Press release

Belgian astronomers help create the most detailed survey of our Milky Way

13 June 2022 – Today, the European Space Agency (ESA) announces the most detailed Milky Way survey to date. The third data release of the Gaia satellite provides a wealth of information on the stars and other celestial objects that make up our Milky Way. Belgian astronomers contributed to the Europe-wide consortium that makes this catalogue available. The survey will allow us to discover new asteroids, binary stars and "starquakes" and shed new insights into our Milky Way Galaxy.

The Gaia satellite has been charting the sky since 2014, and its map includes stars that are a million times fainter than can be seen with the naked eye. Gaia has measured exceptionally accurate distances to almost 2 billion stars, and has measured how fast and in which direction the stars move through space as they orbit the centre of our Milky Way.

Image caption: Artist's view of the Gaia satellite in front of the Milky Way. Image credit: ESA/ATG medialab – ESO/S. Brunier

The third data release of Gaia adds a completely new dimension to these previous results. Using the spectroscopic information that Gaia collected, astronomers have determined stellar temperatures, masses, and ages of these stars. Also the speed at which stars move towards or away from us was determined, as well as their chemical composition. Detailed information about stars that vary in brightness over time or starquakes, or stars that are part of a binary system, is a further important part of the data release. It does not stop there, because Gaia also sees objects much closer by than the Milky Way stars, such as asteroids in the Solar System. Much further away, it has observed millions of galaxies and quasars outside our Milky Way.

The specialised expertise of Belgian researchers played an important role in the Europe-wide consortium that analysed the enormous amount of Gaia data. Astronomers from KU Leuven, the Royal Observatory of Belgium, Université libre de Bruxelles, Universiteit Antwerpen and Université de Liège all contributed to this work. The Belgian participation to the Gaia mission has been made possible through funding provided by the Belgian Federal Science Policy Office (BELSPO) via the PRODEX Programme of ESA.

Additional information

- Gaia data release 3 media kit: https://www.esa.int/Science_Exploration/Space_Science/Gaia/Gaia_data_release_3_media_kit
- Gaia for the public: https://www.esa.int/Science_Exploration/Space_Science/Gaian
- Gaia in depth: https://www.cosmos.esa.int/web/gaia/data-release-3
- The Gaia ESA press release: https://www.esa.int/Science_Exploration/Space_Science/Gaia/Gaia_sees_strange_stars_in_most_detailed_Milky_Way_survey_to_date
- From 13 June 2022, 12:00 CEST onwards, the new Gaia data can be accessed at https://gea.esac.esa.int/archive/
- Gaia's data release 3 was presented today during a virtual media briefing at https://www.esa.int/ESA_Multimedia/ESA_Web_TV There was also a local Gaia event which

highlights the Belgian contribution at the Planetarium of Brussels. The replay of the livestreaming can be found here: https://youtu.be/5VFs0izvNHg

- More in-depth stories on the new Gaia data can be found here: https://www.cosmos.esa.int/web/gaia/dr3-stories
- A series of scientific papers describing the data and their validation process will appear in a special issue of the journal Astronomy & Astrophysics: https://www.cosmos.esa.int/web/gaia/dr3-papers

Belgian contributions to the Gaia mission

KU Leuven

”Here at the Institute of Astronomy of the KU Leuven we are leading a task force responsible for classifying variable stars detected by Gaia. In particular, we focus on stars that show tiny brightness variations due to radial and nonradial oscillations also known as ‘starquakes’”, says Joris de Ridder, Gaia project investigator at KU Leuven. One of the surprising discoveries coming out of the new data, is that Gaia is able to detect different types of starquakes. “Starquakes teach us a lot about stars, notably their internal physics and chemistry. Gaia is opening a goldmine for new 'ensemble asteroseismology' of massive stars,” says KU Leuven astronomer and 2022 Kavli Laureate in Astrophysics Conny Aerts, “even detecting starquakes in many stars for which none were predicted!”

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Royal Observatory of Belgium

ORB - KSB

The Royal Observatory of Belgium (ROB) used its expertise to analyse the spectra collected by the Gaia satellite. "The third Gaia Data Release represents a real breakthrough in the characterization of the stars of our galaxy, especially for the youngest, hottest and farthest ones", says Dr. Yves Frémat. ROB scientists also contributed to determining the line-of-sight velocity of an unprecedented 33 million stars. Dr. Alex Lobel adds: “These data provide long-awaited fundamental information for new and important discoveries in the coming years about the galactic structure and evolution ".
The ROB also contributes to data processing related to asteroids. The present Gaia release contains some 20 million accurate positions of more than 150 000 asteroids. "Never before have we had such highly accurate orbits for so many asteroids", says Dr. Thierry Pauwels, who works on the software to determine the position of asteroids.

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ULB

ULB UNIVERSITÉ LIBRE DE BRUXELLES

This third data release from Gaia is a long-awaited and exciting moment for ULB scientists involved in the Gaia data processing of non-single stars, which make their first appearance in the data archive, in the form of properties of 86 921 eclipsing binaries (objects whose brightness varies due to a companion periodically blocking part of the light) and 134 598 astrometric binaries (detected from disturbances of their space motion caused by the presence of a companion), a 50-fold increase with respect to the number of astrometric binaries known thus far. "Within a few years, Gaia has thus done much better than ground-based astronomy in the past two centuries!", says Christos Siopis leading the analysis of the properties of eclipsing binaries. "But today's joy is saddened by the tragic loss of our late colleague Dimitri Pourbaix, who acted till November 2021 as Belgian Principal Investigator for Gaia, and who will never see the scientific products of his decades-long effort."

