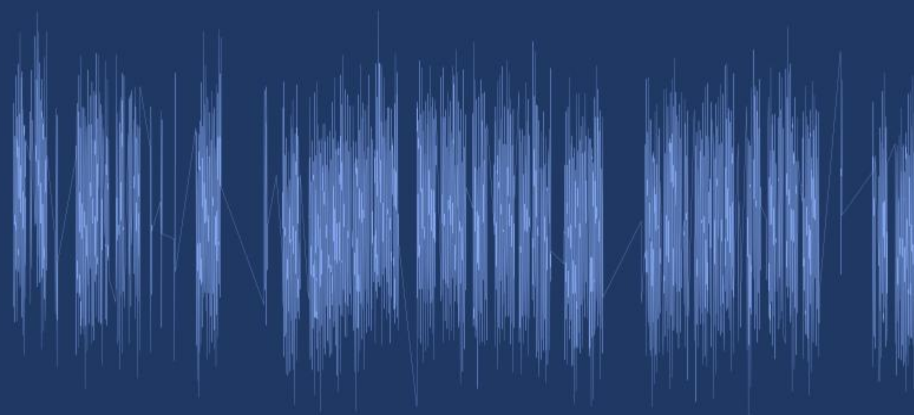
Volume 3 Issue 1 JANUARY-JUNE 2026 ISSN 3062-0090

a journal on cutting edge astrophysics research, tools, and people

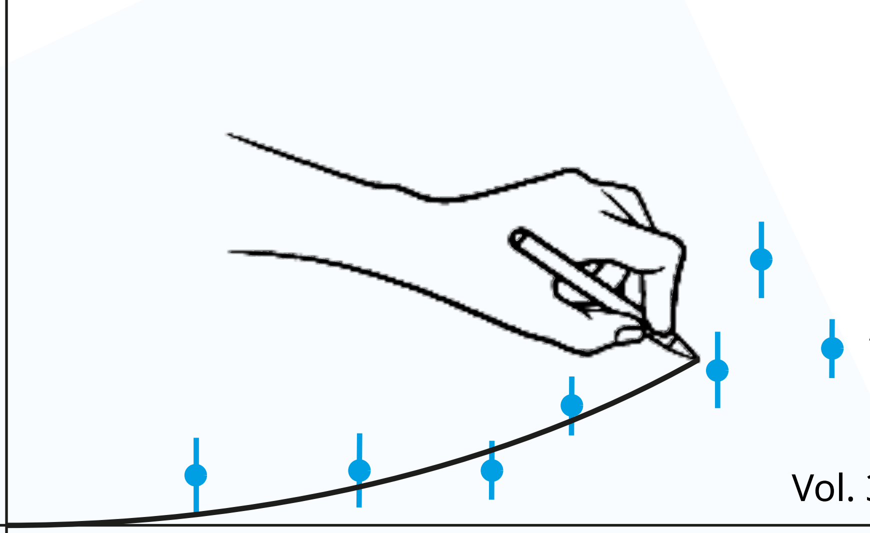
SCIENCE ASCEND



In this issue:

Editor-in-Chief: Y. Güray Hatipoğlu

FIRE



SCIENCE ASCEND

Vol. 3, Issue 1, January 2026

PREFACE

Greetings everyone!

Science Ascend returned a new. Cover, inner pages' layout and design were also arranged and standardized by Maarten Roos-Serote for a more slick, professional, and comfortable view.

However, the looks are not all! This issue informs readers on

Two recent interviews, Singular Spectrum Analysis and its application in astronomy, Venus Sulphur Cycle, Cosmic Strings, and even a Science Outreach observation are in this issue.
Additionally, key information on workshops and conferences in astrophysics will be published in https://fire-ae.org/ascend.html.

See you in the next issue!

Güray Hatipoğlu
FIRE Research and Training Ltd.

CONTENTS

TECHNICAL INFORMATION

Publisher: FIRE Araştırma Eğitim Ltd. Şti.
Responsible person - Editor in chief - Editor: Yasin Güray Hatipoğlu
Authors in this issue: Güray Hatipoğlu, Maarten Roos-Serote, Özlem Yeşiltaş
Media: Online
Publishing frequency: Biannual
E-mail: info@fire-ae.org
Website: https://fire-ae.org/ascend.html
ISSN: 3062-0090

SCIENCE ASCEND
Vol. 3 - Issue 1 - January 2026

Interview with Evgeny Smirnov

Evgeny Smirnov obtained his M.Sc. Degree in Astronomy, Mathematics, and Computer Science at Saint Petersburg State University in 2009, closely followed by his PhD in Astronomy & Mathematics in Pulkovo Observatory (2016). Furthermore, he acquired another M.Sc. Diplomas: Philosophy, Science, and Religion (The University of Edinburgh 2021 and Personality Psychology (Saint Petersburg State University 2022).

