Beyond the Data: Engaging the Public with Astrometry Missions through Visualisations and Fascinating Insights

Stefan Jordan, Astronomisches Rechen-Institut, Zentrum für Astronomie, Universität Heidelberg

Why Outreach for Gaia and Follow-up Missions?

- **Public Awareness and Education:** Outreach efforts help raise awareness about scientific projects and their goals among the general public.
- **Inspiring the Next Generation:** Outreach activities inspire and motivate young people to pursue careers in science, technology, engineering, and mathematics (STEM) fields.
- **Bridging the Gap between Science and Society:** Complicated projects like Gaia can often seem inaccessible or intimidating to the general public due to its technical nature.
- **Increasing Support and Funding:** Effective outreach programs can garner public support and increase the likelihood of securing funding for scientific projects.
- **Motivation for Scientist:** Public outreach can serve as a powerful motivator for scientists themselves when they witness the appreciation and recognition their work receives from the general public.
- **„Bringeschuld“ ("obligation to deliver“):** Public outreach in science is an obligation to provide information, as the public finances scientific projects with their tax money.
- …

Astronomy Outreach in General

- **Visual Nature of General Astronomy:** General astronomy often involves visually captivating phenomena such as colorful nebulae, distant galaxies, or stunning images of planets making it easier to engage the public.
- **Spectacular Events and Discoveries:** Events like supernovae, comets, or eclipses capture the public's attention.
- **Spectacular Objects:** Black Holes mysterious with their mind-bending properties; Exoplanets in particular those where life possibly can exist.
- **Extension of the Universe in Space and Time:** The vastness and scale of the universe evoke a sense of wonder and raises questions about our place in the cosmos. The light from distant cosmic objects has traveled across vast cosmic distances allow us to peer back in time.
- **Potential Risks and Hazards:** The potential threat of asteroid impacts on Earth has garnered significant attention. Gamma ray bursts, close supernova explosions.
- **Evolution of the Universe:** Where do we come from? How were the star and planets formed? What will happen to the universe in the future?

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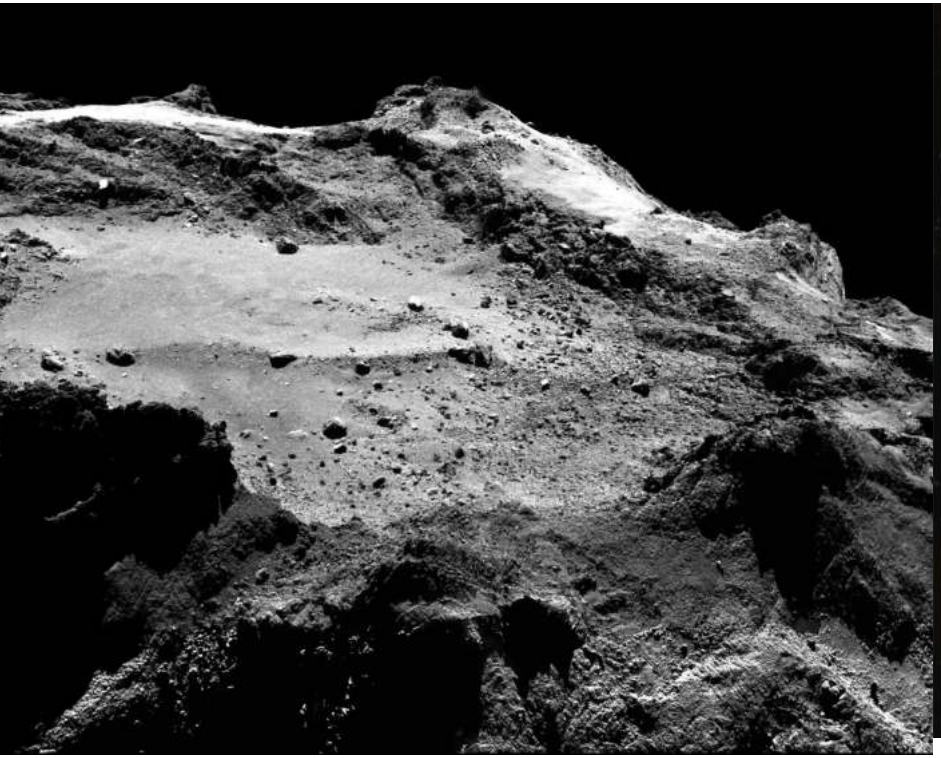

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Specific Challenges of Outreach in Space Astrometry

