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# ViSiON: Visibility Service for Observing Nights

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## Abstract

Preparation of detailed night schedule prior to an observing run can be tedious, especially for solar system objects which coordinates are epoch-dependent. We aim at providing the community with a Web service compliant with Virtual Observatory (VO) standards, to create tables of observing conditions, together with airmass and sky charts, for an arbitrary list of targets. We take advantage of available VO services such as the SIMBAD astronomical database, the Aladin sky atlas, and the *Miriade* ephemerides generator to build a new service dedicated to the planning of observations. The requests for ephemerides charts and tables are handled by a VO-compliant Web service. For each date, and each target, coordinates in local and equatorial frames are computed, and used to select targets accordingly to user's criteria for visibility. This new service, dubbed ViSiON for **V**isibility **S**ervice for **O**bserving **N**ight, is a new method of *Miriade* Web service hosted at IMCCE. It allows anyone to create graphics of observing conditions and tables summarizing them, provided as PDF, VOTable, and xHTML documents.

**Keywords:** ephemerides, virtual observatory tools, methods: numerical

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## 1. Introduction

To prepare and conduct observations from a ground-based telescope, many astronomers create airmass charts, also called visibility plots. These graphics represent the elevation above the horizon, or altitude, of each target during the night, providing a graphical and easy way to schedule the sequence of observations, in which each target should be observed as closely as possible to its highest altitude. Another type of visual guidelines are fish-eye sky charts, in which the successive positions of the targets are displayed by tracks on a stereographic projection of the local frame. It also helps optimizing observations, by avoiding pointing the telescope back and forth from different regions of the sky.

If many astronomers have developed their own piece of code for that purpose, several efforts have been made to make such tools freely available to the community. The *staralt* pages<sup>1</sup>, by J. Méndez, allows productions of such graphics. The *skycalc* software<sup>2</sup>, maintained by J. Thorstensen, represents an easily-portable and interactive solution to these points. Yet, these tools have been developed for objects with fixed coordinates, and the eight planets. Planning observations of moving Solar System Objects (SSOs) may therefore result tedious: one should compute first the coordinates of each object, and then enter them into the software interface. This often results impracticable if the list of targets is long, or many dates are envisioned.

We aim here at providing the community with a simple Web service, fully compliant with Virtual Observatory (VO)

standards, to produce tables and charts of visibility for both fixed coordinates targets and moving solar system objects. This service<sup>3</sup> is dubbed **Visibility Service for Observing Night** (ViSiON). Targeted users are observers willing to prepare an upcoming night, or to check the observability of some targets on-the-fly, and developers of night scheduler and telescope control software willing to include airmass charts in graphical interfaces.

The present article is structured as following: we quickly describe the core of ephemeris computation in Sect. 2. The algorithm of ViSiON is detailed in Sect. 3, and the criteria which define observability are presented in Sect. 4. The different ways to access to the service are provided in Sect. 5 and its links with other VO services in Sect. 6

## 2. Ephemeris computation

The ephemerides of planets and small Solar system objects are computed into a quasi-inertial reference frame, taking into account the post-Newtonian approximations. The geometric positions of the major planets and the Moon are provided by INPOP planetary theory (Fienga et al., 2014). Those of small SSOs (asteroids, comets, Centaurs, trans-neptunian objects) are calculated by numerical integration of the N-body perturbed problem (Gragg-Bulirsch-Stoer algorithm, see Bulirsch and Stoer, 1966; Stoer and Bulirsch, 1980), using their latest published osculating elements, from the *astorb* (Bowell et al., 1993) and *cometpro* (Rocher and Cavalier, 1996) databases. The overall accuracy of asteroid and comet

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<sup>1</sup><http://catserver.ing.iac.es/staralt/>

<sup>2</sup><http://www.dartmouth.edu/physics/labs/skycalc/flyer.html>

<sup>3</sup><http://vo.imcce.fr/webservices/miriade/?vision>

ephemerides provided by ViSiON is at the level of tens of milli-arcseconds, mainly depending on the accuracy of their osculating elements. The positions of natural satellites are obtained thanks to dedicated solutions of their motion, e.g., [Lainey et al. \(2004a,b, 2007\)](#) for Mars and Jupiter, [Vienne and Duriez \(1995\)](#) for Saturn, [Laskar and Jacobson \(1987\)](#) for Uranus, and [Le Guyader \(1993\)](#) for Neptune satellites.