Scientific contact

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ULiège

Researchers from the STAR institute at ULiège have a well-established expertise in the determination of the orbital parameters of binary stellar systems based on their observed radial velocities. From the Doppler effect induced by the back and forth motion of stars orbiting around each other, Gaia can measure the apparent velocities of one or both of their constituting components. The repeated measurements of these radial velocities over time are then subsequently used in order to derive the mass ratio, the period, the inclination and the eccentricity of the systems. Around 200 000 binary stars were thereby detected and characterised in Gaia DR3 by the ULiège team. Our researchers are also involved in the determination of the redshifts and distances of extremely bright extragalactic sources that are quasars. Owing to the expansion of the Universe, the wavelength of the light emitted by such objects undergoes a stretching during its travel through the cosmos. This effect, called redshift, makes the quasar appear redder than when its light was initially emitted, billions of years ago. More than 6 million quasar candidates will have their redshift published in Gaia DR3 and will provide an indirect measure of their distances.

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Universiteit Antwerpen

Scientists from Universiteit Antwerpen contributed to the measurement of radial velocities and to the study of stellar variability. "To get from the first, simulated, light data more than a decade ago to the stunning light curves of tens of thousands of standard candles (my favorite stars, used for measuring cosmic distances), is mindblowing!" says Prof. Katrien Kolenberg from Universiteit Antwerpen. "Moreover, for these stars we now have positions and motions, a 3D map. I feel like a space detective who has just received a new "flashlight" - or rather tens of thousands of them! - to unveil the history and future of our galaxy." Prof. Marc David remarks "Astronomical data reduction is a bit like an archaeological dig: one has to sift a large amount of rubble before the valuable information is uncovered but almost invariably, the result proves well worth the painstaking effort."

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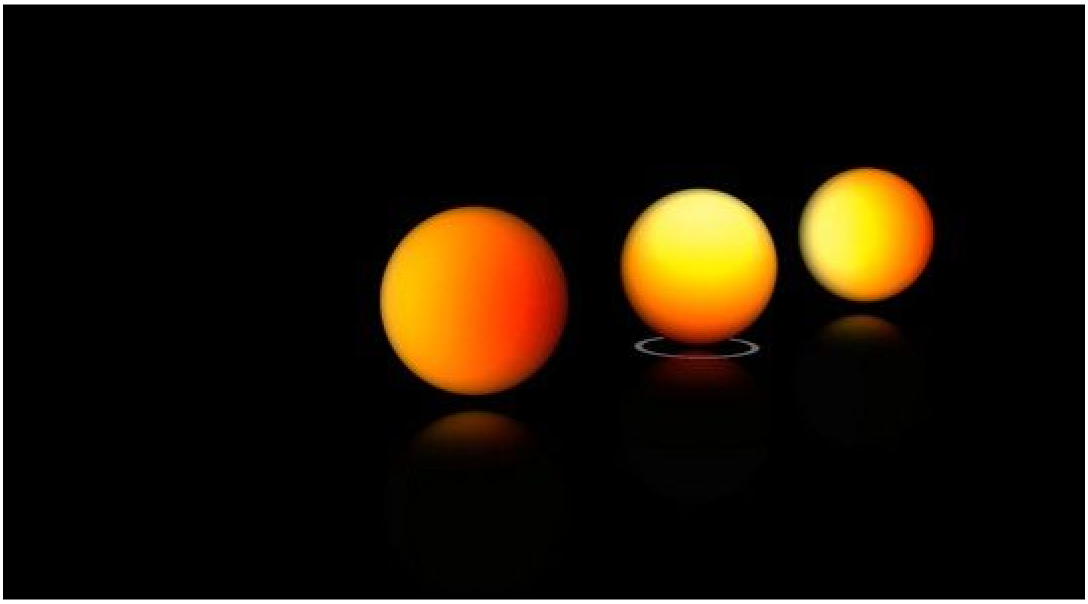
Pictures and videos