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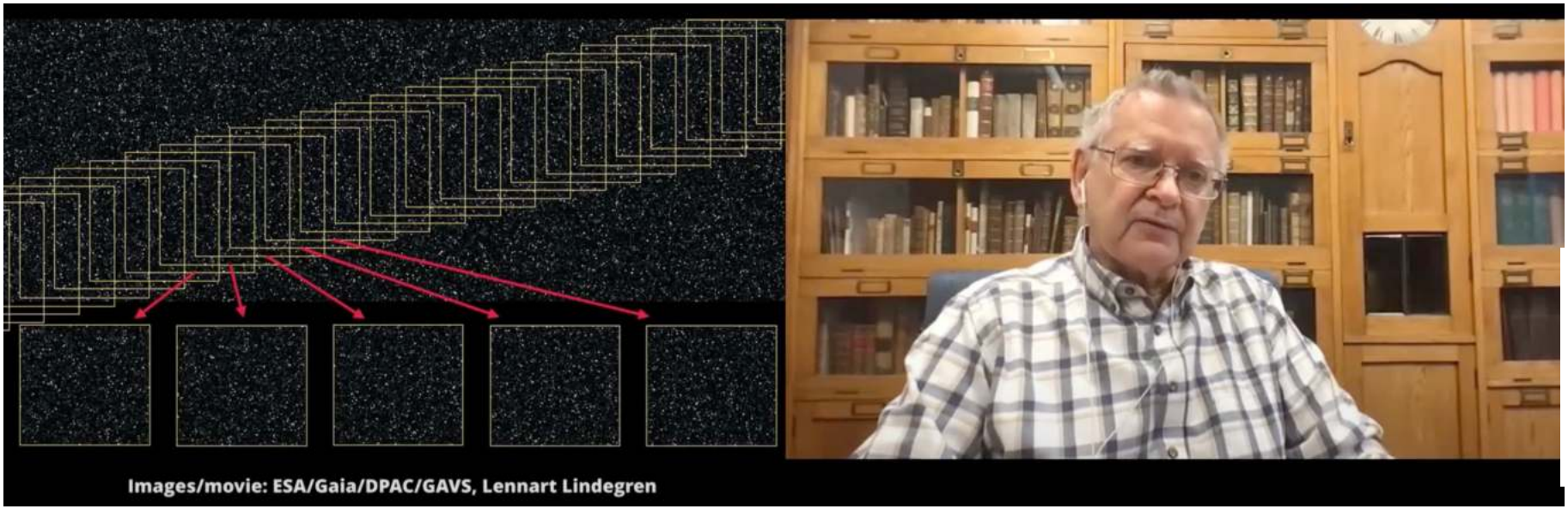

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0	0	0,020046	60,8528					20	0				6	0		0,676936	0,237203	-0,543039	-0,097239	67,58235	6,44121	10,4922	
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0	0	0,031531	77,6709	PHOENIX	4,6003	4,53	4,6347	24	0	-1,4349	-1,4961	-1,2719	9	0	1,3437	1,44924	0,321367	-0,406035		139,63629	7,48898	18,6456	
0	0	0,030103	5,58115					21	0				6	0		-0,170236	0,269599	-0,603428	-0,149211	57,83755	5,11646	11,3042	
0	0	0,033456	78,1256	PHOENIX	4,1853	4,156	4,2915	24	0	-0,3895	-0,5296	-0,2896	9	0	1,3254	4,63558	0,329094	-0,376397		1028,50167	11,3085	90,9498	
0	0	0,022848	63,786	PHOENIX	4,7362	4,6721	4,785	22	0	-0,4189	-0,5588	-0,2124	8	0	1,31706	-0,52083	0,346942	-0,428778		251,87992	8,01988	31,4069	
1	0	0,018041	9,77198					22	0				7	0	1,35544	0,822217	0,235971	-0,554459		96,79431	7,785	12,4334	
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0	0	0,031848	77,7907	PHOENIX	3,4096	3,3815	3,4323	24	0	0,0196	0,0182	0,0211	9	0	1,31393	2,98615	0,322276	-0,332325		2444,3196	7,55794	323,411	
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0	0	0,024241	73,3382					20	0				6	0		0,452112	0,132344	-0,644261	-0,113447	63,74705	6,75255	9,44043	
0	0	0,03227	65,8961	PHOENIX	4,6123	4,4617	4,6786	22	0	-1,2276	-1,3824	-1,0639	9	0		1,30282	0,313949	-0,411055	-0,114945	130,74795	9,06252	14,4273	
0	0	0,040034	79,1926	PHOENIX	4,4275	4,4074	4,4682	24	0	-1,3687	-1,3938	-1,3238	8	0	1,3517	2,16181	0,347903	-0,388738		272,66331	7,27486	37,4802	
0	0	0,020224	130,13					20	0				8	0		-0,966811	-0,084355	-0,681181	-0,055323	62,34013	7,06244	8,827	