The ephemerides of stars, and more generally of all SIMBAD objects ([Wenger et al., 2000](#)), are also computed into a quasi-inertial reference frame, taking into account their proper motion, parallax and radial velocity, as long as the corresponding input parameters are provided by the catalogue. The ephemeris accuracy of SIMBAD objects is thus at the level of the accuracy of their catalogued position.

All the ephemerides in ViSiON are computed relatively to a given observer, in the ICRF reference frame (mean J2000 equator and equinox), and expressed in the UTC time scale. The coordinates of the observer (the topocenter) can be either provided directly by users (longitude, latitude, altitude), or by using the observatory code provided by IAU Minor Planet Center<sup>4</sup> (MPC) for listed observatories.

### 3. Description of ViSiON’s algorithm

For each requested date, a series of computations are performed prior to selection of targets suitable for observation. First, the ephemerides of the Sun are computed, to determine the instants of sunset and sunrise. The limits of the civil, nautical, and astronomical twilights, corresponding to the times when the altitude of the Sun is 6°, 12°, and 18° below the horizon, are also computed at this stage.

Second, the phase and position of the Moon throughout the night are computed and stored. Finally, the topocentric astrometric coordinates of each target are computed, with a time step of 5 minutes, and expressed as equatorial (RA, Dec), horizontal (Az, Alt), and galactic coordinates ( $\lambda_G$ ,  $\beta_G$ ).

Additionally, both solar and lunar elongations are computed at each time step, together with (for Solar system objects only) the solar phase angle, the heliocentric distance and the range to the observer. These detailed coordinates are used to determine for how long each target is visible during the night. The entire list of criteria defining observability is provided in Sec. 4. If there is at least one target observable, the night is included in the result, and these detailed coordinates are the inputs to the airmass and sky charts (see Figs. 1 and 2 for examples). For each date, a table lists all the targets that are visible (see Table 4 for an example), and summarizes their observing conditions at the time of highest altitude (see Table 1 for a description of each parameter).

### 4. Selection and sorting criteria

A suite of parameters are tested to determine if a target shall be considered as visible. The thresholds for selection are provided as inputs, accordingly to each observer’s preference. The

Table 1: List of parameters reported for each visible target, for each requested night. The values reported in ViSiON correspond to the geometry at the time of the highest altitude on sky.

| Quantity               | Description                   | Units    |
|------------------------|-------------------------------|----------|
| Target                 | Target designation            | –        |
| $m_V$                  | Apparent magnitude            | mag      |
| $\phi$                 | Apparent diameter             | arcsec   |
| $\mathcal{D}$          | Duration of visibility window | h:m      |
| Alt                    | Altitude                      | deg      |
| Az.                    | Azimuth                       | deg      |
| RA                     | Right Ascension               | h:m:s    |
| DEC                    | Declination                   | d:m:s    |
| Rate                   | Apparent non-sidereal motion  | arcsec/h |
| $\lambda_G$            | Galactic longitude            | deg      |
| $\beta_G$              | Galactic latitude             | deg      |
| $r$                    | Range to observer             | au       |
| $\Delta$               | Heliocentric distance         | au       |
| $\alpha$               | Solar phase angle             | deg      |
| $\widehat{\text{SEO}}$ | Solar elongation              | deg      |
| $\widehat{\text{MEO}}$ | Moon elongation               | deg      |

following parameters can be specified (see Table 2 for details): altitude, apparent magnitude, solar phase angle, solar elongation, lunar elongation, angular diameter, duration of visibility window, and events limiting the “night” (sunrise/sunset, or civil/nautical/astronomical twilights).