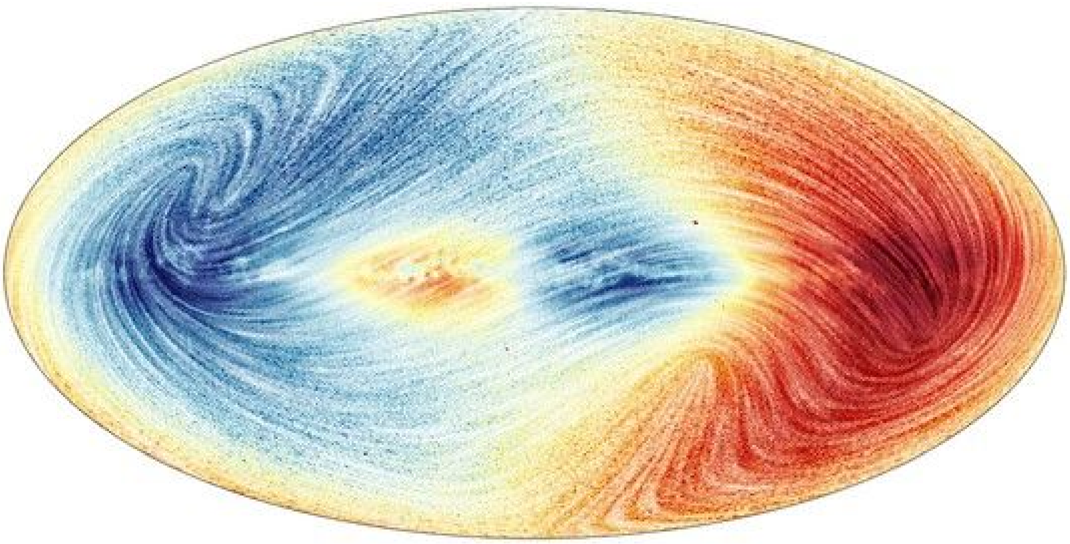
Gaia sees starquakes



Link to the video: https://youtu.be/hMaiTLVFpEw

One of the surprising discoveries coming out of Gaia data release 3, is that Gaia is able to detect starquakes – tiny motions on the surface of a star – that change the shapes of stars, something the observatory was not originally built for.
Previously, Gaia already found radial oscillations that cause stars to swell and shrink periodically, while keeping their spherical shape. But Gaia has now also spotted other vibrations that are more like large-scale tsunamis. These nonradial oscillations change the global shape of a star and are therefore harder to detect.
Nonradial oscillation modes cause a star's surface to move while it rotates, as shown in the animation. Dark patches are slightly cooler than bright patches, giving rise to periodic changes in the brightness of the star. The frequency of the rotating and pulsating stars was increased 8.6 million times to shift them into the audible range of humans.
More information: https://www.cosmos.esa.int/web/gaia/dr3-how-do-they-blink
The KU Leuven contributes to the Gaia data processing to characterise starquakes.

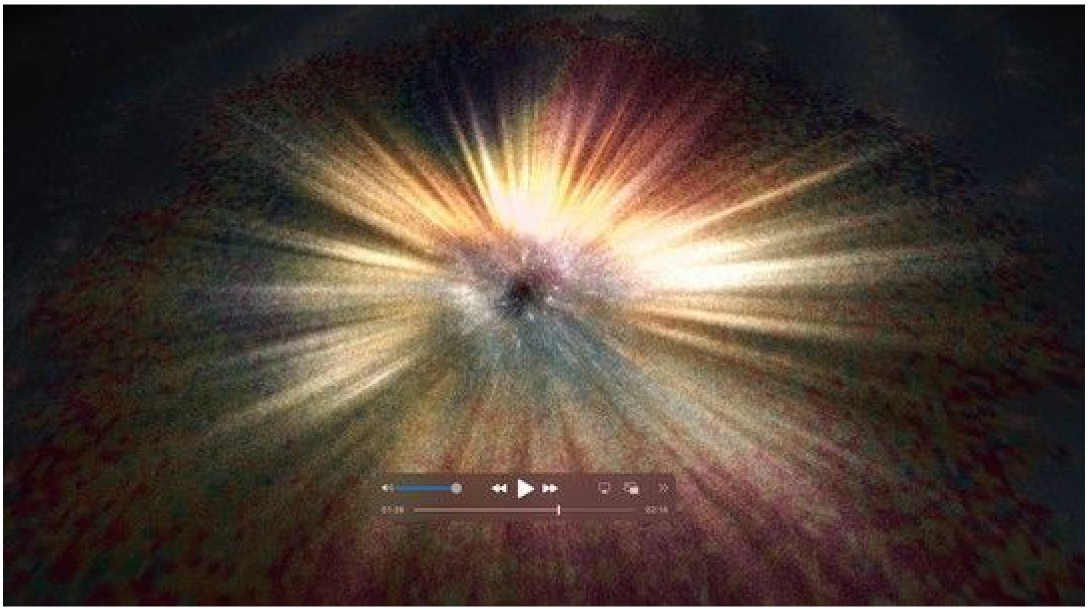
Gaia’s Milky Way in motion (3D)



Link to the picture: https://www.cosmos.esa.int/web/gaia/dr3-do-they-approach-us-or-move-away.

ESA's Gaia data release 3 shows us the speed at which more than 30 million Milky Way stars move towards or away from us. This is called 'radial velocity' and it is providing the third velocity dimension in the Gaia map of our galaxy. Together with the proper motions of stars (movement across the sky), we can now see how the stars move over a large portion of the Milky Way.
This sky map shows the velocity field of the Milky Way for ~26 million stars. The colours show the radial velocities of stars along the line-of-sight. Blue shows the parts of the sky where the average motion of stars is towards us and red shows the regions where the average motion is away from us. The lines visible in the figure trace out the motion of stars projected on the sky (proper motion). These lines show how the direction of the speed of stars varies by galactic latitude and longitude. The Large and Small Magellanic Clouds (LMC and SMC) are not visible as only stars with well defined distances were selected to make this image.
More information: https://www.cosmos.esa.int/web/gaia/dr3-do-they-approach-us-or-move-away.
The Royal Observatory of Belgium, ULiège and UAntwerp contributed to the radial velocity computation of the stars from Gaia data.
Credit: ESA/Gaia/DPAC, CC BY-SA 3.0 IGO.

