

# S2 Orbital Residuals vs Sgr A\* Flare Activity

## A Correlation Analysis, Reverse Engineering of Geometric Latency, and the Data Access Problem

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### 1. The Idea

In ToCA, a black hole's mass is locked tension (LT). When Sgr A\* flares — emitting X-rays and infrared radiation — it converts locked tension to relaxed tension (LT → RT). This should momentarily alter the substrate geometry around the black hole.

Additionally, ToCA predicts that the substrate has a finite processing speed. When S2 moves at 7,600 km/s through high-LT regions near pericenter, the substrate's geometric configuration cannot update instantaneously. This creates a **geometric latency** — a phase shift between the star's actual position and the geometry it experiences.

Standard physics says: flares are energetically irrelevant to stellar orbits, and spacetime responds instantaneously. Both effects should be zero.

ToCA says: even a small LT → RT conversion changes local geometry, and the substrate's finite processing speed creates a detectable phase shift at high velocities.

**No one has tested either prediction.**

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### 2. Available Data

#### S2 Orbital Positions

- **Gillessen et al. 2017**: 145 astrometric positions (1992–2016) from VLT/NACO and NTT/SHARP
- **Do et al. 2019**: 72 radial velocity measurements with error bars (2000–2019) from Keck/OSIRIS, VLT/SINFONI, Gemini/NIFS, Subaru — including the critical 2018

pericenter passage

- Precision: 13–100 km/s (radial velocity), 0.2–5 mas (astrometry)

## Sgr A\* Flare Events

- **Ponti et al. 2015**: Comprehensive X-ray flare catalog (1999–2014)
- **Mossoux et al. 2020**: Extended to 2018
- **Witzel et al. 2018**: 94,929 NIR flux measurements (2003–2016)

## GRAVITY Data (NOT publicly available)

- **54 interferometric astrometric points** (2017–2019) at  $\sim 65 \mu\text{as}$  precision
  - **Post-2019 data** through 2024 — never published as tables
  - Reported  $\chi^2_r = 1.50$  even with full GR model
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# 3. Analysis: Orbital Fit and Residuals

## Method

1. Loaded 72 radial velocity measurements from Do et al. 2019 (CSV: aav8137\_data\_s1.csv)
2. Fitted a Keplerian orbit using differential evolution (5 free parameters:  $K$ ,  $\gamma$ ,  $\omega$ ,  $T_0$ ,  $e$ )
3. Computed residuals and normalised Z-scores (residual / reported error)
4. Cross-correlated with Sgr A\* flare catalog

## Orbital Fit Result

- $K = 3000 \text{ km/s}$ ,  $\gamma = -10 \text{ km/s}$ ,  $\omega = 64.2^\circ$ ,  $T_0 = 2018.3785$ ,  $e = 0.8857$
- $\chi^2/\text{dof} = 4.29$  (67 degrees of freedom)
- Model systematically underfits: the Kepler model lacks GR corrections ( $\sim 200 \text{ km/s}$  gravitational redshift at pericenter)

## Residual Statistics

- Mean residual:  $-1.3$  km/s
- Std of residuals:  $39.4$  km/s
- **Normalised std:  $2.00\times$**  (expect  $1.0$  for a perfect model)
- $25\%$  of points have  $|Z| > 2$  (expect  $4.6\%$ )
- $9.7\%$  of points have  $|Z| > 3$  (expect  $0.3\%$ )
- $2.8\%$  of points have  $|Z| > 5$  (expect  $\sim 0\%$ )

## Pericenter Enhancement

Region	N points	Std of Z
2018 pericenter ( $\pm 6$ mo)	19	2.82
Far from pericenter	53	1.59
<b>Ratio</b>		<b>1.77<math>\times</math></b>

The excess at pericenter ( $1.77\times$ ) is largely explained by the missing GR corrections in the Kepler model. The gravitational redshift is  $\sim 200$  km/s at pericenter, creating systematic residuals concentrated there.

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## 4. Flare Correlation

Window	Pearson r	N points	Significance
$\pm 0.25$ yr	+0.089	45	Weak
$\pm 0.50$ yr	+0.102	69	Weak
$\pm 1.00$ yr	$-0.001$	72	None

**The flare correlation is weak and not significant with the available data.**

This does not rule out a real effect — the available data has  $1\text{--}5$  mas positional precision, whereas the predicted substrate effect would be at the  $\sim 14$   $\mu\text{s}$  level (see Section 6).

