time jumps	View
Date and Time Julian Day	$\langle \langle \mathcal{M} \rangle$ Solar hour $\langle \langle \mathcal{M} \rangle$ Anomalistic mon	th
	$\langle \langle \downarrow \rangle$ Solar day $\langle \langle \downarrow \rangle$ Anomalistic year	
-2200 / 7 / 12		ury
	$\langle \langle , \rangle \rangle$ Sidereal day $\langle \langle , \rangle \rangle$ Mean tropical mo	inth EOV:
	Sidereal year << U> Mean tropical year	ar Projec
4 : 56 : 18	Sidereal century << U> Mean tropical century	ntury
	$\langle \langle \langle \rangle \rangle$ Synodic month $\langle \langle \langle \rangle \rangle$ Tropical year	
	<< U Draconic month	
ΔT = 48592.64s	A Draconic year A Draconic year	
	Gaussian year	

MAMUZ: Nightly Tours



MAMUZ: Nightly Tours



A Few More Highlights

Moon (×2.0)



Also note the horizon panorama made from Google Earth coverage

Eneth	CE.	Cirnophora	Dodolhana	970 m
			RITETAT	

23

Moon

Ø

5

Type: moon Magnitude: -8.38 (reduced to -7.82 by 3.17 Airmasses) +153°22'10.6"/+18°20'20.1",(apparent) +24°50'12.5"/ -30°18'01.8" SGL/SGB: -119°18'51.1"/+47°29'03.2" λ/B (J2000.0): +305°01'50.8"/ -0°47'07.8" λ/β (on date): +305°17'11.9"/ -0°47'14.5" Edintic obliquity (on date): +23°26'07.1' Mean Sidereal Time: 18h43m53.6s Apparent Sidereal Time: 18h43m52.8s 20h39m Transit 1h05m Set: 5h32m Parallactic Angle: -18º38'06.1" IAU Constellation: Cap Hourly motion: +0°21'41" towards 83.2° Hourly motion: da=+0°22'52" do=+0°02'43" Elongation: +179°04'04.8" Phase angle: +0°55'46.3" Illuminated: 100.0% Moon age: 14.8 days old (Full Moon) Position angle of bright limb: +133.4950° Distance from Sun: 1.018 AU (152.317 M km) Distance: 0.002701 AU (404021.405 km) Light time: 0h00m01.3s Orbital velocity: 0.972 km/s Heliocentric velocity: 30.283 km/s Sidereal period: 27.32 days (0.075 a) Synodic period: 29.53 days (0.081 a) Apparent diameter: +0°29'33,98" Diameter: 3474.8 km Sidereal day: 655h43m11.7s Mean solar day: 708h44m03.0s Albedo: 0.120 Penumbral eclipse magnitude: 2.00360 Umbral eclipse magnitude: 0.93309

Magnitude: -8.38 (reduced to -7.82 by 0.17 Airmasses) Mason Opposition Magnitude: -12.74 Maan Opposition Magnitude: -12.74 Wash Opposition Magnitude: -12.74 (% (on date): -0931278.212-199422 (% (on date): -0931278.212-199

Moor

. .

Date and Time

 Date and Time
 Julian Day

 2018
 7
 27
 23
 :
 17
 :
 41

Earth, HoheWand-Skywaik, 859 m FOV 1.1° 14.9 FPS Fri, 2018-07-27 23:17:41 UTC+02:00 刻 招 余 注於 ∑ 冊 圖 圖 圖 圖 2 + 1 ⑤ グ ⑤ 章 聲 ダ ⊕ ≑ 図 ∠ 雨 米 8 25 ☆ ≪ Ⅲ 文 ♪

Admittedly, Nature Wins!

Photo: G. Zotti

Sun

Type: star Magnitude: -16.98 (extincted S-16.48) Absolute Magnitude: 4.83 RA/Dec (on date): 8h47558.465/+17°51'32.3* Corona from 2008, Mongolia

 RA/Dec (on date):
 8h47m58.465/+17'

 RA/Dec:
 +271920'54.77'/+23'

 Ad/Dec:
 +271920'54.77'/+23'

 Sal. long./lat.:
 -151923'23.57'+33'

 Supergal.long./lat.:
 +6790'418.07'-46'

 Scilptic obliguity (on date):
 +1299'3'15.37'-0'

 Scilptic obliguity (on date):
 +239'22'42.2"

 Mean Sidereal Time:
 13h46m53.2s

 Size:
 S13m

 Transit:
 13h00m

 Set:
 20h30m

 Daytime:
 14h58m

 IAU Constellation:
 Cnc

 Distance:
 1015 AU (151.831 M km)

 Gaustin totation velocity:
 1.856 km/s

 Apparent diameter:
 +021'31.05'

 Diameter:
 1392000.0 km

 Sidereal ape:
 5431''

 Sidereal ape:
 5436'''

 Scilere:
 56.13

 Seliere:
 56.106



Solar Eclipse 2020-12-14, IAUS367



Comet Tails in Stellarium (since 2014)