The asymmetric Milky Way in motion



Link to the video: http://alobel.freeshell.org/GaiaDR3/gaiadr3.html

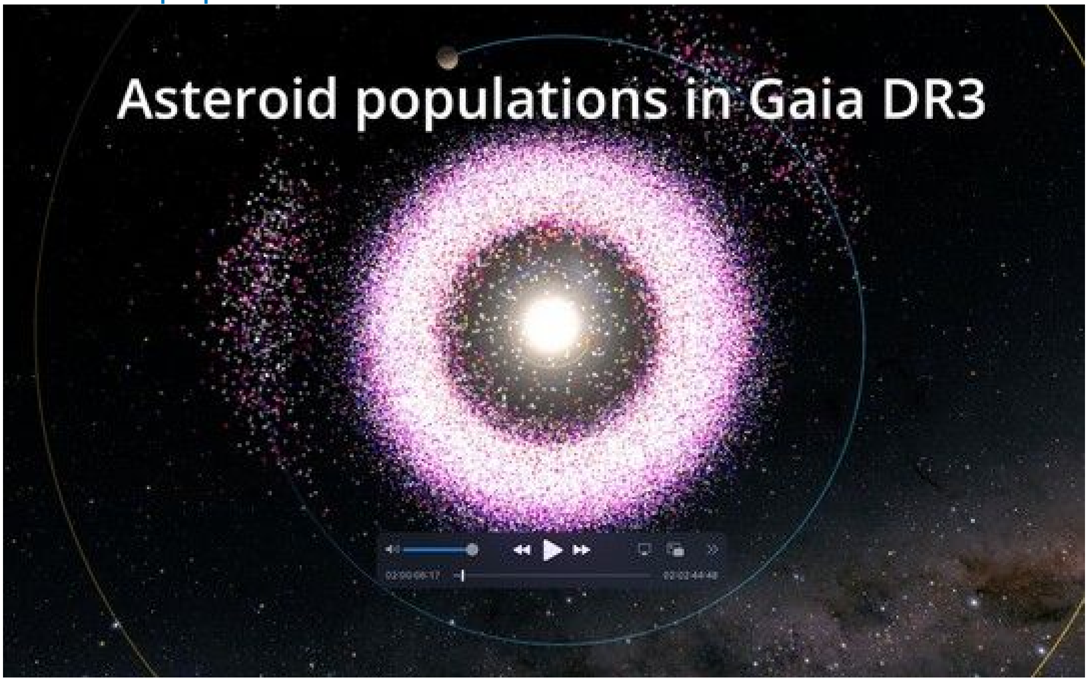
ESA's Gaia data release 3 shows us the speed at which more than 30 million Milky Way stars move towards or away from us. This is called 'radial velocity' and it is providing the third velocity dimension in the Gaia map of our galaxy. We can now see how the stars move over a large portion of the Milky Way's disc.
Thanks to Gaia, we can clearly see that the stars on average do not rotate with circular motions around the centre of the galaxy. This is because our Milky Way is not symmetric around its axis. It is a 'barred' spiral galaxy, and the motions reveal the orientation of the central bar.
More information: https://www.cosmos.esa.int/web/gaia/dr3-do-they-approach-us-or-move-away.
The Royal Observatory of Belgium, ULiège and UAntwerp contributed to the 'radial velocity' computation of the stars from Gaia data.
Credit: ESA/Gaia/DPAC, CC BY-SA 3.0 IGO.

Accurate orbits of asteroids in Gaia DR3

Link to the video: https://alobel.freeshell.org/AsteroidsGDR3/asteroidsDR3.html

From time to time an asteroid occults a star. Only observers inside the shadow of the asteroid will see the occultation. The width of the occultation strip is roughly the same as the size of the asteroid, typically a few tens of kilometres.
However, until now, the uncertainty in the position of the asteroids, and hence also in the occultation path, could easily reach a few hundreds of kilometres. An occultation predicted to be visible in Belgium could turn out to be visible in Rome. Many observers set up their telescopes, but did not see the occultation.
However, with the Gaia observations we now have very accurate orbits for 150 000 asteroids, and their positions can be derived within a few kilometres, so that we can predict with pretty great confidence where an occultation will be visible. Thus, occultation observers can plan their observations much more efficiently.
If enough observers note the timings of disappearance and reappearance of the star, the silhouette of the asteroid can be reconstructed, as we can see here on the figure. This tells us something about the physical properties of asteroids.
Know your enemy. If ever an asteroid is found on a collision course with the earth, we will be better prepared to define a mitigation strategy.
The Royal Observatory of Belgium contributed to the Gaia data processing of asteroids and solar system objects.

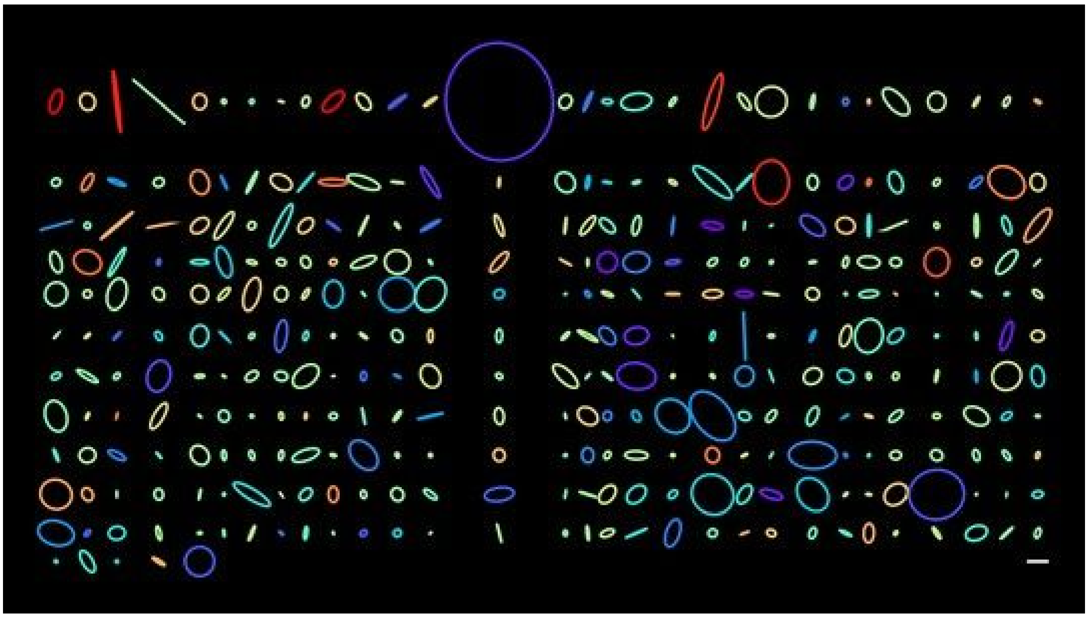
Asteroid populations in Gaia data release 3



Link to the video: https://youtu.be/hMaiTLVFpEw

By far the largest group of Solar System objects in Gaia's data release 3 are 154 741 asteroids for which Gaia has determined their orbits. Depending on their orbits one can distinguish different groups of asteroids.
More information: https://www.cosmos.esa.int/web/gaia/dr3-solar-system-objects.
The Royal Observatory of Belgium contributed to the Gaia data processing of asteroids and solar system objects.