ViSiON proceeds as following: for each target, it computes its ephemerides for each observing date, as described above (Sect. 3). Each parameter (apparent magnitude, elevation, etc) is checked against the selection criteria at every 5 min time step. A time step is considered valid only if the tests against all the criteria have passed. Finally, the target will be considered valid for the date if the number of time steps exceeds the specified minimum duration of visibility (30 min by default) between the two events defining the “night”.

For each date, all the targets that pass the selection are drawn on the graphics, and included in the summary table. Their order can also be chosen by users, among all the parameters listed in Table 1. A double sorting is even possible, with objects being grouped by type first (asteroid, comet, planet, satellite, and fixed-coordinate) then by the requested parameter.

### 5. Access to the service

In 2005, the IMCCE started to implement Virtual Observatory (VO) compliant interfaces to its ephemerides services ([Thuillot et al., 2005](#)). A Web portal<sup>5</sup> describe the various services, such as solar system objects identification (Skybot, [Berthier et al., 2006](#)), or general ephemerides computation (Miriade, [Berthier et al., 2009](#)). All our services are accessible via Web services (based on SOAP and HTTP POST verb) which allow anyone to interface her/his own software with the services, via HTTP request and Web forms, and are integrated

<sup>4</sup><http://www.minorplanetcenter.net/iau/lists/ObsCodes.html>

<sup>5</sup><http://vo.imcce.fr/>

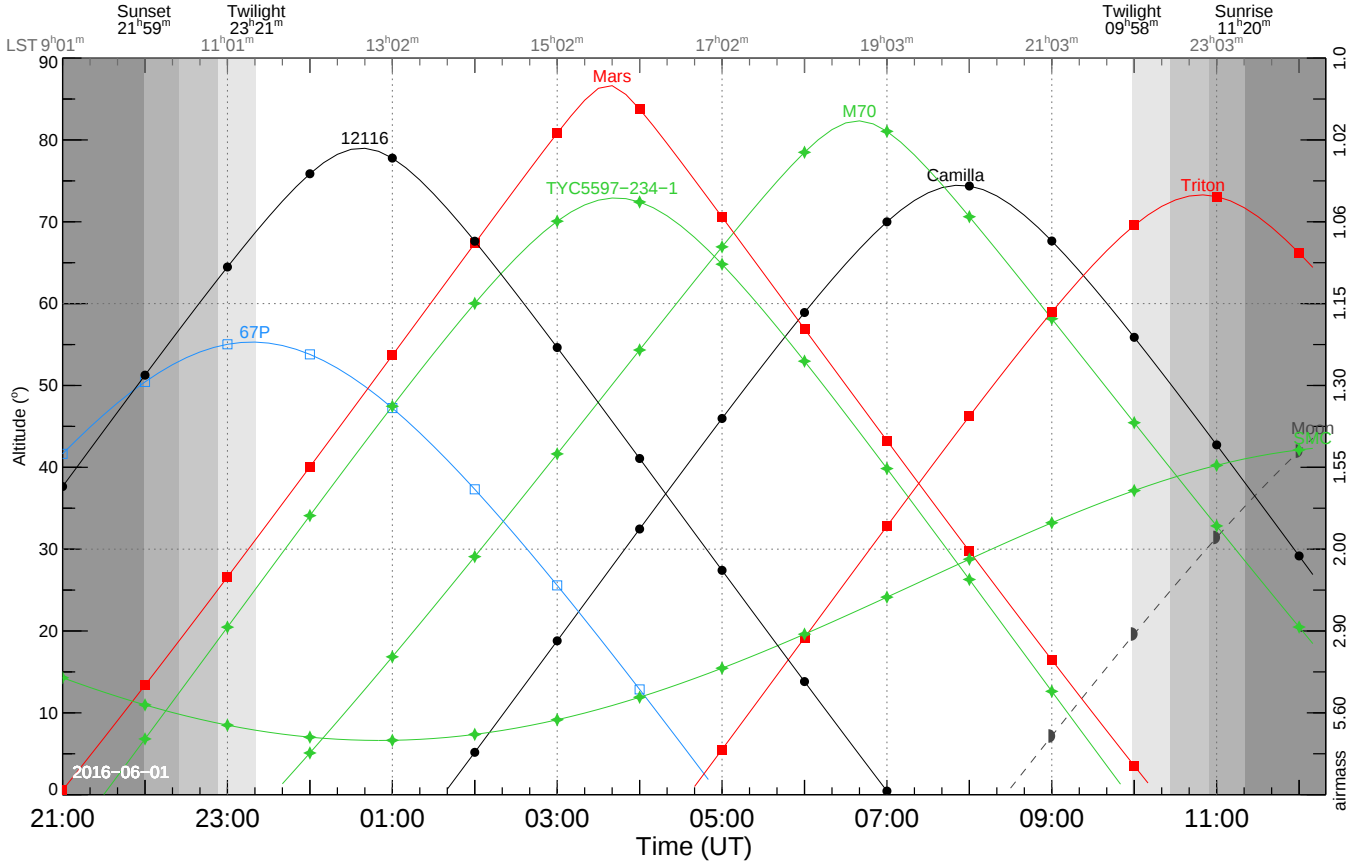


Figure 1: Example of airmass chart produced by ViSiON for a request at La Silla observatory (ESO) on June the 1<sup>st</sup>, 2016. The different levels of gray shading on each side correspond to the day light, civil, nautical, and astronomical twilights. Both universal time (UT) and local sidereal time (LST) are reported on x-axes, and altitude and airmass are provided on y-axes. Each curve represents a target, color-coded as a function of type: planet (Mars), asteroid (12 116 and Camilla), comet (67P), satellite (Triton), and fixed-coordinates such as galaxy (Small Magellanic Cloud: SMC), star (TYC5597-234-1), or clusters (M70).