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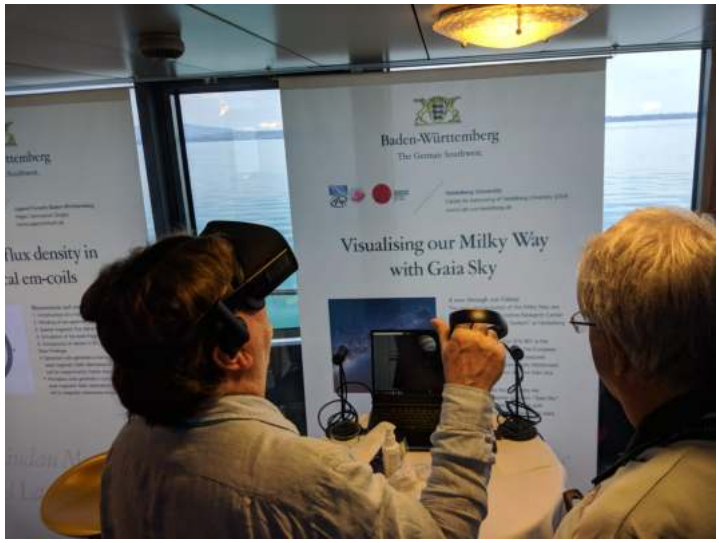
Gaia Sky is developed by Toni Sagristà

Gaia Sky is a real-time, 3D, astronomy visualisation software that runs on Windows, Linux and macOS. It is developed in the framework of ESA's Gaia mission to chart about 1 billion stars of our Galaxy in the Gaia group of the Astronomisches Rechen-Institut (ZAH, Universität Heidelberg).

- **Free and open source** - Gaia Sky is open and free, and will stay this way. Contribute to the development and translations.
- **From Gaia to the cosmos** - Move freely through the cosmos or explore the Solar System in a seamless manner!
- **Gaia** - Observe Gaia in its orbit and discover its movement in the sky and its attitude.
- **Virtual Reality** - The whole Universe in VR!
- **6D exploration** - Represents star positions but also proper motions and radial velocities, if available.
- **Planetary surfaces** - Explore surfaces with elevation maps (using tessellation, if available).
- **3D-ready** - With 6 stereoscopic modes: Anaglyphic (red-cyan), VR headset, 3DTV (H and V), cross-eye and parallel view.
- **360 mode** - With sperhical (equirectangular), cylindrical and Hammer projections.
- **Planetarium projection mode** - MPCDI for real-time usage in multi-projector systems. Ready to produce videos for full domes from the desktop app.
- **Use your data** - Download pre-packed datasets (Gaia eDR3, NBG, SDSS, OCDR2, etc.) or use your own, in *VOTable*, *FITS*, *CSV* and other formats (*STIL*).
- **Real-time filters** - Filter any dataset by distance, magnitude, galactic, ecliptic, equatorial coordinates, and more.
- **SAMP aware** - Implements SAMP commands to interoperate with SAMP-ready software such as Topcat and Aladin.
- **Navigate the galaxy** - Support for controllers and gamepads makes navigating the Galaxy a piece of cake.
- **Record and play your camera paths** - Ready to record and play camera paths off-the-shelf.
- **Scriptable and extensible** - Use Python to script and extend the capabilities of the Gaia Sky.
- **Internationalised** - Translated so far to English, German, Spanish, French, Catalan and Slovenian.

http://www.zah.uni-heidelberg.de/gaia/outreach/gaiasky



Nobel Prize Laureate George Smoot

ESA Astronaut (SpaceX Crew-3) Matthias Maurer

Visualisation of the Gaia Mission with Gaia Sky

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Some of the topic to which Gaia contributes