Social stars



Link to the video: https://youtu.be/TPkjhXmW8k8

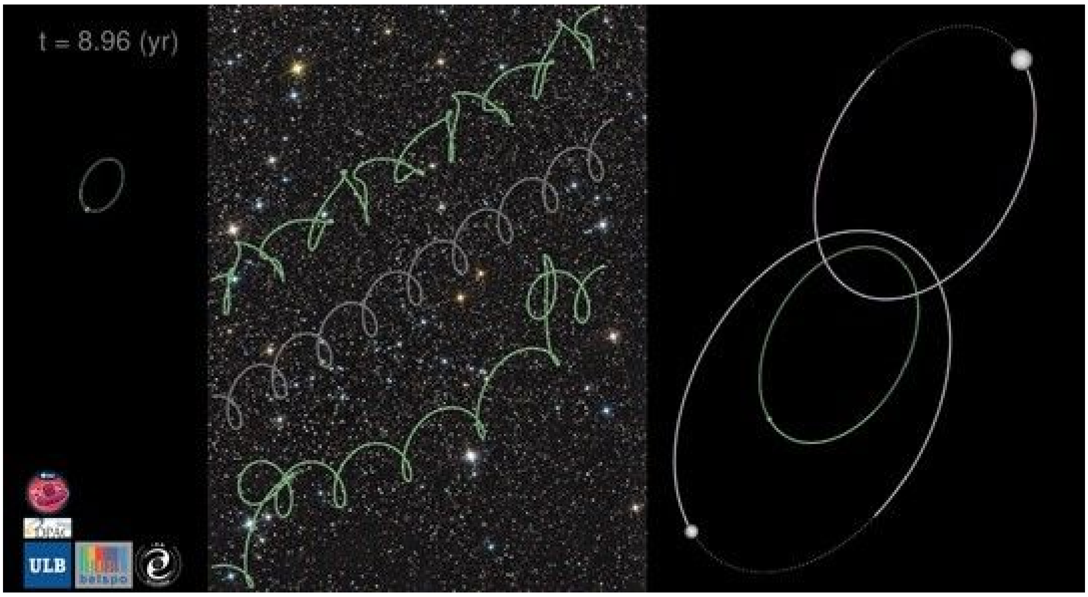
A third of stars are born and live in pairs or even larger groups. Just like humans, they can considerably influence each others' lives, as well as the way they influence their environment. Understanding multiple-star-systems is key to understanding stars, the Milky Way, and the Universe.

With data release 3, Gaia has just delivered a comprehensive database astronomers have long been wishing for, including 813 000 binary stars, to answer the many open questions.
This animation illustrates the sky-projected motions of binary stars whose orbits have been determined by Gaia. Each ellipse corresponds to one of 335 systems located within 50 pc (163 light years) and with periods shorter than 1000 days. These are cases where Gaia sees only the motion of one source, which can correspond to the reflex motion of a star due to the gravitational pull of an invisible companion, or to the apparent motion of the combined light from two orbiting stars so close together that Gaia cannot distinguish them.
The orbits are shown to scale and are ordered by increasing distance from the Sun from top-left to bottom-right. The white horizontal line at the bottom-right indicates an apparent size of 10 milli-arcseconds. The colour roughly corresponds to the source's colour as determined by Gaia with purple/blue indicating hot stars and white dwarfs, green/yellow indicating Sun-like stars, and red indicating cool, low-mass stars.
The animation shows the inferred orbital motions over 1000 days, corresponding roughly to the time range covered by Gaia's data release 3, and the dots indicate the modelled positions of the stellar images after subtracting the effects of proper motion and parallax. The orbits show a range of short and long periods, different sizes, various elliptical shapes, and some are seen edge-on, which limits the apparent motion to a line.
Gaia's data release 3 contains about 500 times more astrometric orbit solutions than the ones shown here.
More information: https://www.cosmos.esa.int/web/gaia/dr3-non-single-stars.
The ULB and the ULiège contributed to the Gaia data processing of non-single stars.

Credit: ESA/Gaia/DPAC, CC BY-SA 3.0 IGO.