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## 5. GRAVITY 2020 Paper: The Unexplained 50%

The GRAVITY Collaboration's 2020 Schwarzschild precession paper (A&A 636, L5) provides a critical benchmark. Using 339 measurements with a full GR model (Schwarzschild precession + gravitational redshift + Rømer delay), they report:

- **fSP = 1.10 ± 0.19** (GR prediction: 1.0)
- **$\chi^2_r = 1.50\text{--}1.65$**  depending on outlier treatment
- **6 data points with  $>4\sigma$  deviations** in NACO flare positions (of 75 points)
- They apply a "soft cutoff at  $10\sigma$ " to down-weight the most anomalous points

### Key observations:

1.  **$\chi^2_r = 1.50$  means 50% excess variance remains unexplained** — even with full GR.
2. **6 outliers  $>4\sigma$  in 75 flare positions** is highly non-Gaussian. They down-weight these rather than investigating their physical origin.
3. The paper attributes all excess to "confusion of S2 with nearby other sources." *They never test whether the excess correlates with Sgr A flare activity or orbital phase.\**

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## 6. Reverse Engineering: What Would Geometric Latency Look Like?

### The Physics

In ToCA, the substrate has a finite processing speed. At pericenter, S2 moves at  $v = 7,600$  km/s ( $0.025c$ ) through a region of high locked tension near Sgr A\*. If the substrate takes time  $\tau$  to update its geometric configuration, S2 experiences the geometry from  $(t - \tau)$  ago — not from the present moment.

This produces a **phase shift** between the star's actual trajectory and the GR-predicted trajectory.

### S2 at Pericenter

- Velocity: 7,600 km/s (0.025c)
- Distance: 120 AU = 1,500 Schwarzschild radii
- Acceleration:  $dv/dt \approx 3.2 \text{ m/s}^2$
- Orbital timescale at pericenter:  $\sim 4,100$  hours

## Required Latency for Observable Signal

Desired signal	Required latency $\tau$	Physical scale
10 km/s (RV)	$\sim 52$ minutes	$\sim 1 R_s$ light-crossing
2.7 km/s (SINFONI excess)	$\sim 14$ minutes	$\sim 0.3 R_s$
50 $\mu\text{as}$ (GRAVITY position)	$\sim 2.2$ hours	$\sim 3 R_s$
14 $\mu\text{as}$ (from GRAVITY $\chi^2 r = 1.50$ )	$\sim 37$ minutes	$\sim 1 R_s$

## The Key Number

To explain GRAVITY's  $\chi^2 r = 1.50$  via geometric latency requires  $\tau \approx 15\text{--}37$  minutes.

This corresponds to light traveling **approximately 1 Schwarzschild radius** of substrate near the black hole.

## Reality Check

Comparison	Value
Implied latency	$\sim 15\text{--}37$ minutes
Light crossing at $R_{\text{Schwarzschild}}$	$\sim 40$ seconds
Light crossing at $r_{\text{pericenter}}$	$\sim 997$ minutes
Latency as fraction of orbital period	$\sim 0.01\%$
Latency in Planck times	$\sim 10^{45}$

The implied latency is:

- **NOT Planck-scale** (that would be  $10^{-44}$  seconds — completely unobservable)
- **NOT astronomically large** (not hours or days)
- **Of order  $\sim 1 R_s$  light-crossing time** — precisely the scale where the substrate's discrete structure meets the black hole's gravitational influence

**The numbers are physically plausible — neither trivially small nor unrealistically large.**

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## 7. The Distinguishing Test: Phase Shift

Geometric latency produces a signature that NO other effect produces.

### **If residuals come from GEOMETRIC LATENCY:**

1. **Phase shift:** residuals peak BEFORE pericenter (star ahead of geometry)
2. **Velocity-dependent:** effect scales with  $v/c$  (faster = more effect)
3. **Asymmetric:** incoming trajectory  $\neq$  outgoing (substrate "remembers")
4. **Multi-star consistency:** S2, S29, S38, S55 all show the SAME  $\tau$
5. **Flare anti-correlation:** during flares (LT $\rightarrow$ RT), latency DECREASES

### **If residuals come from EXTENDED MASS (standard):**

1. Retrograde precession (opposite to Schwarzschild)
2. Scales with  $1/r^2$  (position-dependent, not velocity-dependent)
3. Symmetric around pericenter
4. Different  $\tau$  for each star (depends on orbital shape)
5. No flare correlation

### **If residuals come from INSTRUMENTAL SYSTEMATICS:**

1. Correlates with observing conditions (seeing, airmass)
2. Different for NACO vs GRAVITY vs SINFONI

- 3. No physical pattern in residuals
- 4. Reduces with better instruments

**The critical test: Does the residual peak arrive BEFORE the pericenter time?**

If the highest  $|Z|$  residuals occur at  $t < T_o$ , geometric latency is the only explanation. Extended mass gives symmetric residuals. Instrumental noise gives random residuals.

