Sagittarius A*: Stellar Observations and Analysis

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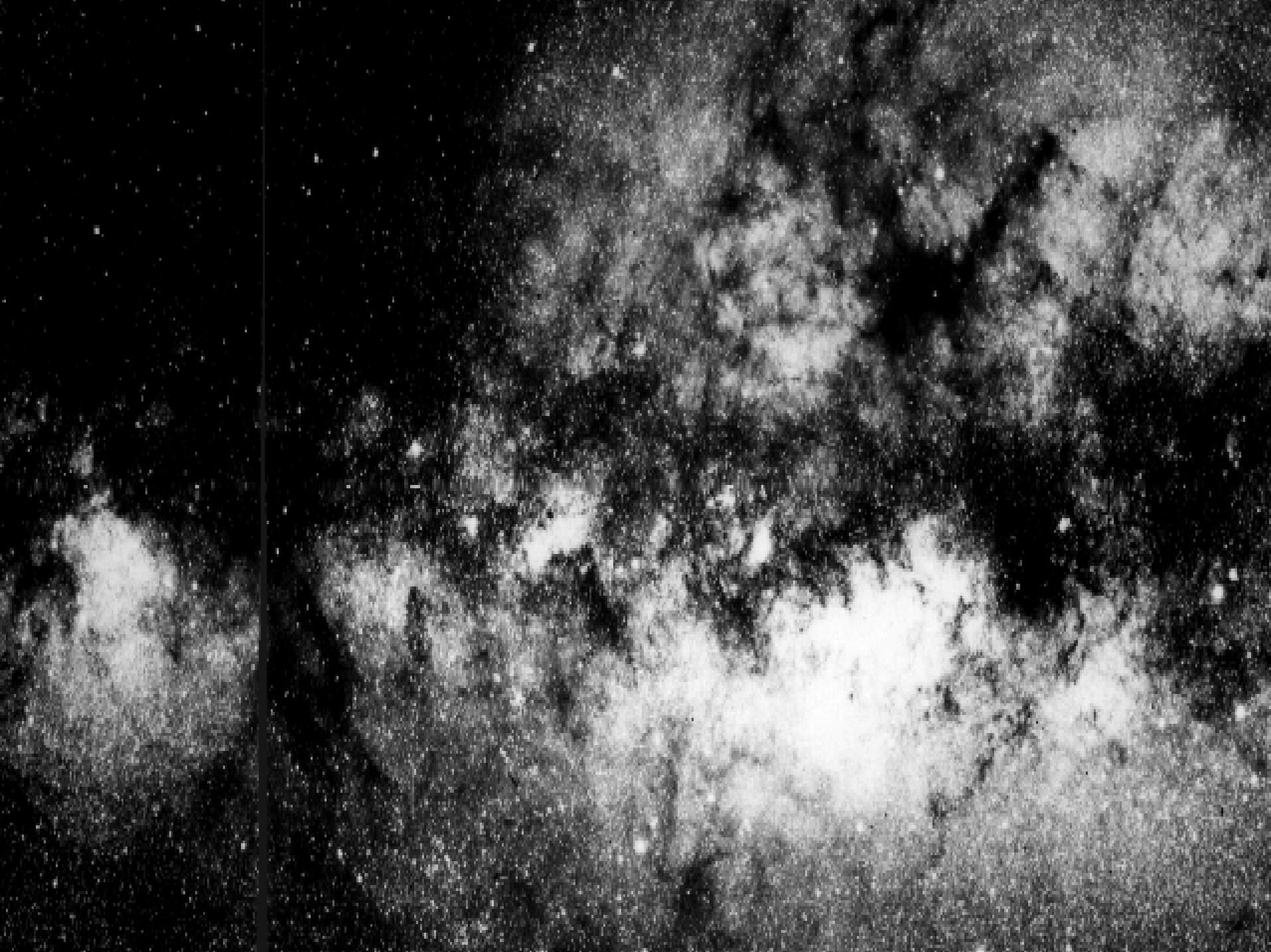