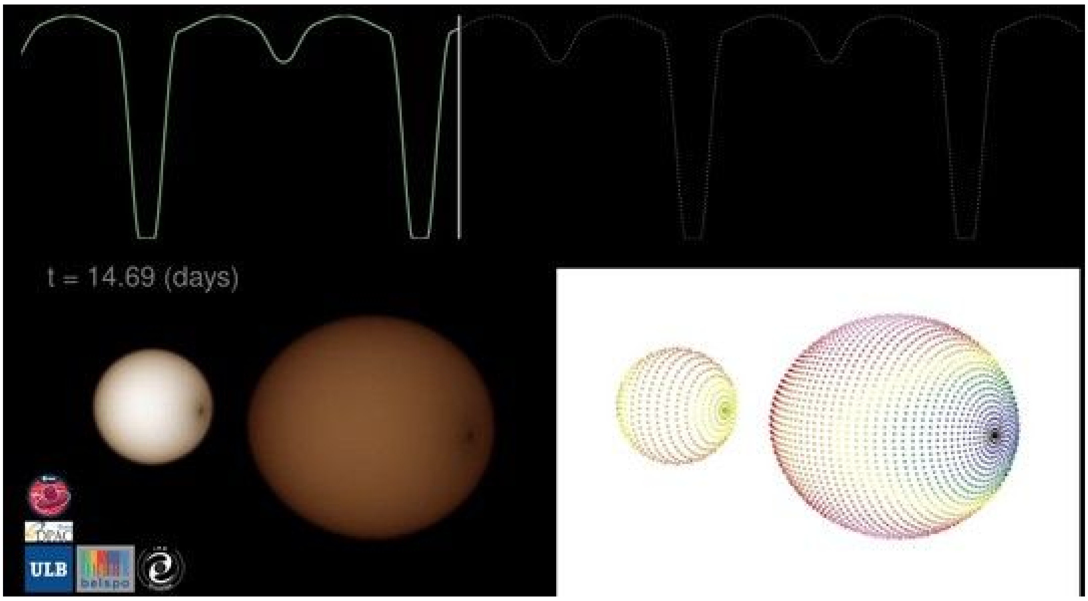
How Gaia detects binary stars

The three animations shows three different techniques that Gaia uses to detect binary stars.



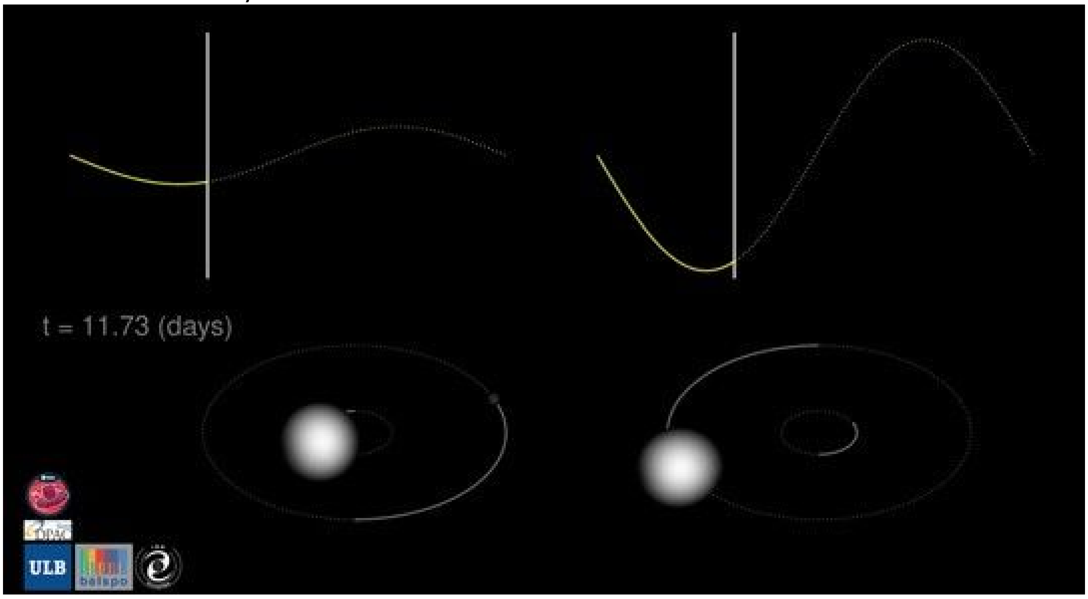
Link to the video: https://youtu.be/p4lCN8Ch2JA

Astrometry: binary stars are detected by a motion on the sky which is not uniform; this can be an elliptic motion or just a part of it for orbits with very long periods. The two sources can't be seen individually as they are too distant; either the two companions have a very different magnitude (an extreme example is a star and a planet) and only the motion of the bright one can be detected; or the sources have a similar magnitude and only the motion of the photocentre is seen. Astrometric binaries generally have long periods (months to years or decades) as the motion on the sky is too small to detect short-period binaries.



Link to the video: https://youtu.be/mS5KgjiMgj4

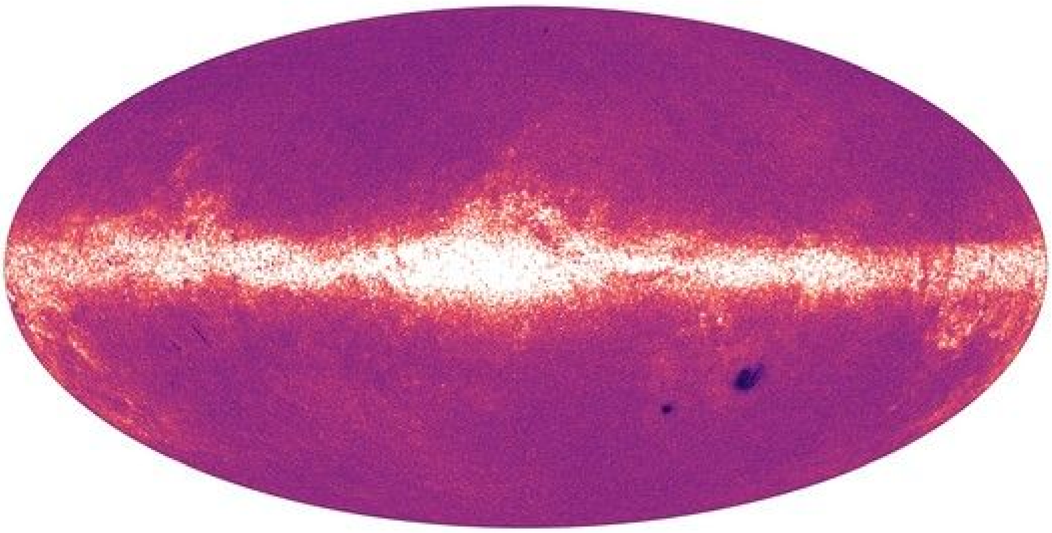
Photometry: eclipsing binaries are detected thanks to the periodic dimming of a star due to a (partial) eclipse by a companion. As the probability that the line of sight is precisely along the plane of the orbit is very small if the two sources are widely separated, the observed eclipsing binaries typically have small periods, in the order of hours to days.