- Simple parabola-shaped tail shells
- Details visually tweaked mostly from
 - C/1996 B1 Hyakutake and
 - C/1995 O1 Hale-Bopp
- Individual parameterisation possible

C/1996 B2 (Hyakutake)

Type: comet (periodic) Magnitude: 0.59 (extincted to: 0.90) Absolute Magnitude: 5.00* 4h05m03.74s/+78°46'17.2" 4h04m30.40s/+78°45'32.6" 8h56m37.46s/+78°46'29.8"(apparent) . +349°31'00.6"/+39°51'43.4" (apparent) Gal. long./lat.: Ecl. long./lat. (J2000.0): +80°17'07.2"/+56°18'17.7" Ecl. long./lat. (on date): +80°13'52.9"/+56°18'15.9" Ecliptic obliquity (on date): +23°26'14.8" Mean Sidereal Time: 13h01m23.1s Apparent Sidereal Time: 13h01m23.4s Circumpolar (never sets) IAU Constellation: Cam-Orbital velocity: 42.438 km/s Sidereal period: 108866.911 a Phase angle: +91°45'19.1" Elongation: +80°28'41.3" Coma diameter (estimate): 586000 km (+1°39'48") Gas tail length (estimate): 9.22 M km (+27°10'28") Core diameter: 10.0 km

				Date a	nd Time					×	
Da		J	ulian Da	iy							
<mark>1996</mark>	-	3	-	28	O	:	33	:	13		

¢/1996 B2 (Hyakutake)

Comet Tails in Stellarium



"C/Ikeya-Seki (1965f=1965VIII)"

 Type:
 Commer (periodic)

 Magnitude:
 6.20

 Absolute Magnitude:
 6.20

 RA/Dec (2000.0):
 12h26m01.34/-1720036.

 HA/Dec (on date):
 12h26m01.34/-1720036.

 HA/Dec (on date):
 12h26m01.34/-1720036.

 Adj./Alt:
 +112936/25.57/+990103.

 Gal. long./lat.:
 +13956/04.87/-1720020.

 Gal. long./lat.:
 +13956/04.87/-97/-13928'39.

 Ecil. long./lat. (2000.0):
 +1392926'3.97/-13928'39.

 Ecil. long./lat. (2000.0):
 +139296'41.3*

 Meah Sidereal Time:
 Th34m16.6s

 Apparent Sidereal Time:
 Th34m16.6s

 Apparent Sidereal Time:
 15h27m.

 Tatast:
 9h51m

 Set:
 15h27m.

 IAU 'Constellation:
 Crv

 Distance:
 1.044 AU (126.202 M km)

 Distance from Sun:
 0.484 AU (72.392 M km)

 Distance:
 1.044 AU (136.202 M km)

 Orbital velocity:
 60.472 km/s

 Sidereal period:
 876.701 a

 Synodic period:
 1.010 a

 Phase angle:
 +70924'54.6"

Type: comet (periodic) Magnitude: 3.54 (extincted to 1.1) Absolute Magnitude: 3.64 (extincted to 1.1) Absolute Magnitude: 3.64 (extincted to 1.1) RA/Dec (12000.0): 12h27 - 12h29 65551 Ikeya-Seki RA/Dec (on date): 12h26m01.9 s/ -17P30/36.6"

/_ PC/Ikeya-Seki (1965f=1965VIII)"

Photo by James W. Young (TMO/JPL/NASA); Wikimedia Commons

8

×

C/2006 P McNaught?

Alnair

Aldhanab

RA/Dec (J2000.0) of cross: 21h49m00.44s/-34°25'00.3"

39'35.00' x26'59.49 X scale: 34.8027'/px Rotation: -118° -15°-5°-1° 0° +1° + ✓ Telescope #3: 50mm Rayleigh criterion: 4.1 Dawes' limit: 3.87" Abbe's limit: 3.77"

8

Lens: None

Peacock

39°35.00'×26°59.49

Comet Debris: Meteors!

- Sporadic meteors (eye candy)
- Meteor Showers plugin (by Marcos Cardinot)
 Auto-update with IMO data
- WANTED

 Fireball/meteorite fall plugin with particular events (Chelyabinsk, Europ. Fireball Network data, ...)

The 1833 Leonid Storm over N. America

Arcturus

8												
	-		-		A.	14 C				- AS		
	1833		11		18	4		12	-	27		
					-							

HiPS Surveys for Non-Optical Wavelengths

Model by Oscar M.: https://3dwarehouse.sketchup.com/model/u30cebaae-ca75-4fd5-a7ca-55b885f7feb7/Arecibo-observatory

Earth, GZ_Arecibo+Radio+Telescope, 270 m

FOV 100° 23.3 FPS Fri, 2020-07-03 02:44:28 UTC-04:27 (LMST)



- Plugin
- Automatic update feature
- Data from:

Catalog of 93 Nova Light Curves: Classification and Properties Richard J. Strope, Bradley E. Schaefer, Arne A. Henden https://arxiv.org/pdf/1004.3698.pdf

Historical Supernovae Plugin

• Currently only simple models for Type Ia or Type II



Type la



- From: Fysika Kosmosa, Moscow 1986, pp 601ff, [http://www.astronet.ru/db/msg/1188703]
- Better modelling desirable (SUGGESTIONS?)