- Asteroids
- White Dwarfs
- Cepheids
- Cataclysmic variables
- Magnetic stars
- AGB stars
- RR Lyrae stars
- Red giant stars
- Luminous blue variables
- Red clump stars
- Runaway and hypervelocity stars:
- Microlensing events
- Exoplanet radii
- Stellar kinematics
- Structure of the Milky Way
- Bolometric corrections
- Star forming regions
- Distances and kinematics of pulsars
- Binaries for gravitational wave detections (LISA)
- Luminosities of exoplanet stars
- Finding open clusters, finding cluster members
- Isochrone ages of stars
- Gaia photometry
- Stellar distances
- Determining open and globular cluster properties (kinematics, age, metallicities)
- Finding and analysing tidal streams
- Galactic disk
- Investigation of the Milky Way halo
- Proper motion of Milky Way satellites and galaxies in the Local Group
- Quasars
- Strongly lensed quasars
- Hubble constant
- Reference system
- Dark Matter
- Planetary Nebula

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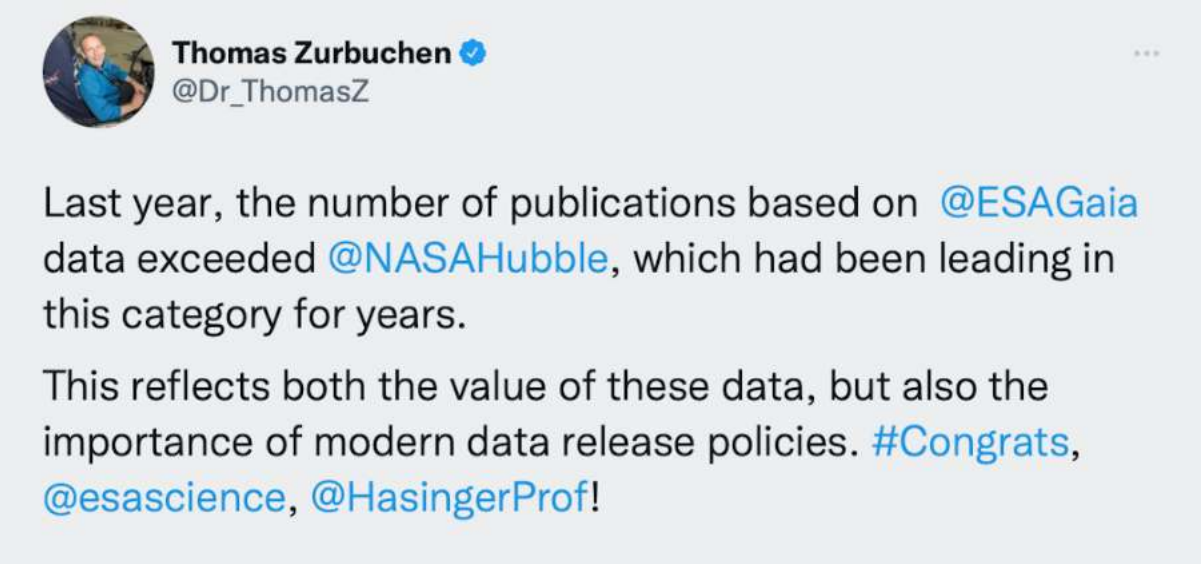

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Gaia Team

The Gaia collaboration was awarded the Lancelot M. Berkeley Prize for Meritorious Work in Astronomy in January 2023 at the AAS Winter Meeting.