In his professional life in the private sector, he held software engineering roles in StegSoft and Vstretcher. After that, he founded 4xxi in the project management and consultancy field, Newtonew in agile project management, social media management, sales, and Denovo on IT consultancy and AI research. Considering this wide range of experiences and expertise, the interview contained almost all of them in the questions around large language models (LLMs). The questions were mainly on our motivation to use LLMs, their potential benefit on project management tasks, using LLMs in scientific research, conducting literature review with them, and the place of LLMs and even more potentially advanced future AI versions in scientific discoveries.
Intrinsically, he stated that LLMs can help us to understand who we are better, and LLMs also have a strong mathematical roots that's why he had an interest in comprehending that deeply. In project and product management which are not fundamentally different than each other, LLMs has roles to fill but not roles to replace, with an example from User Story creation, some part of the documentation and direction/ guidance to developers might be accelerated, yet there are lots of decision making and fine tuning using the information and data not loaded on LLMs, on the actual work it does not make user story creation by humans obsolete currently. Making story points and similar metrics more accurate has its deep challenges as well, specifically coming from the problems with the metric itself.
Moving on to the scientific research, LLMs and AI has obvious advantages in summarizing, literature review, number crunching, and similar, but these are dangerous when the users can't do these successfully by themselves and don't validate the outputs. In the case of literature review, too, losing the context of a scientific field and new developments is among the dangers of poor utilization of LLMs. It is much better to use LLMs to optimize tasks you can already do yourself and validate outputs so that you save time/ resources. One example research study he published while using automatic classification in some parts of the study is this article.

The last question was the potential of LLMs to make discoveries. The way we craft knowledge and discovery is built up from texts, and what LLMs generate is not significantly different, though they also contain biases we introduce to them. This is good as it shows us who we are, but the actual breakthrough will be when artificial general and super intelligence will be realized.

As his final remarks, Evgeny Smirnov cautioned us that even though the technology of LLMs, like that of atomic bombs or similar things, has its dangers, humans have a passion to discover, get interested, and learn in their roots, so our fear should not stagnate growth.

The interview can be watched here.

Interview with Prof. Özlem Yeşiltaş,

Prof. Özlem Yeşiltaş graduated from the Physics Department of Gazi University with a B.Sc, and followed with an M.Sc. and a Ph.D. in the same department. Considering that she is also a professor in the same department may look straightforward, but the reality is quite different. Even though she had expertise in mathematical physics in her graduate studies, she attended the European Fusion Development Agency (EFDA) Euratom Fusion Summer School in Culham, England, focused on fusion energy power plants. This was followed by a researcher position at the Türkiye Nuclear Energy Institute (TAEK, currently in TENMAK). Then, she attended the 7th Workshop on Quantum Physics with Non-Hermitian Operators (PHHQP VII), closer to her graduate studies, followed by a Post-Doctorate study at Concordia University related to another theoretical field, cosmic strings. A few years later, she was a visiting scientist at the Hungarian Academy of Sciences, Institute for Nuclear Research, ATOMKI, followed by Assistant, Associate, and Full Professor positions at Gazi University, her current affiliation. In short, she has been in various fields and has also participated in interdisciplinary and international teams. The interview focused on her career, important turning points, and what they contributed to her,

as well as tips and recommendations on teaching, outreach, and having a healthy life-career balance. In the first part of her career, she stated that she knew she was interested in an academic career from the beginning and followed the usual steps with undergraduate and graduate studies. At times, there were good and challenging parts, though persistence was the key to finishing her studies. She also noted the usually attested "obsessive" characteristic of the academicians, which, in fact, is a must-have for having the outputs in the minimum required quality. Of course, this quality also works well in other research-based roles and in other institutes; hence, she chose to work in TAEK while also pursuing the requirements for the Associate Professor position in Türkiye. This decision also originated from her characteristics of experimenting with something not tried before and expanding her vision rather than the convenient path. While doing both experimental and theoretical parts, this experience also made her decide more clearly that the academic environment is more suitable for her.

After this episode in her career, she managed to start working on quantum gravity topics, and with this, she has been working on three sub-fields under the mathematical physics field. These can be summarized as quantum gravity mathematical problems, non-Hermitian Quantum Mechanics, fermion dynamics, and how cosmic strings impact these fundamental particles, with and without gravitational fields, and lastly, integrable systems.

While conveying this expert field knowledge to other audiences and students, she stated that making analogies from real life is of utmost importance.

SCIENCE ASCEND
Vol. 3 - Issue 1 - January 2026

One example is the estimated similarity of cosmic string topological defects after phase change in the universe to that of solid white cracks in typical ice cubes. Even if there is not any observed evidence for this, it is appropriate to convey the idea.

The ideas are, of course, in the mathematical physics domain and abstract, but they still do not prevent them from being useful in other fields after some methodological steps. One case is her published work on Black Scholes and the volatility-related utility of it in the finance domain. This equation is actually a classical differential equation, and the utility relation of this between quantum mechanics and finance is that it shows the time-dependent evolution of the system. She further elaborated on how her view of solving mathematical problems can be adapted into this option pricing and volatility dynamics, and that the interdisciplinary approach, rather than getting confined to a specific field, is better (see this link).

In the final question, she also states the importance of having hobbies to pursue an academic career. This is critical since focusing on similar problems or sometimes even a single problem for prolonged periods can weigh people down. In this case, she had been involved in a chorus that is successful enough to make international trips to different countries, as well as fitness, weight lifting, and kick-box sports. Specifically, she has been involved in sports and karate since her student days as a licensed member. Such activities provided her with the stability and determination to advance her career. It is also crucial that we should not be too sedentary and always have some movement, with communication between the brain, mind, and body.

As the concluding remarks, she stressed that the development of a country is closely related to the relationship of the public with science, arts, and sports. Even if we can’t produce, we should at least strive to consume them better. They should definitely be spread out to the general public more than they are now in Türkiye. Even starting with 3-year-olds and higher, fundamental science and analytical thinking should be introduced to the children with appropriate methods.

The interview can be watched here.