STELLARIUM SKY CULTURES How Various Cultures See and Use the Sky

- Patterns formed by stars
- Imagined figures in the sky
- Orientation in
 - Time
 - Space (seafaring etc.)
- Mythology

Bands Segnus

Constellations

"official" IAU constellations

- Constellations
 - "official" IAU constellations
 - line art ("stick figures")

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 - figure artwork (optional)

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 - figure artwork (optional)
- Asterisms
 - inofficial figures
 - only line art

- Constellations
 - "official" IAU constellations
 - line art ("stick figures")
 - figure artwork (optional)
- Asterisms
 - inofficial figures
 - only line art
- Ray Helpers
 - Long distance "pointers" (alignments)

Delphinus

Pegasus

Honores Friderici Great Square of Pedasus

e Y in Acua ius (The Um

Vulbecula

Lacert

Other Cultures, Other Figures!

Arab/al-Sufi

Belarus

Ojibwe



Missing/TBD: Lunar Stations

- Observed by many Asian cultures
- current *workarounds* by coding as asterisms
- but several schemes seem to exist:
 - asterism
 - abstract region in ecliptical coordinates
 - abstract region in equatorial coordinates
 - others?

Missing/TBD: Dark Constellations

- Dark clouds in the Milky Way
 - Australian Aboriginals: "Emu in the Sky"
 - Inca "Yacana" (Llama)
 - A few more
 (see Gullberg et al., 2020)
 - others?

How to show these properly?



Gullberg et al., 2020

We don't know everything!

- Seasonal Constellations
 - depending on Solar longitude
 - other schemes?
- Different aspect of planets
 - e.g. Mercury, Venus as Morning/Evening Stars
 - others?
- Seasonally differing star names?
- Temporally evolving Sky Cultures?
 - MUL.APIN \rightarrow Greek \rightarrow Ptolemy \rightarrow "European/Western" \rightarrow IAU
 - − Old Chinese \rightarrow ... \rightarrow Modern Chinese?
- Any other needs?

...

Translation Issues (1)

- Proper name or just a term in original language ?
- Shall we totally switch off "Western" names?
 - Will the "foreign" user still know the stars&planets?
- Translation
 - Not every translatable name has been translated to English
 - Serious problem for our "Community Translators"
- Meaning
 - Missing context prevents translation
 - E.g. What is the "Blue Birth Woman" in (D/L/N)akota Skyculture?
 - "Snake Large Anus" → ???

Translation Issues (2)

TODO: Show any useful combination of

- Original spelling
 - All characters from Unicode (Cuneiform, Hieroglyphs, Maya, ...)
- Transliteration
 - May depend on user language
 - Need experts for transliteration
- Translation to user language
 - Meaning may get lost!
 - Needs experts in the respective culture
 - How to preserve meaning and myths?
 - Add meta information for translators?
- \rightarrow Need better description.

Review and Quality Assurance?

New in version 0.19: Tentative Classification scheme

- Traditional
 - "Living" sky culture
 - Created by members of respective culture/community
- Ethnographic
 - "Living" sky culture
 - From fieldwork by foreign researchers
- Historical
 - Past sky culture
 - Textual transmission by historians
- Single
 - Discrete, mostly historical work (Bayer, Schiller, Hevelius, Bode, ...)
- Personal
 - Not based on (peer-reviewed) culture astronomy research
 - Not supported by noteworthy community
- Incomplete
 - No references/further reading
 - Obviously lacking information

If YOU can and want to participate

please contact us

https://github.com/Stellarium/stellarium

Funded collaboration preferred!

Thank You for Your Attention!

Contact: Georg Zotti LBI ArchPro Hohe Warte 38 1190 Vienna, Austria Georg.Zotti@univie.ac.at http://archpro.lbg.ac.at

In press:

G. Zotti, S. Hoffmann, A. Wolf, F. Chéreau, and G. Chéreau. The simulated sky: Stellarium for cultural astronomy research Journal for Skyscape Archaeology, 6(2), 2020



Download Stellarium only from https://stellarium.org Current release V0.20.3 (2020-09-27) Extensive PDF Manual

Stellarium 0.20.3 User Guide Georg Zotti, Alexander Wolf (editors)



LBI ArchPro Partners





Vestfold og Telemark

FYLKESKOMMUNE

Norwegian Institute for Cultural Heritage Research



UNIVERSITÄT WIEN Vienna University of Technology





ArcTron ^{3D}

Expertise in Three Dimension







Zentralanstalt für Meteorologie und Geodynamik