

# Occultations by major and minor planets in 2022

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The accompanying graphs contain the predicted occultations of catalogue stars by major and minor planets in the year 2022. They are a selection from a much larger number of events found, taking into account the star's magnitude, the duration of the occultation, the distribution of potential observers and the altitude above the local horizon.

## 1 Star catalogues

Two *merged catalogues* were created from the following star catalogues, the order given being the order of precedence in the merging process:

1. Gaia DR2 <sup>1</sup>. This contains a total of 1 692 919 135 sources. Only those with a G-magnitude  $\leq 16.00$  were downloaded, their number is given in the table below. Of these, only those having a 5-parameter solution were used.
2. TGAS <sup>2</sup>
3. FK6, Part I and Part III <sup>3</sup>
4. Hipparcos 2 <sup>4</sup>
5. Tycho-2 catalogue <sup>5</sup>
6. UCAC5, the fifth USNO CCD Astrograph Catalog <sup>6</sup>
7. PPMX <sup>7</sup>

The *first catalogue* contains all stars of visual magnitude  $V \leq 12.50$ . The *second catalogue* contains stars of visual magnitude:  $12.50 < V \leq 15.00$ . For the merging, stars from different catalogues were considered to be the same if their mutual distance was less than  $2''$  and the magnitude difference was less than 1.00.

Table 1 gives the total number of stars in each catalogue as well as the number retained after eliminating multiple entries.

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<sup>1</sup>Gaia Collaboration: *Gaia* Data Release 2, A&A 616, A1 (2018)

<sup>2</sup>Arenou F. et al.: *Gaia* Data Release 1, A&A 599, A50 (2017)

<sup>3</sup>Wielen R. et al.: Veröffentlichungen des Astronomisches Rechen-Instituts Heidelberg, No. 35 (1999) and No. 37 (2000)

<sup>4</sup>van Leeuwen F.: Validation of the new Hipparcos reduction, A&A 474, 653 (2007)

<sup>5</sup>Høg E. et al.: The Tycho-2 catalogue of the 2.5 million brightest stars, A&A 355, L27 (2000)

<sup>6</sup>Zacharias N. et al.: UCAC5: New Proper Motions Using *Gaia* DR1, AJ 153, 167 (2017)

<sup>7</sup>Röser S. et al.: PPM-Extended (PPMX) – a catalogue of positions and proper motions, A&A 488, 401 (2008)

Table 1: Merged star catalogues used for the predictions.

Star catalogue	Total stars	Catalogue 1	Catalogue 2
Gaia DR2	76 533 659	4 719 676	31 468 059
TGAS	2 057 050	24 905	74 919
FK6	4 150	52	0
Hipparcos 2 (HIP2)	117 955	1 859	34
Tycho-2 (TYC2)	2 311 925	35 687	18 797
UCAC5	107 758 513	472 470	3 864 293
PPMX	18 088 919	388 287	1 389 082
Total		5 642 936	36 815 184

## 2 Selection criteria for the planets

Only occultations with a maximum duration of at least 3 seconds were considered with both catalogues.

The *first* star catalogue was used for comparison with the ephemerides of 4383 minor planets: numbered ones larger than 40 km and also objects with multi-opposition orbits and semi-major axis larger than 5.40 AU (Centaurs, Kuiper Belt Objects, ...). This resulted in 7047 occultations visible from somewhere on the Earth, each of which was then inspected for observability. The final selection comprised 1878 events.

For the 8 major planets only occultations of stars brighter than visual magnitude 10 were selected. Out of 718 events, 5 were selected.

The *second* catalogue was used for a special search with 3365 objects with semi-major axis larger than 5.40 a.u.; 101 events out of 718 were selected.

Diameters have been taken from the WISE or IRAS surveys to which some occultation diameters were added. In case no diameter was published an approximate value was computed from the formula

$$\log D = 3.62 - 0.20H$$

where  $D$  is the diameter in km and  $H$  the absolute visual magnitude constant.

## 3 Explanation of the graphs

The results are presented as one PDF file for each predicted occultation, each file containing two pages.

### 3.1 First page

- The top line gives the name of the major or minor planet and the star designation. The latter is only used to identify the star <sup>8</sup> <sup>9</sup>.
- The second line gives the instant of closest geocentric approach (in U.T.).