The Case of Astrobot JWST in BlueSky

Outreach for science is critical for many reasons. A high majority of scientific research infrastructures are publicly funded, the researchers of the future are the current new generation in public, crucial in building trust[1], and explaining a scientific case to different audiences requires one to be an expert and an empathetic person simultaneously. Among the ways of outreach, social media has a wide range of tools and places.
Each one of them requires a different strategy to adopt for higher reaches and more effective interactions. This post focused on BlueSky, where Science Ascend is also recently active and contributing. BlueSky has no advertisement and is comparatively low in user-post-interaction volume, but the interactions are more organic. There are also many accounts for astrophysicists and simply astrophysics lovers. Furthermore, BlueSky has a specific AstroSci feed that can be reached here. It is customized to contain posts about astrophysics research only from accepted members and is moderated in this way.

After pointing out all these outreach advantages of BlueSky, this article now focuses on the Astrobot JWST (from Yuval Harpaz, a Psychology PhD holder with interests in Python and spatial data visualization) account there, with its automatic feed from new JWST data releases. Visit the account.

1 Kuske, J., Martinez, C., Leathers, T., & Villagomes, D. (2025, May 20). What is science outreach and why is it important?. UC Davis.

The main activity this tool does is querying the last two hours of JWST image releases, combining the image with the information from the headers of these FITS files and automatically posting content to BlueSky, among other things, both directly or after some automatic processing, with also alt texts. This way, the reach of JWST images increases significantly, and anyone randomly shuffling through the "Discover" tab of BlueSky may just see them. This is where things are getting interesting in terms of how the public interacts with the images. Below are non-exhaustive categories for their typical reactions:

- There are superficial interactions, including loving, joking about it, or simply referring to any other post JWST-related.
- Some people are simply asking what that image is; probably the caption is either unread or a bit cryptic to them.
- Space and alien life-related remarks
- Common image noises and errors, when amplified, are considered to be user or sensor failure.
- Some of the misunderstandings or questions may be caught by experts from that area, and a positive learning experience occurs. Yuval Harpaz also intervenes in explaining the processing he applies, but the best case is similar to BlueSky users who process JWST images and create them to reach out to people.
- pointing out the painting resemblances, or the similarity to music album covers.

• Another similar reaction is resembling a part or all image to something, maybe a Christmas tree, Santa (probably recency bias towards Christmas), an explosion, etc.
• Other people would like to learn more about the image out of sheer curiosity and check the program name and more with the provided information.
• Critics of both the alt text and caption labels

The oldest post of Astrobot JWST is on 12 November 2024; the interaction and community did not immediately appear, and the content evolved as well. The caption, colored images were changed. Prettier-looking images generally attracted more interaction, and with the Saturn image of JWST, the interactions drastically increased for such cases, only coinciding on 7 December 2025, prior to that, community feedback and interactions as comments and likes were nonexistent. Additionally, Beta Pictoris, with its exoplanet fame (Beta Pictoris b), and several gravitational lensing-visible images were far more interactive, probably because the things they represented were famous elsewhere and easily connected with the audience.

In summary, potential leads and insights these observations hinted at,

1. Science Outreach for JWST images requires a multi-pronged support, ranging from an automatic pipeline, to a pretty visualization of the image, to explaining the shortcomings of sensors, focus, or area information in plain language, and experts to answer questions from the public.
2. Captions can be more instructive for a general audience, and maybe darker parts of the image may be used to draw and inform objects, especially when people just pass by looking at images only. One critical piece of information most-inquired about is the type of object in focus, such as whether it is a star, galaxy, or else, especially when it is not obvious.
3. Already known (Saturn), recently famous (3I/ATLAS) targets might be prioritized to increase the interaction and inform the audience efficiently.
4. Alt Text may also include critical and erroneous features of the image, while sometimes generally aiding visually-impaired people. (though this requires far more processing before posting)

These are clear from the public interactions taking place in Astrobot JWST content, and thanks to the efforts of its builder and supporters. Nevertheless, a more systematic approach and collaboration with them may provide a much better picture for the outreach. At the same time, Science Ascend itself will have its own outreach projects, and their results will be directly examined in the next issue.

Venus, clouds and sulphur

The sulphur cycle in the atmosphere of Venus has been an object of study and debate for decades. Sulphurdioxide can be observed using Earth-bound and spacecraft instruments and it is detected by instruments on entry probes into the atmosphere of Venus.

On 3 December 2025 Europlanet organised a special webinar to discuss new observations and insights into this topic. Speakers Thérèse Encrenaz (Paris Observatory, France) and Rakesh Mogul (California State Polytechnic University) presented their work followed by an extended and lively discussion with the 50-people large audience. The full session can be viewed here.

Thérèse Encrenaz and collaborators have been been patiently collecting a unique dataset using the same (!) instrumentation to observe Venus for almost 15 years. It is the TEXES (Texas Echelon Cross-Echelle Spectrograph) imaging spectrometer (5-25 micron wavelength range) mounted at the NASA InfraRed Telescope Facility (IRTF, Mauna Kea Observatory). They have published a series of seven research papers to date. From their data the abundance and spatial distribution of H_2O and SO_2 can be inferred at around 60km altitudes, around the cloud tops.

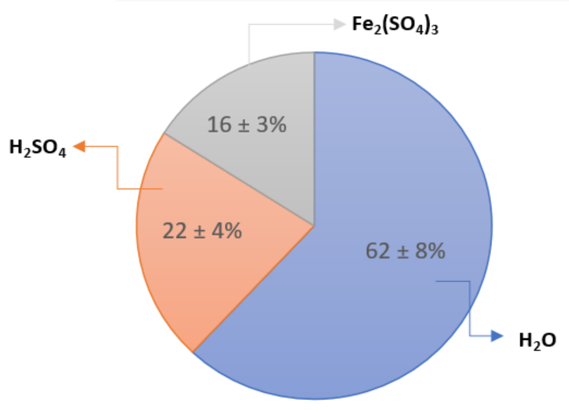
The main observation is that SO2 is very heterogeneously distributed spatially and the abundances are varying significantly over time. Water on the other hand is much more homogeously distributed with little variation over time.