in several VO-compliant software such as the well-spread Aladin Sky Atlas (Bonnarel et al., 2000).

There are two ways to use the ViSiON web service: by writing a client to send requests to the Miriade server and to receive and analyze the response (as for instance the ephemerides tool for observations in *Service Mode* hosted by ESO, see Carry and Berthier, 2016), or by using a command line interface and a data transfer program such as curl or wget. We also propose a simple query form on our SSO VO portal<sup>6</sup>. In any case, the service accepts nine parameters, described in Table 3. Only the list of targets is mandatory, all the other parameters being optional. We describe them in detail here.

**Targets (name).** Planets can be requested by setting the name parameter to their name or number, preceded by the “p:” prefix, for instance p:Mars and p:5 to request visibility of Mars and Jupiter. Any entry in astorb and cometpro can be retrieved, using the “a:” and “c:” prefixes, e.g., a:Ceres, a:21, or c:67P for the asteroids (1) Ceres and (21) Lutetia, and the comet 67P/Churyumov-Gerasimenko. All the satellites present in the references listed in Sect. 2 are available, though the “p:”

or “s:” suffixes, e.g., p:Phobos, s:Enceladus for the corresponding satellites of Mars and Saturn.

For objects with fixed coordinates, ViSiON queries the SIMBAD service. The targets are therefore inherited from SIMBAD, which currently contains above 8 millions entries. These targets are submitted to ViSiON using the “u:” prefix, e.g., u:Sirius, u:HIP\_87937, u:M\_31 for Sirius, the Hipparcos star 87937, and Messier 31. For objects without a catalog entry, it is always possible to directly submit equatorial coordinates (in decimal hours and degrees in astrometric J2000) to ViSiON, with the “e:” prefix. For instance, the equatorial North pole can be queried via e:0.0+90.0.

