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Proper motions of dusty sources in the Milky Way's Nuclear Star Cluster

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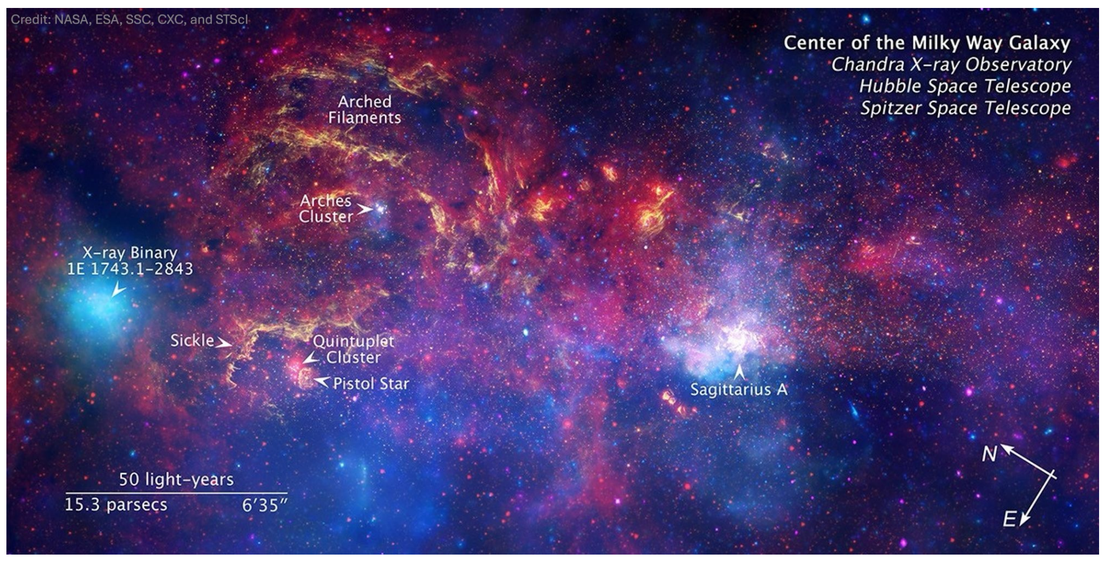
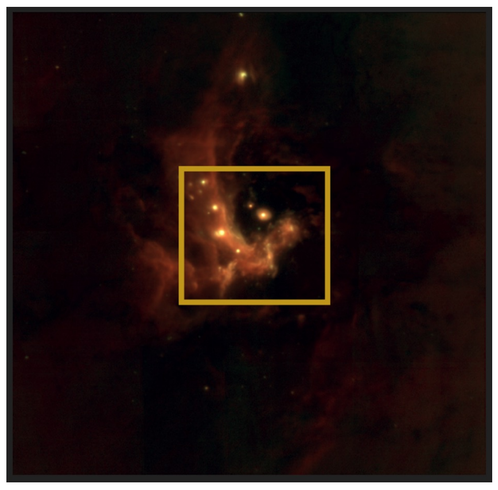
Motivation



Centre of the Milky Way: Chandra X-ray Observatory, Hubble Space Telescope and Spitzer Space Telescope.



Five inner parsecs of the GC. Several studies have already been carried out on the proper motions in the section highlighted in the yellow box.

Improving the understanding of the Galactic Centre (GC) and of the dynamical processes operating in the immediate vicinity of the central supermassive black hole (SMBH) Sgr A*.

Abstract:

In this work, stellar reference objects were used to transform multiple observations into a shared coordinate system, enabling consistent source matching and proper motion measurements.

Innovations:

- Expand to the **inner five parsecs**
- **More sources** than previous studies
- **Mid-Infrared** analysis

Data & Observation

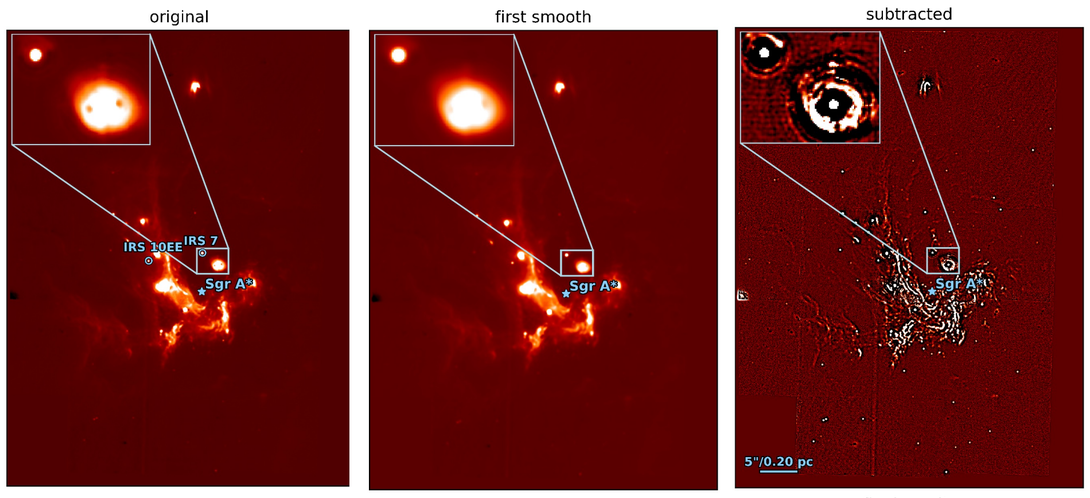
The VLT – The Very Large Telescope right after sunset.