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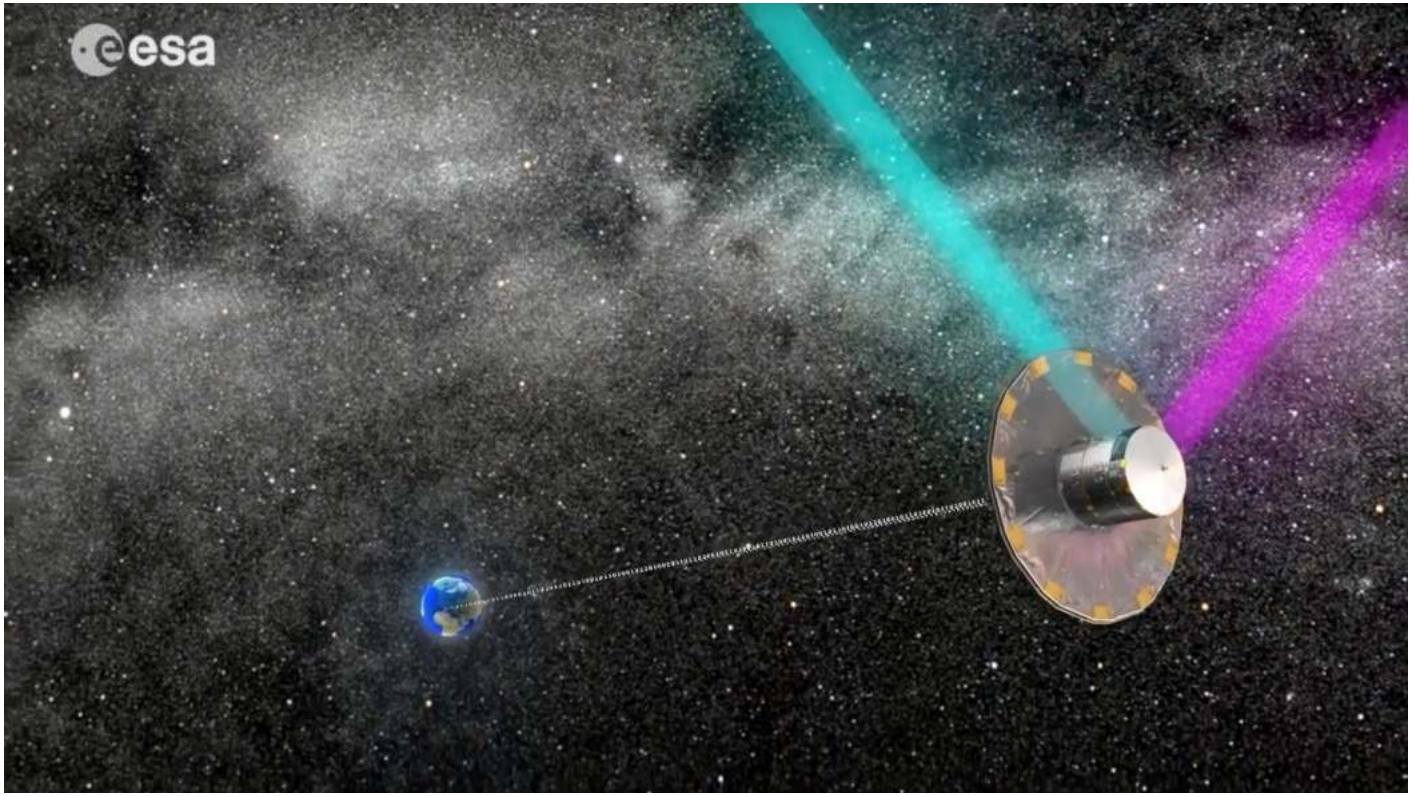

The Human Aspect of Science

- **Human Connection:** Including scientists from the project in outreach efforts humanises the mission.
- **Expert Insight:** Their insights provide a deeper understanding of the project and its significance compared to those with an outside view.
- **Personal Stories:** Scientists can share personal stories, anecdotes, and challenges they faced during the project.
  Passion and Enthusiasm: Scientists' genuine enthusiasm for their work can be contagious and inspire the public's interest in the mission.

COORDINATION UNIT 5 - A HUMAN STORY

Picture taken at the Coordination Unit 5 meeting as held in the summer 2020. Credit: ESA/Gaia/DPAC

This year has been strange and stressful for many reasons, both inside and outside Gaia and science. With the release of Gaia EDR3 occurring in 2020, we were expecting the usual amount of

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Articles in Scientific Magazines

Gaias neuer Datenschatz

Dritter Katalog des Weltraun

Nach dem ersten Teil von Gaias drittem Sternkatalog Ende 2020 kam nun ein großer Nachschlag dazu: Im Sommer 2022 wurden neue k 0 ' 2 3 ' B 2 OB 3 Bp Ъ ' B B 3 Bn ` j P ` gewonnen wurden. Die hochpräzisen Messwerte sind relevant für alle k 2 B 3 Bj QB q2 B3 B 3 ' ⊞ ` OB ' Bo anstellen und wo Durchbrüche zu erwarten sind.

Von Stefan Jordan

Der Satellit Gaia wurde im Jahr 2013 von der Europäischen Weltraumbehörde ESA gestartet (siehe SuW 5/2013, S. 36). Das Projekt dient der Astrometrie, um wichtige Messdaten vor allem von Sternen zu sammeln, zum Beispiel ihrer Position, Entfernung, Eigengeschwindigkeit und ihres Spektrums. »Sterne und Weltraum« begleitet die Mission von Anfang an und berichtete jüngst über neue Entdeckungen, die mit dem Projekt gemacht wurden (siehe SuW 1/2021, S. 28, und SuW 4/2022, S. 18). Nach wie vor werden täglich durchschnittlich etwa fünf Forschungsarbeiten publiziert, die von den Gaia-Daten profitieren.