In all cases, ViSiON accepts aliases for each target, that can be used to simplify the labels on the graphics, with the syntax prefix:name=alias. For instance in Figs. 1 and 2, the Small Magellanic Cloud was requested as e:0.9-72=SMC, while Mars was requested using p:4 and M70 with u:M\_70. This option may be useful for minor planets with high numbers and provisional designation: to avoid the display of 2000 WO137 on the graphics when querying for a: 123456, one can force the usage of the IAU number by specifying a: 123456=123456.

<sup>6</sup><http://vo.imcce.fr/webservices/miriade/?forms#Vision>

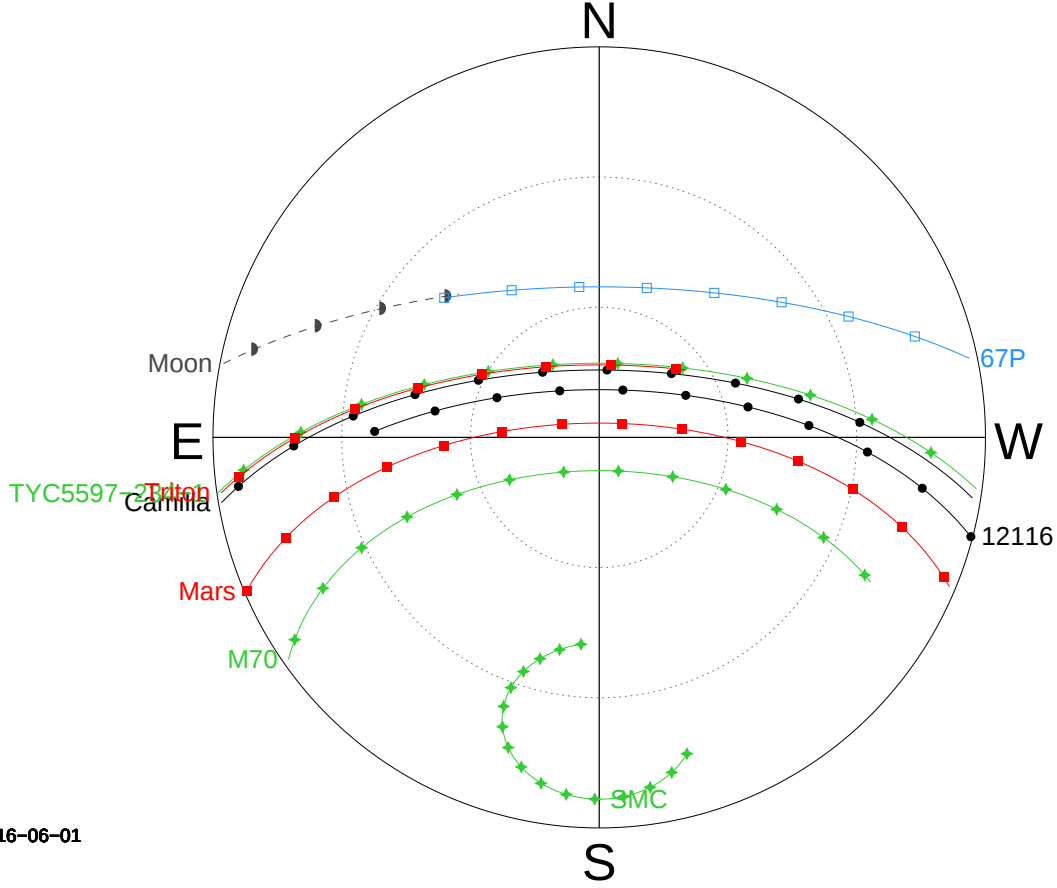


Figure 2: Example of sky chart produced by ViSiON for a request a La Silla observatory (ESO) on June the 1<sup>st</sup>, 2016. As in Fig. 1, each curve represents a target, color-coded as a function of its type.