- VLT – The **V**ery **L**arge **T**elescope
- VISIR – The **V**LT **I**mager and **S**pectrometer for mid-**I**nfra**R**ed

Year	Pixel Scale $(\frac{\text{arcsec}}{\text{px}})$	FoV of a Single Image (arcsec × arcsec)
2010	0.127	32.5 × 32.5
2016	0.045	38.0 × 38.0
2018	0.045	38.0 × 38.0
2022	0.045	38.0 × 38.0

Details of the observations at each epoch.

High-Pass Filtering



- Prevents overlapping of the PSF wings.
- Distinguishes between real and artificial sources.
- Separation of individual signals.
- Highlights structures close to the telescope's detection limit

Smooth-subtract-smooth with a Gaussian filter:

- First smoothing: FWHM of IRS 7 and IRS 10EE.
- Second smoothing: diffraction limit of the images.

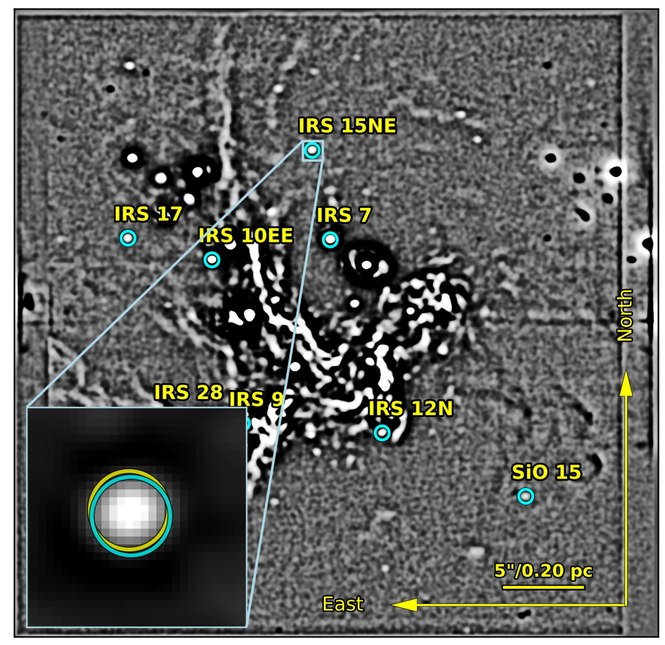
Cropped image from 2022. First row: unprocessed image, first smooth, smooth-subtract image. Second row: result. Smoothing function: Gaussian filter.

Methods

Astrometric Calibration

- Extract position of Calibration Stars.
  - *DPUSER* and *SAOImageDS9*
- Setting a reference frame.
  - 2022
- Motion of the Calibration Stars for x and y direction respectively:

$$d_* = t_{\text{dif},\zeta} * v_*;$$
$$*\in \{\text{starlist}\}, \zeta \in \{\text{year}\}$$
$$\text{pos}_{*,\text{new}} = \text{pos}_{*,\text{old}} + d_*$$



Example for movement of the calibration stars for the case 2016 – 2022. Zoom shows the SiO maser star IRS 15NE.

Star	$v_{\text{R.A.}}$ $(\frac{\text{mas}}{\text{yr}})$	$\text{d}v_{\text{R.A.}}$ $(\frac{\text{mas}}{\text{yr}})$	$v_{\text{Decl.}}$ $(\frac{\text{mas}}{\text{yr}})$	$\text{d}v_{\text{Decl.}}$ $(\frac{\text{mas}}{\text{yr}})$
IRS 15NE	-1.925	0.019	-5.802	0.028
IRS 7	-0.002	0.044	-4.665	0.093
IRS 12N	-1.122	0.021	-2.834	0.024
IRS 9	3.080	0.016	2.291	0.033
IRS 10EE	0.070	0.017	-1.984	0.020
IRS 17	-1.073	0.165	-1.059	0.240
IRS 28	1.548	0.050	-5.493	0.088
SiO 15	-2.562	0.058	0.738	0.068

Proper motions for the calculation of the motion of the calibration stars from Darling et al. (2023) [1].