<sup>8</sup>The Gaia catalogue identifies stars by a 64-bit (19-digit) number. I replaced this by the corresponding FK6, HIP2, TYC2 or UCAC4 designation (in that order) wherever possible. If no match was found, the star was given a fictitious name of the type "Gaia mmm-nnnnnn".

<sup>9</sup>Since the PPMX has no star names of its own, my PPMX number simply is the sequential number in the catalogue when reading in the 24 data files from north to south.

- Under the heading "Planet" the following data are given:
  - a = semi-major axis, e = eccentricity of the orbit
  - V. mag. = visual magnitude of the planet
  - Diam. = absolute diameter in km and apparent diameter in seconds of arc.
  - $\mu$  = instantaneous motion at closest approach, in seconds of arc per hour.
  - $\pi$  = horizontal equatorial parallax in seconds of arc.
  - Ref. = source for the orbital elements.
- Under the heading "Star" are given:
  - Source cat. = an abbreviation for the source catalogue from which the positional data for the star are taken:
    - \* GDR2a = Gaia Data Release 2, 5-parameter solution
    - \* TGAS = Gaia Data Release 1
    - \* FK6 = FK6 Catalogue (Parts I and III)
    - \* HIP-2 = Hipparcos catalogue
    - \* TYC2 = Tycho-2 catalogue; the suffix "p" indicates Tycho data referring to the photocentre of two entries
    - \* UCAC5 = Fifth USNO CCD Astrograph Catalog
    - \* PPMX = PPMX catalogue
  - $\alpha$  = right ascension (J2000.0) at the epoch of occultation
  - $\delta$  = declination (J2000.0) at the epoch of occultation
  - V/Rmag = visual magnitude of the star if given, else the red magnitude if given, else blank; when the source catalogue is GDR2a, Vmag is actually the G magnitude, the "broad-band, white-light, Gaia magnitude"
  - B/Imag = blue magnitude of the star if given, else the infrared magnitude if given, else blank
- The last line contains information about the occultation:
  - $\Delta m$  = drop in magnitude
  - Max. dur. = maximum duration for an observer on the central line (in seconds of time)
  - Sun = elongation of the Sun (in degrees)
  - Moon = elongation (in degrees) and illuminated fraction (in %) of the Moon
- The small star chart shows a portion of the sky of about 15 by 15°. Only stars of visual magnitude 7.0 and brighter are included. The dashed rectangle indicates the part shown by the larger chart.
- The large star chart is based on the merged catalogue or on both catalogues. The star to be occulted is encircled and is always in the middle. A visual-magnitude scale is added to the right, mostly ranging from 1 to 10; for faint stars the range may be 2–11, 3–12, etc. The star chart also shows the path of the minor planet with crosses indicating the daily position at 0h UT.

- The world map shows the Earth as seen from the star, i.e. the centre of the disk is the point on the Earth's surface where the star is in the zenith. The night side is the part within the heavy lines and is shaded darker. The shadow path is indicated by the central line and the northern and southern limits (including the effect of the Earth's rotation). The dashed lines show the position of the central line for a shift of  $1''$  perpendicular to the predicted shadow path (i.e. for a difference of  $\pm 1''$  in the shortest geocentric distance planet-star). The times written at the bottom refer to the first and last cross lines; also the interval between two cross lines is given.

### 3.2 Second page

This page contains a larger version of the world map, with a much higher resolution for the coastal data and with country borders added. In addition, cities with more than 500 000 inhabitants are represented by small circles roughly proportional to the population.

## 4 Availability of the files

The PDF files can be obtained from the following FTP site of the "Vereniging voor Sterrenkunde" (VVS, the Flemish Astronomical Association):

<http://bedekkingen.vvs.be/predictions/asteroids2022>

## 5 Distribution of the graphs

A selected number of predictions is sent to Mat Drummen (NL) for inclusion in the *Sterrenkijds* and to Andreas Dill (BE) for preparing the *Hemelkalender*.

## 6 Mailing Lists and Web Sites

European observers are advised to subscribe to the PlanOccult mailing list, maintained by Jan Van Gestel (Belgium): <http://vps.vvs.be/mailman/listinfo/planoccult>

For more up-to-date information on predictions, finder charts and occultation news, consult the web site <http://www.asteroidoccultation.com> that has links to asteroidal occultation resources in Europe, N. America, Australia/New Zealand, and Japan.

## 7 Acknowledgements

Eric Broens (VVS) was of great help in making the files available on the Web.