*Topocenter (observer).* The location on Earth of the observer can be specified by providing the longitude (0,360° West), latitude (-90,+90° North), and altitude (meters above sea level) or the IAU MPC<sup>7</sup> observatory code, in which case ViSiON retrieves the coordinates of the observer from the MPC list. For instance, the Paris observatory can be specified as -2.336537 +48.8364 132.0 or 007.

*Dates of computation (ep, nbd, step).* The ep parameter sets the first (or only) date at which the visibility is sought (YYYY-MM-DD). If more than one night is desired, their total number can be specified with nbd (integer ≥1) and the number of skipped nights between each by step (integer ≥0). For instance, four dates, one each week, starting from June, the 1<sup>st</sup>, 2016, these parameters should be set to ep=2016-06-01, nbd=4, and step=7.

*Selection criteria (cuts).* Any number of selection criteria can be specified, using the syntax tag<sub>1</sub>:value<sub>1</sub>, ..., tag<sub>N</sub>:value<sub>N</sub>, where the tag<sub>i</sub> are listed in Table 2. Tags accepting both a minimum and a maximum value shall be set using the following syntax tag<sub>i</sub>:{min:value<sub>min</sub>}

and tag<sub>i</sub>:{max:value<sub>max</sub>} to set only one extrema, or tag<sub>i</sub>:{min:value<sub>min</sub>, max:value<sub>max</sub>} to set both. For instance, to limit targets to sources brighter than V = 20, one should specify mag:{max:20}. To select only objects matching all criteria during 2 hours between the sunrise and sunset, the two parameters duration:120, event:sun must be specified.

*Sorting options (sort).* The entries in the summary tables (see Table 4 for an example) are sorted in increasing right ascension by default. Changing this behavior is achieved by specifying sort=key, in which key can take any value among the reported parameters (Table 1). For instance, to sort object by increasing apparent magnitude, one should specify sort=mv. It is also possible to first group targets by type before applying the sorting, using sort=type>key.

*Output formats (mime).* The results can be generated in three formats: VOTable, xHTML pages, and PDF file by specifying the mime parameter. Most users will likely use the PDF and xHTML outputs, for convenient display and interaction. The VOTable output has been designed for a more advanced usage, into a workflow for instance. It allows to directly query ViSiON from, e.g., a software to control observing queues, retrieving the values in the table, and the graphics for display

<sup>7</sup><http://www.minorplanetcenter.net/iau/lists/ObsCodes.html>

Table 2: Selection criteria in ViSiON. For each, we indicate if a minimum and/or a maximum value can be specified, and which are the default limits. The phase angle and apparent diameter selection only applies to solar system objects, and is disregarded for the other targets.

| Quantity        | Description                   | Minimum | Maximum | Defaults     |
|-----------------|-------------------------------|---------|---------|--------------|
| Alt.            | Highest altitude reached      | ✓       | ✓       | [30 to 90°]  |
| $m_V$           | Apparent magnitude            | ✓       | ✓       | [No default] |
| $\alpha$        | Solar phase angle             | ✓       | ✓       | [0 to 180°]  |
| $\widehat{SEO}$ | Solar elongation              | ✓       |         | [No default] |
| $\widehat{MEO}$ | Moon elongation               | ✓       |         | [No default] |
| $\phi$          | Apparent diameter             | ✓       | ✓       | [No default] |
| $\mathcal{D}$   | Duration of visibility window | ✓       |         | [30 min]     |
| Event           | Start/End of the “night”      |         | ✓       | [civil]      |

Table 3: List of input parameters to ViSiON (see Sect. 5 for the list of access points). For each, the default (between brackets) and range are specified.

| Parameter | Description                                              | Range, or example values    |
|-----------|----------------------------------------------------------|-----------------------------|
| name      | Designation of the requested targets                     | p:Mars, a:Pluto, u:M_31     |
| observer  | Observer’s location (IAU code or geographic coordinates) | [Paris, France]             |
| ep        | Starting epoch                                           | [now] — JD — YYYY-MM-DD     |
| nbd       | Number of date of computation                            | $[1] \leq \text{nbd} < 366$ |
| step      | Time interval (days) between two dates                   | [1]                         |
| cuts      | Criteria for visibility selection                        | (see Sect. 4)               |
| sort      | Parameter used to sort entries                           | [RA]                        |
| mime      | Mime type of the results                                 | votable — html — [pdf]      |
| from      | Name of the caller application                           |                             |

within a graphical interface.