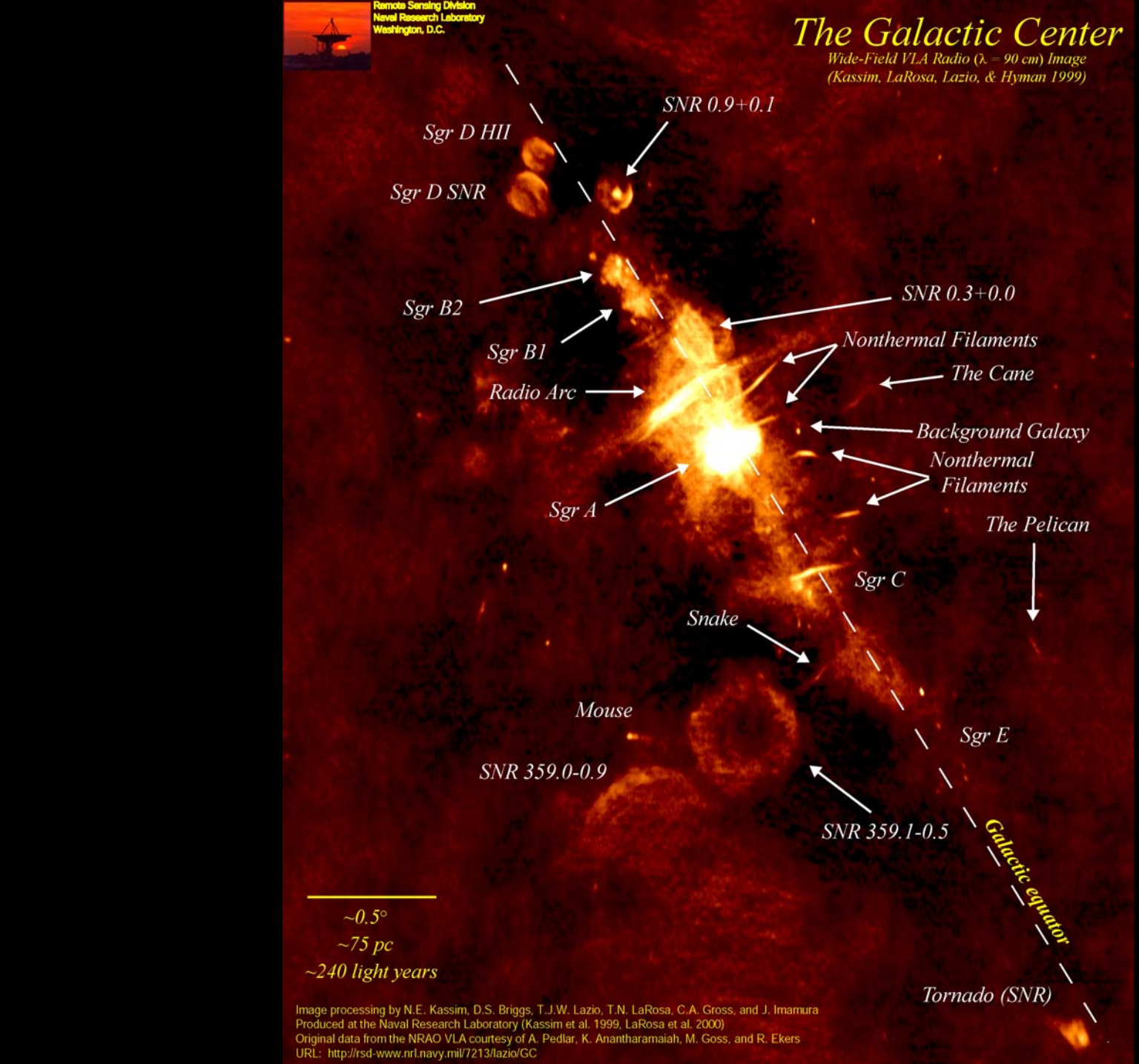
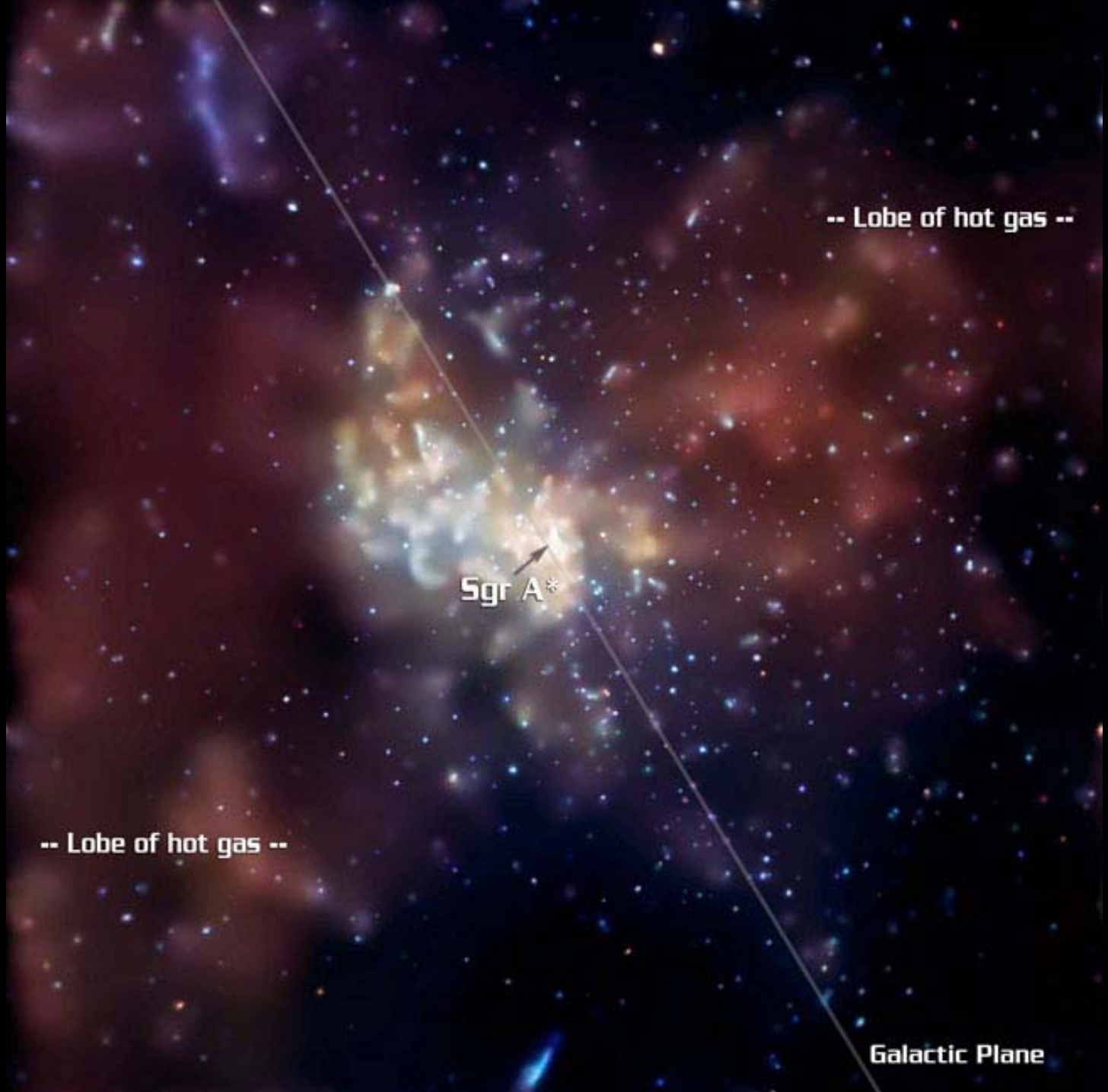
Overview