The cause of the temporal variations of SO_2 are not clear. Since SO_2 parttakes in photochemical processes in the clouds a correlation with solar flux could be expected. Part of the observations seem to hint at such a correlation. But when taking into account all the observations, this correlation is a lot less clear. Other possible sources such as volcanism or impacts cannot be ruled out, but are as yet difficult to prove.

Rakesh Mogul and co-authors shed a new light on the chemical composition of the clouds in their recent paper on the re-analysis of Pioneer Venus Entry Probe data. Pioneer Venus released its Large Probe into the atmosphere in 1978. The observations from the Neutral Mass Spectrometer and the Gas Chromatograph instruments showed features that were never well understood. Though it was clear from the first analysis of the data in the early 1980s that cloud particles had clogged the inlets of these instruments during part of the descent, the new analysis results in a much better understanding of the effects of this clogging, and the subsequent unclogging by evaporation of the clogs as the probe was diving deeper into the hotter layers of the atmosphere. Mogul describes a very elaborate and detailed analysis, from which it becomes clear that the data recorded during the phase when cloud particles clogged the instruments is sounding the chemical composition of these particles, much more than that of the atmosphere.
With that in mind, a new bulk (!) composition for the cloud particles can be derived. This composition is rather different from what has been assumed to date, especially with respect to the total water and iron content. It turns out

SCIENCE ASCEND
Vol. 3 - Issue 1 - January 2026

that water accounts for more than 60% in terms of bulk weight, whereas ferric sulphates and sulpheric acid account for about 20% each. This can be seen in the following figure.

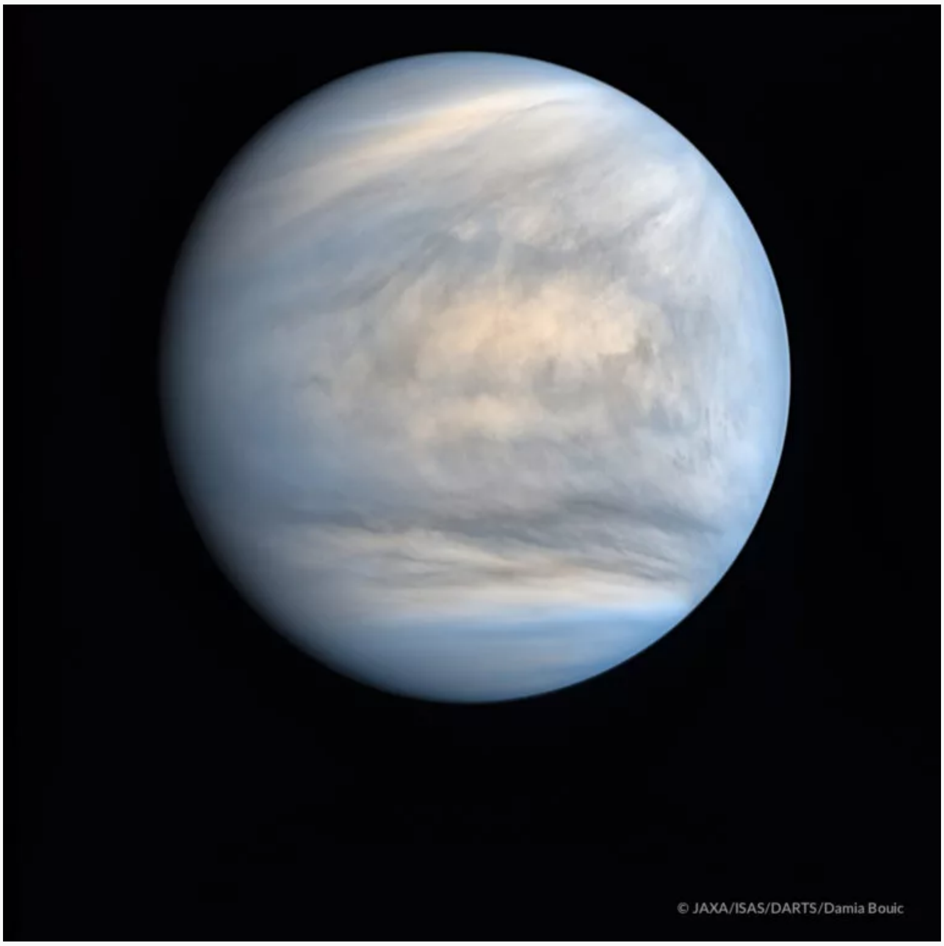


Created with the data from Mogul et al. 2025

Most of the water, however, is present as hydrated iron and magnesium sulphates, not in volatile form. It is the volatile fraction that comes into play when the clouds are observed via remote sensing, from which a high acidity of over 75% by weight H2SO4 has been derived and known for many decades.

The big question is how to fit the results of these works and many other work by other researchers on this topic into a complete picture. How do the new insights into the cloud particle chemical composition lead to a better understanding of the overall chemistry and cycles in the clouds? Ongoing discussion between researcher groups is much needed. I wonder whether other (old) sets should be reevaluated with this new information in mind.