Link to the video: https://youtu.be/G0DSaQKINA4

Spectroscopy: these binaries have a radial velocity that varies periodically, depending on whether a star approaches or recedes from us. They are detected thanks to this variation. If the sources have a similar magnitude, the spectral lines of the two objects can be seen, though frequently only the lines from the brightest are seen. As the amplitude of the radial velocity variation increases when the period is shorter, short-period binaries are more frequent, typically from hours to months.
Thanks to these techniques, Gaia is able to detect thousands of binary stars. In the best cases, it is possible to estimate the mass of the companions and sometimes their individual magnitudes too. From this, astronomers may discover among normal stars some hidden treasures such as an exoplanet, or, on the heavy side, a white dwarf or compact companions such as neutron stars or even black holes.
More information: https://www.cosmos.esa.int/web/gaia/dr3-non-single-stars.
The ULB and the ULiège contributed to the Gaia data processing of non-single stars.

Quasars and extragalactic objects



Link to the picture: https://www.cosmos.esa.int/web/gaia/dr3-quasar-candidates

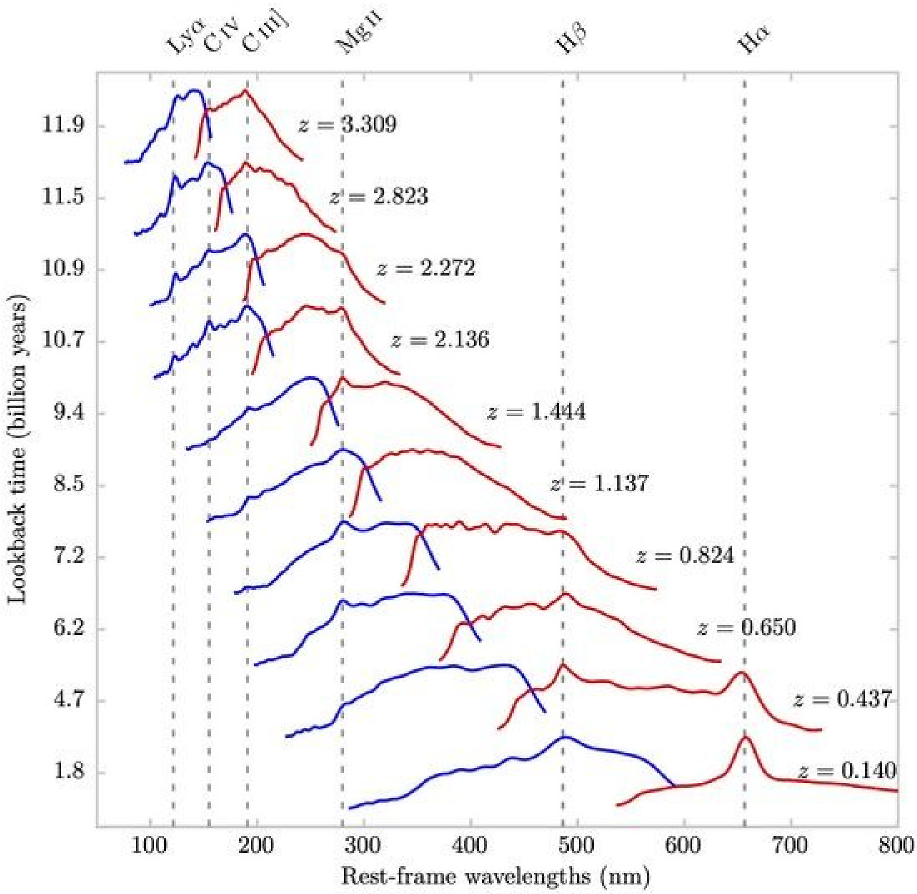
The figure shows a skymap of quasar candidates in the Gaia third data release. Quasars are extremely bright extragalactic sources. Along its journey through the cosmos, the light from distant quasars encounters a wavelength elongation that is due to the expansion of the universe. As a consequence, the emitted light appears redder and covers a more expanded wavelength range than when it was initially emitted, billions of years ago. This is called a cosmological redshift.

Quasars are believed to be powered by the accretion of matter onto massive black holes at the centers of galaxies, a process that emits more energy than thermonuclear reactions. Quasars are amongst the most luminous objects in the universe and the most important tracers to study the accretion history of supermassive black holes, the early structure formation, and the history of cosmic reionisation.

However, finding and characterising quasars is extremely challenging because of their low spatial density and high contamination rate from Galactic objects. ULiège contributed to the Gaia data processing and analysis of extragalactic objects such as quasars. Their software selects sources with high probabilities of being quasars and then analyses the observed blue and red spectra in order to estimate their cosmological redshifts.

More information: https://www.cosmos.esa.int/web/gaia/dr3-quasar-candidates.

A spectral analysis of quasars



Link to the picture: https://www.cosmos.esa.int/web/gaia/iow_20201222

The figure shows the blue and red spectra of ten known quasars selected with apparent magnitude between 17 and 18. All selected quasars exhibit several strong emission features at the rest-frame wavelengths where they are expected, regardless of redshift and despite the low resolution and broad line-spread function of the spectrophotometry.