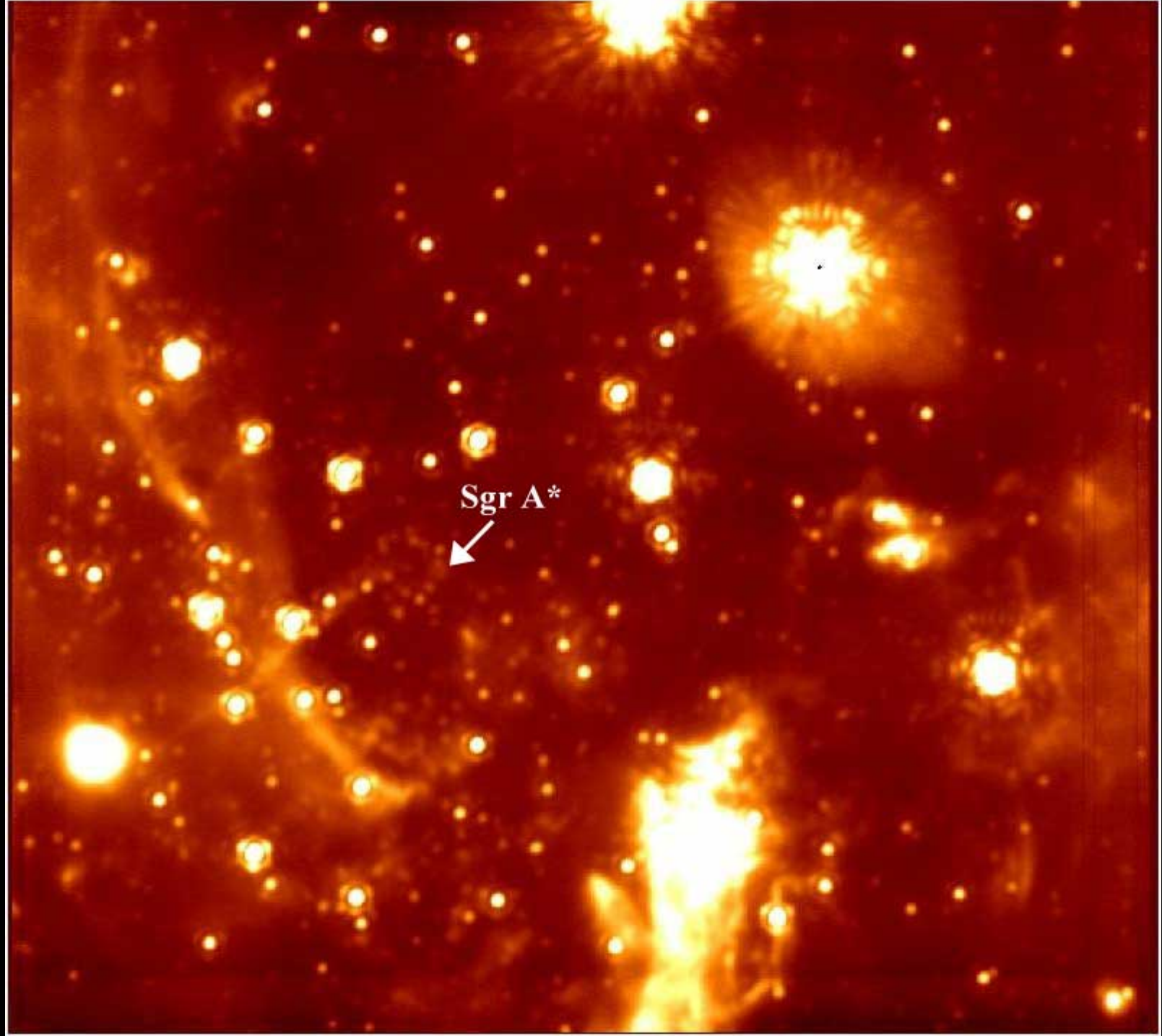
- **General View of Galactic Center**
  - **Proposed Models for SgrA***
- **Observational Data**
  - **Andrea Ghez**
  - **Data Reduction**
  - **Stellar Orbits: Ghez et al.**
  - **Orbit of S2 with NAOS-CONICA**
- **Analysis**
  - **Ghez et al.**
  - **S2**
- **Future**
- **Conclusion**