*User identity (from).* We encourage users to provide their identity using the `from` parameter when they query ViSiON via its Web service (option not available in the query form). We only keep this information for statistical purposes. It also allows to identify frequent users and their requests, in the case support is required.

## 6. Bridges to other services

To help further the observers in planning or conducting their observations, ViSiON dynamically builds links to three VO services for each target, provided in the last three columns of the summary table (see the example in Table 4). They provide, with a simple click, access to a view of the sky around the target in Aladin (Sec. 6.1), information on the target at CDS (Sec. 6.2), and detailed ephemerides at IMCCE (Sec. 6.3).

### 6.1. Aladin at CDS



An interactive view of the sky around the target position is loaded in an instance of the Aladin Sky Atlas (Bonnarel et al., 2000), host at the *Centre de Données astronomiques de Strasbourg* (CDS). By default, ViSiON requests the Digital Sky Survey (DSS) to be displayed (Fig. 3), and overplots the known moving targets (at the time of passage at the maximum altitude) from the Skybot service (Berthier et al., 2006). Users can then take advantage of all the tools offered by Aladin, such as overlaying additional catalogs and fields of view for instance, around their target position.

### 6.2. Target information at CDS



The orbital elements of the asteroids and comets from the *astorb* and *cometpro* catalogs hosted at CDS, used in the computation of ephemerides, are displayed in a Web browser. For targets with fixed-coordinates, the SIMBAD entry corresponding to their identifier is opened if resolved as a celestial object.

### 6.3. Miriade at IMCCE



In the case of moving targets, the coordinates reported in the summary table at the time of highest altitude may not be sufficient to point the targets. This is the case for particularly fast-moving targets, such as near-Earth asteroids (NEAs), or for instruments with small fields of view. Ephemerides with a time step of 10 min can therefore be displayed in a Web browser, computed on the fly at the IMCCE by the Miriade service (Berthier et al., 2009). These ephemerides are dedicated to observation, and local, horizontal, and equatorial coordinates are listed for the entire night.

## 7. Conclusion

We have created a freely accessible service, named ViSiON, compliant with Virtual Observatory standards, which allows anyone to create graphics and data tables of observing conditions of solar system and (extra)galactic objects. The access is standardized, and both command-line and Web form are available. Results can be returned in human-readable format

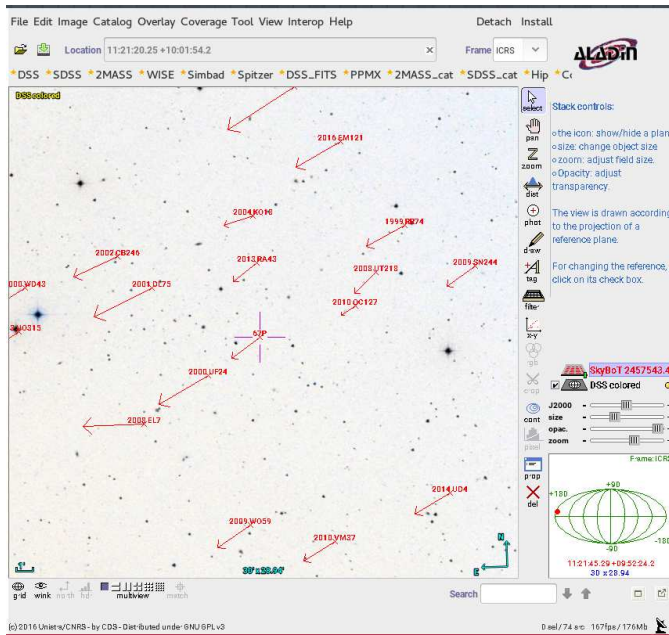


Figure 3: Example of the Aladin instance launched by ViSiON. Here the target was the comet 67P/ChuryumovGerasimenko on June 4, 2016.