Diese Erfolgsgeschichte geht weiter, denn nun wurde ein großer Datensatz veröffentlicht: der dritte Gaia-Katalog (Gaia Data Release 3, kurz Gaia DR3). Die gemessenen Größen betreffen sehr unterschiedliche astronomische Objekte wie Sterne, Asteroiden, Galaxien und Quasare. Von unschätzbarem Wert ist dabei, dass die beeindruckende Zahl von einer halben Milliarde Sternen in unserer Galaxis klassifiziert werden konnten.

Gaias Stärke liegt im Messen der Positionen von Himmelsobjekten und deren Veränderungen. Aus vielen tausend Einzelmessungen an praktisch jedem Stern bis zur 21. Größenklasse können hochpräzise Standardkoordinaten, Entfernungen und Bewegungen ermittelt werden. Gaia erledigt das milliardenfach an Sternen in unserem Milchstraßensystem. Da diese astrometrischen Daten aus einem Zeitraum von 34 Monaten zusammen mit den Messungen der Sternhelligkeiten und -farben die Grundlage für alle weiteren Daten und Spezialkataloge von Gaia DR3 darstellen, wurden sie bereits im Dezember 2020 veröffentlicht. In diesem Early Data Release 3 (Gaia EDR 3) konnte die ohnehin schon hohe Genauigkeit der Gaia-Entfernungen gegenüber Gaia DR2 noch einmal um 30 Prozent verbessert werden. Bei Sternen 13. Größe beträgt diese etwa 30 millionstel Bogensekunden (Mikrobogensekunden; 1 Bogensekunde = 1/3600 Grad), was einer Verschiebung von 5,5 Zentimetern in der Entfernung des Mondes entspricht. Bei den Eigenbewegungen ergab sich sogar eine Verbesserung der Genauigkeit um einen Faktor zwei.

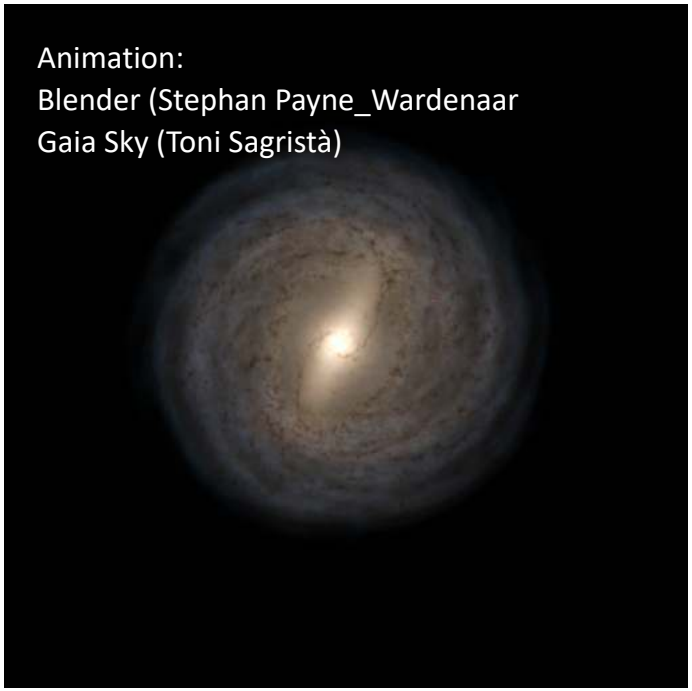
Am 13. Juni 2022 konnten nun auch die restlichen Teile von Gaia DR3 veröffentlicht werden. Wie facettenreich ihr Charakter ist, demonstrieren einige Kennzahlen in nebenstehender Tabelle.

Zusammen mit den Messergebnissen wurden vom Gaia-Team auch neun wissenschaftliche Arbeiten im europäischen Fachjournal »Astronomy and Astrophysics« veröffentlicht. Die Nutzerinnen und Nutzer des Katalogs erfahren darin anhand von Beispielen, welches Poten-

Gesamtzahl der Objekte	1811709771
	Schon im Gaia Early Data Release 3
Eigenbewegungen und Parallaxen	1467744818
Quasare [1]	1614173
Helligkeiten	1806254432
	Neu im Gaia Data Release 3
Radialgeschwindigkeiten	33812183
Helligkeiten [2]	32232187
z ' BP geschwindigkeiten	3524677
Niedrig aufgelöste Photometerspektren	219197643
Hochaufgelöste z , ' P	999645
Analysen variabler Sterne	10509536
t ' Himmelsobjekte	1590760469
Mehrfachsternsysteme	813687
Quasare [3]	6649162
Galaxien [3]	4842342
Objekte im Sonnensystem [4]	158152