Views of the Galactic Center:
Radio
X-ray
Infrared




Remote Sensing Division
Naval Research Laboratory
Washington, D.C.
The Galactic Center
Wide-Field VLA Radio (λ = 90 cm) Image
(Kassim, LaRosa, Lazio, & Hyman 1999)
SNR 0.9+0.1
Sgr D HII
Sgr D SNR
Sgr B2
Sgr B1
Radio Arc
SNR 0.3+0.0
Nonthermal Filaments
The Cane
Background Galaxy
Nonthermal Filaments
Sgr A
The Pelican
Sgr C
Snake
Mouse
Sgr E
SNR 359.0-0.9
SNR 359.1-0.5
Galactic equator
~0.5°
~75 pc
~240 light years
Tornado (SNR)
Image processing by N.E. Kassim, D.S. Briggs, T.J.W. Lazio, T.N. LaRosa, C.A. Gross, and J. Imamura
Produced at the Naval Research Laboratory (Kassim et al. 1999, LaRosa et al. 2000)
Original data from the NRAO VLA courtesy of A. Pedlar, K. Anantharamaiah, M. Goss, and R. Ekers
URL: http://rsd-www.nrl.navy.mil/7213/lazio/GC


-- Lobe of hot gas --
Sgr A*
-- Lobe of hot gas --
Galactic Plane

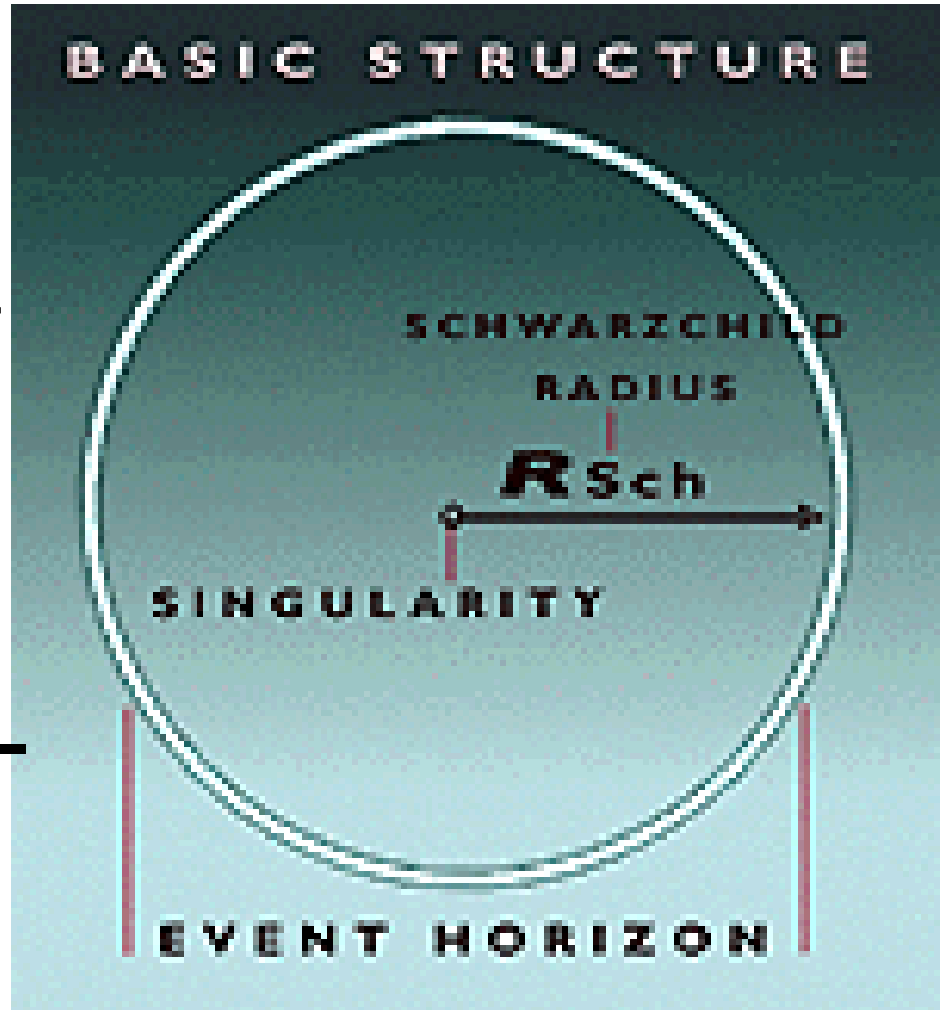

Sgr A*

Proposed Models for SgrA*

- 1. Supermassive Black Hole
  - At least 10^5 M_s
- 2. Fermion Ball Model*
  - Condensation of heavy (~17 keV) , degenerated fermions
- 3. Cluster of Dark Astrophysical Objects
  - Neutron stars or stellar black holes
- 4. Ball of Bosons

How do we prove it's a supermassive black hole?