Coordinate Transformation & Proper Motion Calculation

- Polynomial Transformation:

$$P\colon \mathbb{R}^2 \to \mathbb{R}^2\colon \begin{pmatrix} x \\ y \end{pmatrix} \mapsto \begin{pmatrix} P_2(x,y) \\ P_2(x,y) \end{pmatrix}$$

- Detect all sources with *photutils.detection.DAOStarFinder.*
- Use the transformation matrix.
- Calculate the proper motions with a weighted linear fit.
- Position uncertainties:
  - Estimated error caused by *DAOStarFinder*
  - Jackknife method

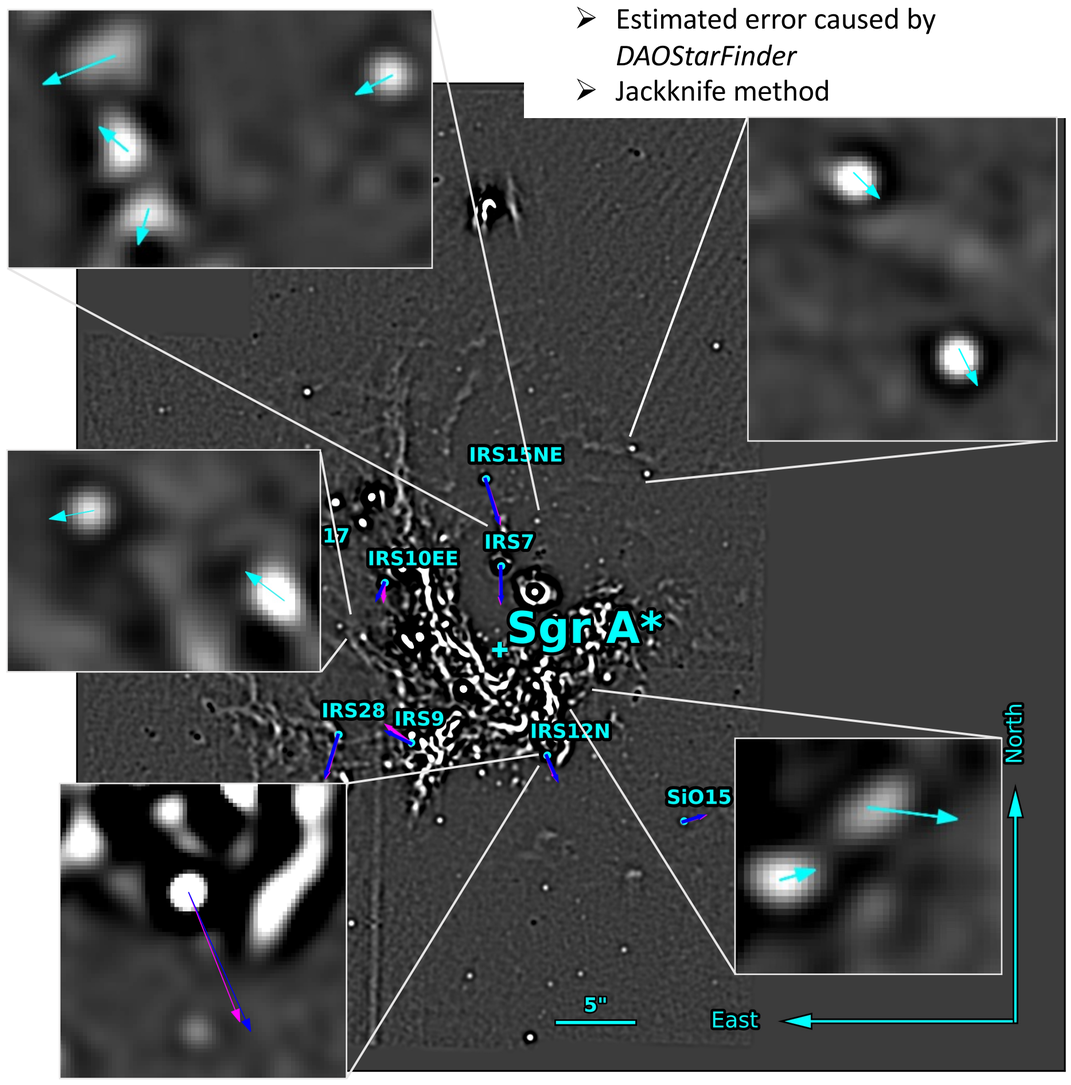


Image from 2022 with the calibration stars proper motions from Darling et al. (2023) [1] (pink) in comparison with the new calculated ones (blue) and some random proper motion examples (cyan).

Future steps

- Improve the error calculation.
- Classify the individual sources with help of the sources from Darling et al. (2023) [1] and Bhat et al. (2022) [2].

References

[1] J. Darling, J. Paine, M. J. Reid, K. M. Menten, S. Sakai, and A. Ghez, ApJ, 2023, 955, 2, 117.
[2] H. K. Bhat, N. B. Sabha, M. Zajaček et al., ApJ, 2022, 929, 2, 178.

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