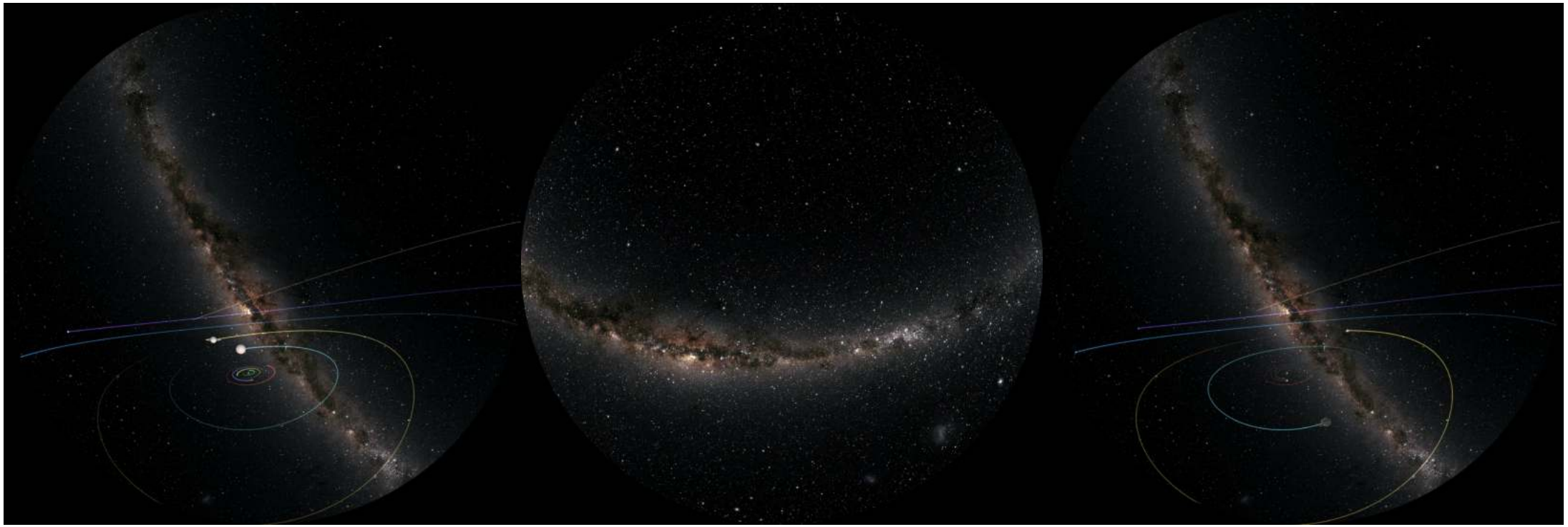
Collaboration with Planetaria

Multipliers of Astronomy Knowledge: Planetaria have a significant audience and act as amplifiers, disseminating astronomy knowledge to a wide audience.
Experience in Astronomy Outreach: Planetaria are very experienced connecting scientific research to the public
Visualisation: Planetaria use advanced technology to transform complex data into captivating visuals.



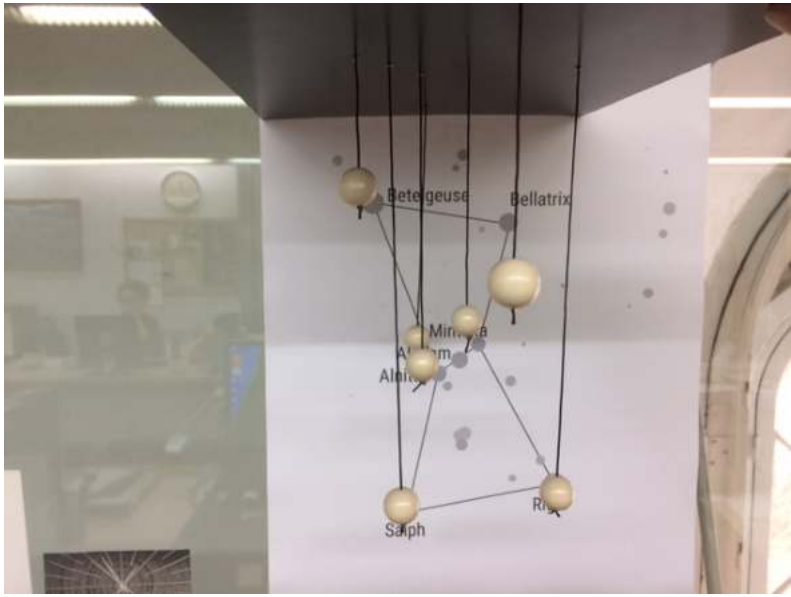
A collaboration of the Astronomisches Rechen-Institut in Heidelberg with the Planetarium in Mannheim, Germany, resulted in a planetarium show focused on the Milky Way. Gaia measurements played a significant role in animating a realistic representation of our galaxy for the full dome. And Gaia's role to understand the Milky Way was often mentioned in the show.