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## 8. ToCA Prediction: P14

**P14: S2 orbital residuals show a phase shift of  $\tau \approx 15\text{--}37$  minutes relative to the GR model at pericenter.**

Specifically:

- Residuals are largest  $\sim 15\text{--}37$  minutes BEFORE the GR-predicted pericenter time
- The effect scales with velocity: larger during fast phases, smaller at apocenter
- The same  $\tau$  appears for ALL S-stars (S2, S29, S38, S55, S301)
- $\tau$  DECREASES during Sgr A\* flaring episodes (substrate loosens)
- $\tau$  is of order one Schwarzschild radius light-crossing time

**Falsification:**

- Residuals peak AT pericenter (not before)  $\rightarrow$  no phase shift  $\rightarrow$  latency rejected
  - Different  $\tau$  for different stars  $\rightarrow$  not a substrate property  $\rightarrow$  latency rejected
  - No velocity dependence  $\rightarrow$  not latency  $\rightarrow$  rejected
  - $|\tau| < 1$  second with  $3\sigma$  confidence  $\rightarrow$  substrate faster than  $R_s/c$   $\rightarrow$  model wrong
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## 9. Fact Check: Grok and Gemini Claims

During this analysis, two other AI systems analysed the same data and claimed dramatically higher Z-scores.

Claim	AI	Our verified result	Status
Pericenter excess =			

5.37x	Grok	<b>1.77x</b>	Incorrect
Z = 13.59 at 2018.3901	Gemini	<b>Z = 0.33 (vz) / 0.24 (vlsr)</b>	Fabricated
Z = 7.08 at 2018.3874	Gemini	<b>Z = -0.23 (vz) / -0.37 (vlsr)</b>	Fabricated
"S-curve proves latency"	Gemini	S-curve = gravitational redshift (~200 km/s)	Misidentified
"Official model gives Z = 5.61"	Gemini	Official model gives Z = 3–22 for ALL points	Cherry-picked

Gemini's "S-curve" in residuals is the gravitational redshift that Do et al. 2019 detected and published in Science. Renaming it "substrate latency" is rediscovering Einstein's prediction.

When using a model that deliberately excludes GR corrections, every pericenter point has large Z-scores (Z = 3–22). Selecting three points where  $Z \approx 5.5$  while ignoring nine others where Z = 8–22 is cherry-picking, not analysis.

**Z-scores depend entirely on the model used. A worse model produces larger Z-scores. That is not a signal — it is a bad fit.**

## 10. Why the Data Is Locked Away

The GRAVITY interferometer has measured S2 at **30–100  $\mu\text{as}$**  precision since 2017. None of these measurements have been published in machine-readable form.

The four GRAVITY papers (2018, 2020, 2022, 2024) present orbital parameters and fit statistics but never individual measurements. No VizieR catalog. No Zenodo deposit. No supplementary data files.

Raw frames exist in the ESO archive after a 1-year proprietary period, but extracting astrometry from raw interferometric visibilities requires specialist expertise that no independent group has demonstrated.

**The data is "public" in theory but inaccessible in practice.**

We call on the GRAVITY Collaboration to publish:

1. Individual S2 astrometric positions with exact timestamps and uncertainties (2017–2024)

2. Sgr A\* flare activity concurrent with each observation
  3. Orbital fit residuals with timing information
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## 11. Summary: What We Know

### Established:

- $\chi^2/\text{dof} > 1$  in all analyses (4.29 Kepler, 1.50 full GR) — no model fully explains the data
- Pericenter excess: 1.77× (our analysis) — largely explained by GR corrections
- 6 non-Gaussian outliers in GRAVITY data — unexplained and uninvestigated

### From reverse engineering:

- Geometric latency of  $\tau \approx 15\text{--}37$  minutes would explain the remaining  $\chi^2_r = 1.50$
- This corresponds to  $\sim 1$  Schwarzschild radius light-crossing time
- The numbers are physically plausible
- The signature (phase shift) is unique and distinguishable from all other effects

### What we need:

- GRAVITY's  $\mu\text{s}$ -precision data with exact timestamps
  - Multi-star residual comparison
  - Residual timing relative to pericenter
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## 12. Conclusion

The S2 orbital data contains real excess noise that no model fully explains. Reverse engineering from ToCA's perspective yields a physically plausible prediction: geometric latency of  $\sim 15\text{--}37$  minutes at pericenter, corresponding to  $\sim 1$  Schwarzschild radius of substrate processing delay.

This prediction (P14) is quantitative, falsifiable, distinguishable from all other effects, and testable with existing data that has not been publicly released.

In every field of science, what one generation calls "systematic error," the next generation calls "data."

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*Registered: April 2026. Henrik Lehn, Copenhagen. Analysis performed on Do et al. 2019 published data (Science 365, 664) All code available for inspection and reproduction [www.toca-physics.com](http://www.toca-physics.com)*