(HTML, PDF) and VOTable for insertion in other programs, like telescope scheduler for instance. The results are tight with three other VO services, hosted at CDS and IMCCE to provide further information on targets and help in preparing the observations.

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| Target            | $m_V$ | $\phi$ | $\mathcal{D}$ | Alt | Az. | RA               | DEC                  | Rate | $\lambda_G$ | $\beta_G$ | $r$   | $\Delta$ | $\alpha$ | $\widehat{\text{SEO}}$ | $\widehat{\text{MEO}}$ | Links                                                                               |                                                                                     |                                                                                     |
|-------------------|-------|--------|---------------|-----|-----|------------------|----------------------|------|-------------|-----------|-------|----------|----------|------------------------|------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Moon              | -7.03 | 1997   | $12^h 30^m$   | 29  | 61  | $2^h 17^m 50^s$  | $10^\circ 08' 50''$  | 1772 | 335         | -46       | 0.002 | 1.012    | 143.3    | 36.6                   | 0.0                    |  | —                                                                                   |  |
| 67P Churyumov-... | 18.54 | 0.11   | $5^h 49^m$    | 55  | 359 | $11^h 20^m 43^s$ | $10^\circ 04' 6''$   | 23   | 248         | 62        | 2.86  | 3.12     | 18.9     | 95.3                   | 139.8                  |  |  |  |
| 12116             | 18.09 | 0.00   | $7^h 50^m$    | 78  | 356 | $12^h 40^m 44^s$ | $-13^\circ 37' 24''$ | 8    | 299         | 48        | 2.46  | 3.12     | 15.8     | 122.6                  | 162.3                  |  |  |  |
| TYC5597-234-1     | 11.85 | 0.00   | $10^h 50^m$   | 72  | 2   | $15^h 46^m 30^s$ | $-7^\circ 32' 31''$  | 0    | 360         | 34        | 1.00  | 1.00     | 0.0      | 160.2                  | 153.4                  | —                                                                                   |  |  |
| Mars              | -1.97 | 18.56  | $11^h 00^m$   | 86  | 348 | $15^h 40^m 47^s$ | $-21^\circ 19' 39''$ | 53   | 347         | 25        | 0.50  | 1.51     | 9.4      | 165.9                  | 152.5                  |  | —                                                                                   |  |
| M70               | 9.06  | 0.00   | $10^h 30^m$   | 82  | 181 | $18^h 43^m 12^s$ | $-32^\circ 17' 31''$ | 0    | 363         | -13       | 1.00  | 1.00     | 0.0      | 151.5                  | 112.9                  | —                                                                                   |  |  |
| (107) Camilla     | 13.07 | 0.10   | $8^h 30^m$    | 74  | 2   | $19^h 57^m 9^s$  | $-9^\circ 05' 38''$  | 10   | 392         | -19       | 2.96  | 3.71     | 11.8     | 131.4                  | 95.0                   |  |  |  |
| Triton            | 13.52 | 0.12   | $5^h 40^m$    | 73  | 359 | $22^h 54^m 2^s$  | $-7^\circ 54' 59''$  | 0    | 243         | -56       | 29.93 | 29.96    | 1.9      | 90.3                   | 53.8                   |  | —                                                                                   |  |
| SMC               | 0.00  | 0.00   | $7^h 30^m$    | 39  | 168 | $0^h 53^m 59^s$  | $-72^\circ 00' 0''$  | 0    | 302         | -45       | 1.00  | 1.00     | 0.0      | 101.9                  | 83.3                   | —                                                                                   | —                                                                                   |  |

Table 4: Example of the summary table associated with Figs. 1 and 2. Values are reported at the time of the highest altitude. See Table 1 for a description of each column.