Gaia Sky Videos for Planetaria

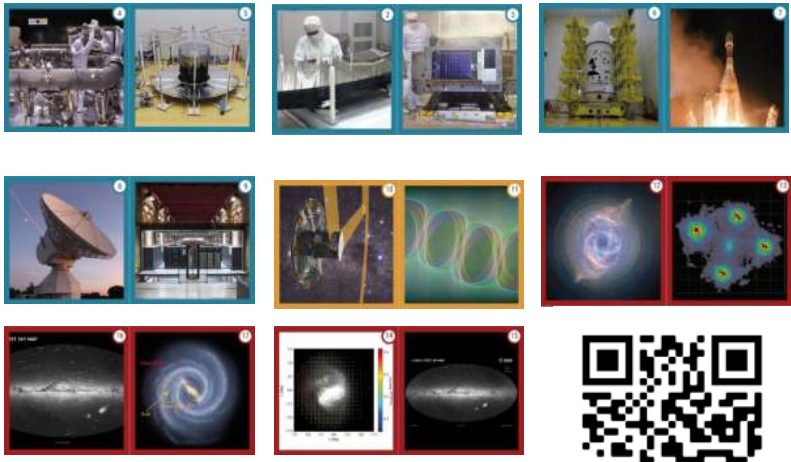


Robin Geyer, Dresden Observatory

Gaia Teaching tools from the University of Barcelona



- Bookmarks
- Memory Game: https://gaia.ub.edu/?p=10302
- 3 D constellations for schools: https://serviastro.ub.edu/en/projects/constellations-in-3d
- Instructions to build (in Spanish): https://serviastro.ub.edu/sites/serviastro/files/fitxers/material/2019-09/conscast.pdf



http://www.ub.edu/laubdivulga/festacienciaub/festacienciaVII/bombolla-3d.html

Gaia Posters

A set of Gaia posters in English and other languages:

https://serviastro.ub.edu/en/materials/exhibitions/mil-milions-dulls-a-mil-milions-destrelles

The Gaia posters, which original version in Spanish and English was prepared by the Gaia team from the University of Barcelona, were translated into German, improved, and technically implemented by the joint team from ARI/ZAH, University of Heidelberg and Lohrmann Observatory, Technische Universität Dresden.

Positive Experience

- The Gaia mission enjoys a high level of esteem and recognition within the astronomical community.
- The mission generates an extensive amount of stories, weekly pictures, and materials for data releases. This is largely attributed to the active involvement of teams responsible for research papers, who also contribute to the creation of images and videos for outreach purposes.
- During the intervals between data releases, numerous authors, upon recognizing the significance of their scientific findings, contribute to the production of stories and visualisations for publication on the ESA website.
- The collaboration between Gaia DPAC and ESA is highly effective, particularly within the small DPAC/ESA outreach team.
- Additionally, significant efforts are undertaken at the local and national levels to engage in outreach activities, often conducted in the languages specific to the respective regions involved.

Shortcomings

- The Gaia team responsible for regular outreach material at the CU/DPAC level is quite small, comprising essentially two to three individuals.
- The ESA Communication team is engaged in various missions and may not always have the capacity to write stories and similar content.
- High-level decisions from ESA are not always transparent, and the influence of DPAC is often limited.
- The potential impact of stories, pictures, and videos could be significantly greater if we were able to publish them on social media platforms with a larger subscriber base.
- Numerous aspects of outreach, such as engaging with schools, have unfortunately not been possible to the extent that we would wish due to the lack of personal.

Possible Improvements

- Have a larger group of people working for outreach on a project level (plus people doing outreach on local scale)
- Make sure that software for visualisations are up-to-date.
- Find a way to publish the outreach material most efficiently.
- Will ESA update their outreach group?