Maarten Roos-Serote (ScienceCurve.Space)

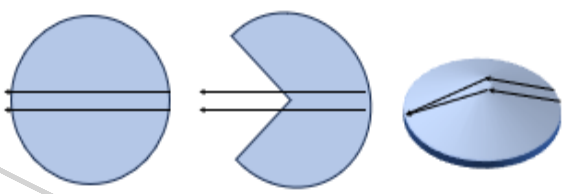


Global view of Venus in ultraviolet from Akatsuki. False-color image using 283 nm and 365 nm UVI channels. Image: JAXA / ISAS / DARTS / Damia Bouic. Licensed under Creative Commons BY-NC-ND 3.0.

Cosmic Strings: Relics of the Early Universe

Phase transitions of quantum fields in the early universe may have produced cosmic strings: hypothetical, ultra-thin line-like defects in spacetime formed during cosmic cooling and symmetry breaking. Although the name suggests ordinary strings, cosmic strings are not made of normal matter. Instead, they are regions where the field configuration did not settle uniformly, leaving behind "fossil" traces of the universe's highenergy youth. Depending on the underlying theory, strings can be classified broadly as gauge (local) or global strings, with different field structures and observational signatures.

A defining property of a cosmic string is its enormous mass per unit length, denoted by μ which is μ≈1022kg/m accompanied by an equally large tension. Rather than behaving like a conventional massive object that pulls everything inward, a straight string modifies the geometry of the surrounding space in a distinctive way. The spacetime around an ideal straight string is locally flat but globally conical: one can picture it by cutting a thin wedge out of a sheet of paper and taping the edges together to form a cone. The result is that a "slice" of space is effectively missing, which alters the paths of light and can lead to striking gravitational effects.



How might we detect cosmic strings?

Even though no confirmed detection exists so far, ongoing searches across multiple channels place strong constraints on how large Gμ (a dimensionless measure of string strength) could be. Several key strategies are used:

• Gravitational lensing: A straight cosmic string can produce double images of a background galaxy or quasar. A characteristic feature is that the two images are typically nearly identical and show little distortion or magnification, unlike lensing by galaxies or clusters. This "clean split" is one of the most distinctive observational signatures.

• Gravitational waves: Cosmic string networks can form loops that oscillate and radiate gravitational waves. Sharp features such as cusps (brief ultra-relativistic points) and kinks (bends) may generate bursts, while a population of loops could produce a stochastic gravitational-wave background potentially accessible to pulsar timing arrays or laser interferometers.

• Cosmic microwave background (CMB): Moving strings can imprint subtle, line-like discontinuities or nonstandard patterns in CMB temperature and polarization maps. These signatures differ from the usual random fluctuations seeded by inflation and provide an important avenue for constraints. • High-energy particles (model-dependent): In some scenarios, strings can interact with other fields and produce high-energy particles, though the viability of this channel depends strongly on the underlying microphysics.

SCIENCE ASCEND
Vol. 3 - Issue 1 - January 2026

Why Cosmic Strings Still Matter?

The absence of a confirmed signal is not a failure; it is information. Each non-detection narrows the allowed parameter space for early-universe theories and helps refine models of symmetry breaking and high-energy physics beyond laboratory reach. At the same time, improved surveys, higher-resolution sky maps, and increasingly sensitive gravitational-wave searches continue to strengthen our ability to spot the unique fingerprints of strings.

A single robust detection would be transformative: it would provide a direct window into physics at extreme energies and connect fundamental field theory to observable cosmological structure.

Cosmic strings remain compelling precisely because they sit at the intersection of deep theory and potential observation linking the smallest scales of quantum fields to the largest scales of the universe.

Prof. Özlem Yeşiltaş
Department of Physics, Gazi University

What is Singular Spectrum Analysis

Singular Spectrum Analysis is a method to disentangle time-series data into linearly separable components. It does not make a priori assumptions about the data, and it is a non-parametric method. It has many different branches, and the main form (one-dimensional) has the following four steps (Golyandina & Zhigljavsky, 2020).

1-] Trajectory matrix:
With an L window length, one-dimensional time-series data becomes a multi-dimensional Hankel matrix as:

$$X = \begin{bmatrix} y_1 & y_2 & y_3 & \cdots & y_K \\ y_2 & y_3 & y_4 & \cdots & y_{K+1} \\ y_3 & y_4 & y_5 & \cdots & y_{K+2} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_L & y_{L+1} & y_{L+2} & \cdots & y_T \end{bmatrix}$$

2-] Singular Value Decomposition:
This step multiplies the X matrix above by its transpose and decompose it using Singular Value Decomposition (SVD) via XXT = UΣVT. This is, in fact, similar to considering shifted parts of the time-series as if they are another variable. Then, periodic-oscillatory signals have the same impact between two rows if the row number difference is a multiple of that periodic signal. In other words, a periodic component with a 20 unit period, will be similar in row-1 and row-21, and be reflected as a correlated part of the signal.

3-] Eigen-vector Selection:
This is where we separate the one-dimensional series into different components. There are many ways for this step, and one is grouping correlated elements into one cluster, and separating the most uncorrelated ones in different clusters, looking at the correlation between the reconstructed elements (w-correlation matrix). Further, if there is a priori knowledge about the frequency of a specific signal or noise, choosing L window as a multiple of that frequency will assist in separating that component. More details on selecting L window length are in Golyandina, Nekrutkin, and Zhigljavski (2001).

4-] Reconstruction of the one-dimensional time-series data:
This is where the 1D time-series data will be reconstructed. If we retain all components, the same data will be obtained. Otherwise, there will be some data reduction. The rest is reverting SVD and having the multiplication of the Hankel matrix with its transpose, but this is not the same as before, after the data reduction as some principal components were eliminated. Lastly, the Hankel matrix will be reverted to a 1D time-series data.