As Gaia observes higher redshift quasars (characterised by the letter z in the figure), they can also appear dimmer because they are more distant. As a result, their spectra become noisier and almost all spectral features are washed-out except for the very strongest emission lines (H-alpha and Ly-alpha). Through the redshift effect, scientists can estimate the lookback time – how long it took the photons emitted from the quasar to travel through the intergalactic medium towards Gaia – providing us with “pictures” of the Universe as it was billions of years ago. Quasars pushed back the limits of the observable universe significantly in both distance and lookback-time.

More information: https://www.cosmos.esa.int/web/gaia/dr3-quasar-candidates.

The ULiège contributed to the processing of Gaia data to characterise quasars and extragalactic objects.

Credits: ESA/Gaia/DPAC, L. Delchambre, R. Andrae, M. Fouesneau, O. Creevey, R. Sordo, and all of Coordination Unit 5 and 8 (CU5/CU8) of Gaia DPAC. We wish to thank the Gaia Data Processing Centre at the Institute of Astronomy in Cambridge (DPCI) for producing the high-quality spectrophotometry and Centre National d’Etudes Spatiales (CNES; DPCC) upon which this work rests.

Appendices

FAQ – fast facts

What is Gaia?

Gaia is an ESA mission launched on 19 December 2013 and it has been observing the sky since 29 July 2014. Its goal is to create the most accurate 3D map of the Milky Way by surveying more than a billion stars. This includes not only star positions and motions but also other key astronomical parameters like their “brightness” (what scientists called magnitude), their colours, and their temperatures. Gaia also maps other objects, such as solar system objects (asteroids, comets and satellites), galaxies and quasars. It will also find new exoplanets and even provide some tests of Einstein's theory of general relativity.

Where is Gaia?

Gaia circles the Sun at a distance of 1.5 million km from Earth away from the Sun, in what is known as the L2 Lagrangian point. The spacecraft co-rotates with Earth around the Sun.

How does Gaia work?

Gaia's mission relies on repeated observations of star positions in two fields of view, detecting any changes in the object's motion through space. To achieve its mission the spacecraft is spinning slowly, sweeping its two telescopes across the entire celestial sphere to make four complete rotations per day. ESA's ESTRACK stations at Cebreros (Spain), New Norcia (Australia), and Malargüe (Argentina) are used to communicate with the spacecraft. Gaia will communicate with Earth on average about 8 hours per day, transmitting its science and operational data.

What are the Gaia data releases?

The huge amount of data Gaia produces (more than a million Gigabyte for the entire mission) requires an enormous amount of computer power and a vast range of scientific expertise that only international networking can provide. Different teams of scientists work on different subsets of the data or on the software designed to process this data abundance. The results of the processing are partially released periodically until the end of the mission, with each new release giving more data and new insights. A first minor data release occurred on 14 September 2016, the second – more extensive – one on 28 April 2018. The third release occurred in two parts: an early version on 3 December 2020, and now the full third version. Two further data releases are planned.

Which countries are involved in Gaia?

Scientists involved in Gaia come from twenty European countries (Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Poland, Portugal, Slovenia, Spain, Switzerland, Sweden, and the United Kingdom) as well as from further afield (Algeria, Brazil, Chile, China, Israel, and the United States).

Glossary

Binary stars: A binary star is a system consisting of two stars orbiting around each other, or more precisely, around their common centre of mass. Recent studies suggest that more than half of all stars are part of binary or multiple star systems.

Parallax: Parallax is the difference in apparent position of an object viewed along two different lines of sight – just hold a finger out in front of your face, close one eye at a time, and watch your finger and other objects move. The further an object, the less it moves, and thus the smaller the parallax. Astronomers use parallax to measure the distance to nearby astronomical objects, using the different orbital positions of Earth around the Sun as the different lines of sight and applying basic geometry.

Proper motion: Stars are not stationary but move around the centre of our Milky Way. Our Sun for example rotates at the speed of 220km/second around the galactic centre. Proper motion is the rate of the observed changes in the apparent places of stars on the sky, as seen if one places himself or herself in the centre of our solar system.

Quasars (or QSO): A quasar, or quasi-stellar object (QSO), consists of a supermassive black hole surrounded by an orbiting accretion disk of gas and dust. As material in the surrounding disk falls toward the black hole, huge amounts of energy are released, making it one of the most luminous objects in our Universe.

Radial velocity: The radial velocity of a star is a measure of how fast the star is moving towards us (negative radial velocity) or away from us (positive radial velocity). The radial velocity of a star is measured using the Doppler effect. Due to the relative motion between the star and the observer, the light coming from the star is shifted to shorter (bluer) wavelengths when the stars moves towards us, and to longer (redder) wavelengths when moving away from us. This is similar to the change in pitch of a siren passing by.

Variable stars: A variable star is a star whose brightness fluctuates. This variation may be caused by a change in emitted light (intrinsic) or by something partly blocking the light (extrinsic). All stars are variable to a certain degree (our Sun changes about 0.1% in brightness during its solar cycle), but more drastic changes are seen in objects such as eclipsing binary stars, where one star passes in front of another and blocks out some or all of its light, or pulsating giant stars, where the star swells and shrinks, changing its size and brightness (e.g. starquakes). Also dark and bright spots on the stellar surface, such as the Sun's solar spots, can cause observed brightness variations.

Spectroscopy: Many of Gaia's measurements are based on light spectra of the stars, which the spacecraft collects. Stellar spectra indicate how bright the star shines at different colours of light. Like a unique fingerprint, they contain detailed information about the star's composition, temperature, and motion. Obtaining spectra requires the light from a star to be passed through a prism and split into a spectrum, rather like water droplets in the atmosphere splitting sunlight into a rainbow. When the spectrum is magnified, dark narrow lines can be seen that correspond to the light absorbed by chemicals in the star. Every element and molecule generates its own chemical fingerprint through a series of unique spectral lines at different wavelengths.