SSA's Practical Importance for Astrophysics

There are several advantages of using this method in astrophysics.

• When there is no trend in data, it reproduces the same results as Fast Fourier Transformation (DFT). However, when there is a trend, SSA is more robust than DFT (Thekkeppattu, Trott, & McKinley, 2023).

• The step-by-step basic SSA can be constructed easily in commonly used programming languages. For instance, in Python 3.x, only NumPy linear algorithms SVD is sufficient.

Moreover, there are also caveats to be wary of:

• SSA assumes that the input data has the same timestep between consecutive values,

• The chosen window length is critical for the periodic signal recovery process; the likelihood is drastically higher when the window length is a multiple of the period of interest.

In addition to the basic SSA, according to the studies below, we see that multichannel SSA, Iterative Oblique SSA, and Monte Carlo SSA were present in various astronomy-related studies in 2025.

Multichannel SSA

This version of SSA is not much different from the basic SSA application. This is because in the basin Trajectory Matrix (or Hankel Matrix) constructed, each row acts like a different series. When we add other 1D series, e.g., collected photometric measurements from different wavelength bandwidths of R, V, or I, they are also different series, so we may add them up by horizontally or vertically stacking.

Iterative-Oblique SSA

This algorithm is the iterative version of Nested Oblique SSA (Golyandina and Shlemov, 2013). The idea with the nested Oblique SSA is that we can't properly extract signal from noise using an oblique-non-orthogonal coordinate system directly, while basic SSA may disentangle noise and signal, but may not be able to separate the signal components from each other, considering their separability, or simply if they are in similar frequencies etc. Oblique SSA algorithm is as follows:

> The input is given in L, R matrices consistent with the actual input Y. (Consistency is when L is left-orthonormal with the to-be-obtained P after the previous ordinary SVD decomposition of previously, e.g., Cholesky decomposition result, and similarly for R, it is right-orthonormal to Q obtained later.)
> Calculating OL and OR,
> Calculating OLYORT,
> Finding the ordinary SVD of OLYORT,
> sigmai = sqrt(lambdai), Pi = OL+Ui and Qi = OR+Vi , superscript + means pseudo-inverse.

The iterative version has an accuracy and a maximum number of iterations to iterate over the oblique part of the aforementioned decomposition.

Monte Carlo SSA

This was born out of the need to statistically decide between actual signal components and noise while working with SSA results (Allen and Smith, 1996). The problem is that the largest eigenvalue associated component is not an evidence of a physically meaningful signal. Monte Carlo SSA does the following steps:
> Autoregressive and Moving Average (ARMA) noise model parameter estimation, with AR(1).
> Simulating according to the ARMA noise model generated above
> Establishing confidence intervals in one of the available ways, one is projecting the surrogate data generated above on the same eigenvectors.
> Constructing a null hypothesis according to the confidence intervals for an eigenvalue and associated component to be considered signal or colored noise.

SSA in 2025 Astronomy Literature

The section below showcases 15 articles from 2025 that is filtered with "singular spectrum analysis" in NASA ADS and on the "astronomy" subject.

Galactic Astrophysics

Arora et al. (2025) utilized multi-channel SSA (as it implies, not 1D) in their study of the Milky Way (MW) morphology's temporal evolution. Among their purposes is disentangling the effect of filamentary accretion and satellite perturbation (such as the Large Magellanic Cloud, LMC) on the MW halo structure. They started with basis function expansions (BFEs) to define the spherical characteristic of the Halo and its temporal evolution, as the dipole term was related to the deviation from the symmetry, while the quadrupole term was on the triaxial spherical shape's temporal deformations. For retrieving these, they used the Latte suite within the FIRE-2 project of zoomed cosmological hydrodynamical simulations (stars based on Starburts99 stellar volution models and Planck results consistent lambda-CDM cosmology) with time-evolving BFE models. From within the BFE representation of the halo density field, time-dependent weighting amplitude coefficients were introduced as inputs to SSA, in the maximum permissible half-length of the entire time series available. In this way, they aimed to suppress the high-frequency effects and obtain more accurate results on long-term trends. They also utilized the mSSA principal components' correlation values between them to group together (while also applying the Discrete Fourier Transformation) filament-driven groups and LMC groups.

Tavangar and Johnston (2025) followed a similar approach and found the mSSA application successful. Petersen and Weinberg (2025) provided a computer software for a similar basis function expansion and mSSA application for discovering new dynamical correlations.

Solar and Stellar Astrophysics

Le Mouël et al. (2025) conducted a research study on the solar magnetic cycle and the impacts of planetary motions on it, and through their analysis, they also applied SSA to sunspot number (since 1750) and terrestrial length-of-day (since 1780) records. Their separate results included a shared trend component and 11 oscillatory components.
Shen et al. (2025) also worked on sunspot numbers, and they also worked on the F10.7 index (Solar flux at 10.7 cm wavelength, radiowave calculated for 1 astronomical unit distance) with the Iterative Oblique SSA (IOSSA) technique. They obtained periodic components for each, which are mostly in good agreement.
Shirafkan et al. (2025) had a curious framework for length-of-day (LOD) prediction via Monte Carlo SSA (MCSSA, Allen and Smith, 1996) and Autoregressive-Moving Average (ARMA) methods. They feed LOD timeseries to MCSSA first to retrieve oscillations, and the difference between the reconstructed signals and original signals are modeled with ARMA later on. They reported improvement in both the short-term and long-term forecast of LOD values with this novel method.

Sajadian and Asadi (2025) worked with Transiting Exoplanet Survey Satellite (TESS) lightcurve data of 17 known double white dwarf systems. After denoising them with SSA, 6 of these systems yielded periodic signals noticeable by the Lomb-Scargle periodogram later. They evaluated the results with simulated pure noise periodograms in the same frequency and false alarm probability metric.

Earth-Planetary Astrophysics

Guessoum et al. (2025) employed SSA for predicting earth orientation parameters (EOPs)[1]. In their framework of a 1D convolutional neural network (CNN) prediction of EOP, they first used EOP to separate deterministic components and residuals and feed them to the 1D-CNN, then, with the effective angular momentum time series of atmospheric, oceanic, and hydrological angular momentum, the predicted the EOP.
Katzenberger (2025) was working on Monsoon hysteresis and atmospheric memory, and used SSA to smooth the data in chosen window-lengths. To elaborate, SSA was applied to different parameters in the chosen window length, and the first component was retrieved as the smoothed version.
Malkin et al. (2025) utilized a parametric and non-parametric (SSA) approach to gap-fill a 2-year-long period in polar motion time series, and even though the results of both methods were in agreement with each other within pole coordinate results of the International Earth Rotation and Reference Systems Service (IERS) C01 series, SSA was preferred as a more complete PM model basis.

1 Irregularities in earth rotation, examples are polar motion, length of day, and precession-nutation corrections

Özdemir et al. (2025) applied mSSA to GNSS time series of ground motion for the North Anatolian Fault. They also filled the gaps between the time-series data with mSSA iteratively in the 30-day time window after linearly interpolating them, using stations' own noise dynamics. For the actual slow slip event detection, gap-filled data was fed to SSA in 5, 10, 15, 20, 25, and 30-day time windows. They combined the first component from all these by taking their mean. In other words, SSA extracted a trend.

High-Energy Physics

Peñil et al. (2025) studied a blazar case and its stochastic flares to see their impact on periodicity determination. They created a model of a sinusoidal signal with parameters selected according to Peñil et al. (2022), contaminated it with red and Gaussian noise, and injected flares. They used the same methods on real use cases. They used Lomb-Scargle periodogram, continuous wavelet transformation, and phase-dispersion minimization, but the SSA they proposed performed better than them in flare-affected data. They also applied sigma-clipping, which yielded comparable results to SSA, but that method also introduced gaps in the lightcurve. Peñil et al. (2025-II) studied the impact of gaps in the lightcurves on the results of Lomb-Scargle periodogram, Phase-dispersion minimization, and SSA with random gaps, annual variability with random gap distribution, and annual variability with periodic gap distribution. The SSA they used (Golyandina & Zhigljavsky, 2020) does not provisionally gap fills, but construct a weighted trajectory matrix, and decomposition is done with weighted singular value decomposition.

In the end, a missing data fraction below 50 % permits the classical SSA use, but seasonal observational gaps of 1 year has a risk of spurious periodicity detection. Furthermore, when a purely noise light curve was applied, SSA with a window length of 20 % of the total LC span yielded the best results among other window length ratios of 30 % and 40 %. In the same year (2025) another paper from similar people (Rico et al. 2025) made a systematic periodicity and trend search on Fermi-Large Area Telescope (LAT)-detected 494 sources' lightcurves with SSA and identified 46 candidates (21 known and 25 new discoveries of this study) for quasi-periodic gamma-ray emission blazars.

Instrumentation – Methods

Shi et al. (2025) developed the Instantaneous Phase Discontinuity method in MATLAB to denoise magnetic interference without disrupting the natural signal integrity. The suite of methods they utilized also included a classical SSA method.

Hoffman et al. (2025) used multichannel SSA to fill gaps to increase the data quality of the Korean Pathfinder Lunar Orbiter (KPLO) magnetometer (KMAG) instrument on the together with a suite of other algorithms that removes stray magnetic fields and corrects low-frequency trends. Specifically for the mSSA case, the method extracts the significant components from each side of a gap, and makes both forward and backward projections, and combines them with a weighted approach (dual projection scheme (Hassani and Mahmoudvand, 2013)).

Overview

From these studies, we can see an extensive use of multichannel SSA followed by gap-filling with SSA to estimate the missing parts. Probably due to the space constraints, we did not see specific statistical properties and separability discussions over signal and noise in the researchers' datasets, and oblique SSA was only applied once. Nevertheless, the central aim was generally denoising the data or separating the noise from the signal for better periodicity estimation, which was reported to be successful for their cases.

SSA Theoretical Bibliography

Allen, M. R., & Smith, L. A. (1996). Monte Carlo SSA: Detecting irregular oscillations in the Presence of Colored Noise. Journal of Climate, 9(12), 3373-3404. https://doi.org/10.1175/1520-0442(1996)009

Golyandina, N., Nekrutkin, V., & Zhigljavsky, A.A. (2001). Analysis of Time Series Structure: SSA and Related Techniques (1st ed.). Chapman and Hall/CRC. https://doi.org/10.1201/9780367801687

Golyandina, N., & Shlemov, A. (2013). Variations of singular spectrum analysis for separability improvement: non-orthogonal decompositions of time series. arXiv preprint arXiv:1308.4022.

Golyandina, N., & Zhigljavsky, A. (2020). Singular Spectrum Analysis for Time Series. Germany: Springer Berlin Heidelberg.

Thekkeppattu, J. N., Trott, C. M., & McKinley, B. (2023). Singular spectrum analysis of time series data from low-frequency radiometers, with an application to SITARA data. Monthly Notices of the Royal Astronomical Society, 520(4), 6040-6052.

2025 Bibliography of Astronomy Studies utilized SSA

Arora, A., Garavito-Camargo, N., Sanderson, R. E., Weinberg, M. D., Petersen, M. S., Varela-Lavin, S., Gómez, F. A., Johnston, K. V., Laporte, C. F. P., Shipp, N., Hunt, J. A. S., Besla, G., Darragh-Ford, E., Panithanpaisal, N., Daniel, K. J., & EXP Collaboration. (2025). Shaping the milky way: The interplay of mergers and cosmic filaments. \apj, 988(2), 190. https://doi.org/10.3847/1538-4357/ade30d

Guessoum, S., Belda, S., Modiri, S., Karbon, M., Ferrándiz, J. M., Śliwińska-Bronowicz, J., & Schuh, H. (2025). Joint short-term prediction of polar motion and length of day with multi-task deep learning methods. Earth, Planets and Space, 77(1), 25. https://doi.org/10.1186/s40623-025-02150-8

Hassani, H., & Mahmoudvand, R. (2013). Multivariate singular spectrum analysis: A general view and new vector forecasting approach. International Journal of Energy and Statistics, 1(01), 55-83.

Hoffmann, A. P., Park, H., Jo, W., Jin, H., Moldwin, M. B., Zesta, E., & Garrick-Bethell, I. (2025). Enhancing magnetic field analysis on the kmag instrument: Applying waic-up for spacecraft interference removal and interpolating data gaps. Earth and Space Science, 12(11), e2025EA004427. https://doi.org/10.22541/essoar.174558993.34462664/v1

Katzenberger, A. (2025). Anjakatzenberger/monsoon_hysteresis_reveals_atmospheric_memory: Codes for publication 'monsoon hysteresis reveals atmospheric memory' (Version v1.0) [Computer software]. Zenodo. https://doi.org/10.5281/zenodo.15260911

Le Mouël, J.-L., Courtillot, V., Kossobokov, V., Gibert, D., Lopes, F., Boulé, J.-B., & Zuddas, P. (2025). On the planetary forcing of the Solar dynamo: Evidence from a Lagrangian framework. arXiv E-Prints, arXiv:2511.18939. https://doi.org/10.48550/arXiv.2511.18939

Malkin, Z., Golyandina, N., & Olenev, R. (2025). Filling the gap in the IERS C01 polar motion series in 1858.9-1860.9. Journal of Geodesy, 99(7), 53. https://doi.org/10.1007/s00190-025-01978-y

Özdemir, A., Jara, J., Doğan, U., Jolivet, R., Çakir, Z., Nocquet, J.-M., Ergintav, S., & Bilham, R. (2025). Detecting millimetric slow slip events along the north anatolian fault with gnss. \grl, 52(10), e2024GL111428. https://doi.org/10.22541/essoar.173193625.52928746/v3

Peñil, P., Torres-Albà, N., Rico, A., Ajello, M., Buson, S., & Adhikari, S. (2025). Distortions in periodicity analysis of blazars: The impact of flares. \mnras, 539(2), 993–1014. https://doi.org/10.1093/mnras/staf482

Peñil, P., Ajello, M., Buson, S., Domínguez, A., Westernacher-Schneider, J. R., & Zrake, J. (2022). Evidence of Periodic Variability in Gamma-ray Emitting Blazars with Fermi-LAT. arXiv preprint arXiv:2211.01894.

Peñil, P., Torres-Albà, N., Rico, A., Buson, S., Ajello, M., Domínguez, A., & Adhikari, S. (2025). Distortions in periodicity analysis of blazars ii: The impact of gaps. \mnras. https://doi.org/10.1093/mnras/staf1842

Petersen, M., & Weinberg, M. (2025). EXP: nbody EXPansion code [Computer software].

Rico, A., Domínguez, A., Peñil, P., Ajello, M., Buson, S., Adhikari, S., & Movahedifar, M. (2025). Singular spectrum analysis of Fermi-LAT blazar light curves: A systematic search for periodicity and trends in the time domain. Åp, 697, A35. https://doi.org/10.1051/0004-6361/202452495

Sajadian, S., & Asadi, A. (2025). Probing periodic trends in the tess light curves of the seventeen known double white dwarf systems. The Astronomical Journal, 170(3), 163. https://doi.org/10.3847/1538-3881/adf0f6

Shen, Y., Zhao, C., Li, P., Hu, M., Zhang, B., & Li, W. (2025). Multiscale periodic analysis of sunspot number data and F10.7 index. Advances in Space Research, 75(12), 8880–8896. https://doi.org/10.1016/j.asr.2025.03.064

Shi, F., Zeng, L., Fu, Y., Zeren, Z., Liu, D., & Cao, J. (2025). Instantaneous phase discontinuity: An innovative method for time-frequency overlap signal separation in denoising in situ magnetic field data. Journal of Geophysical Research (Space Physics), 130(11), e2025JA034093. https://doi.org/10.1029/2025JA034093

Shirafkan, S., Sharifi, M. A., Modiri, S., Belda, S., Khazraei, S. M., & Amiri-Simkooei, A. (2025). Short- and long-term prediction of length of day time series using a combination of MCSSA and ARMA. Earth, Planets and Space, 77(1), 35. https://doi.org/10.1186/s40623-025-02166-0

Tavangar, K., & Johnston, K. (2025). Correlating phase spirals across the galactic disk from a satellite perturber. American Astronomical Society Meeting Abstracts #245, 245, 125.02.