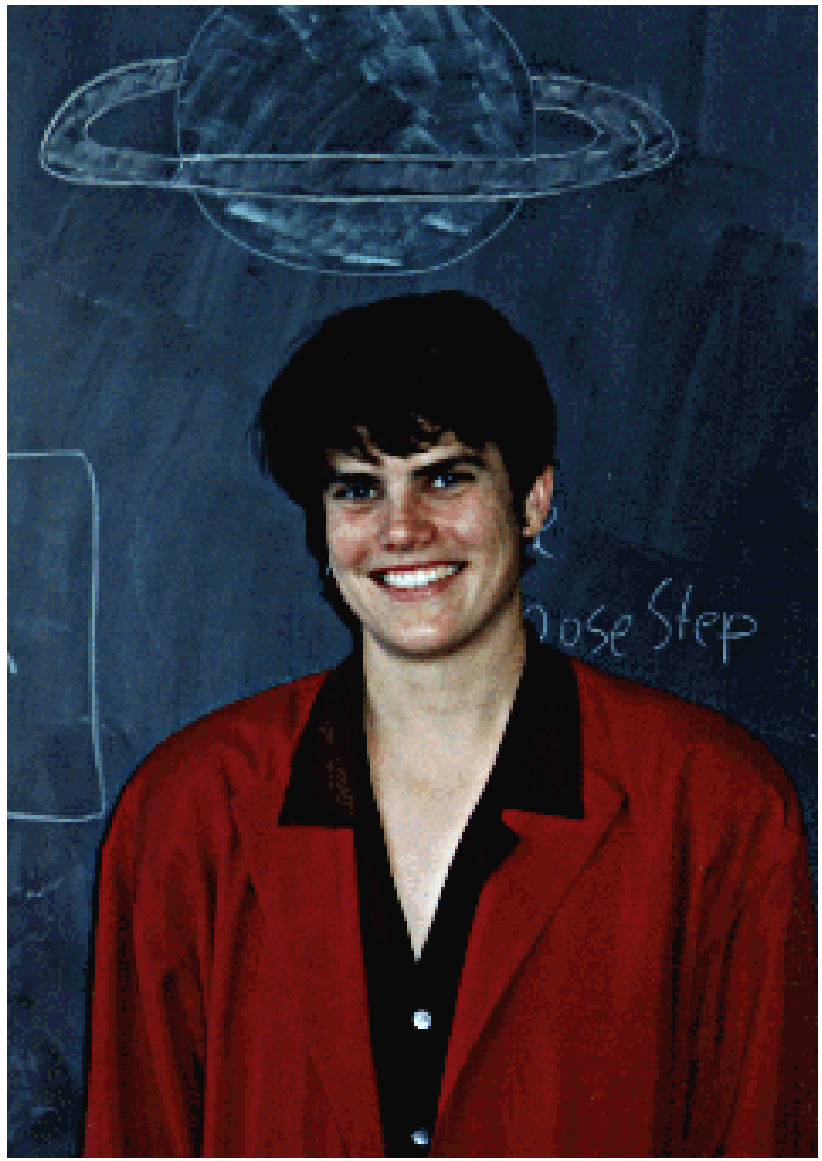
- Mass – for supermassive at least 10^5 M_S
- Size – Very Dense
- **Event Horizon – only way to prove 100%**



Observational Data

Professor Andrea Ghez

- Professor of Astronomy at UCLA
- UCLA Galactic Center Group: Principal Investigator
- Tracking stars for 14 years
- 100 stars analyzed



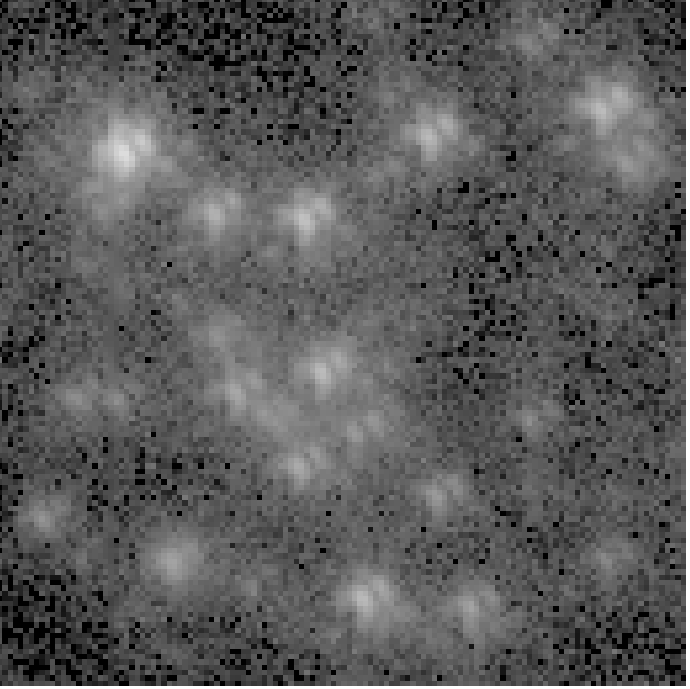
W. M. Keck Observatory

- Two 10m telescopes
- Largest Optical + Infrared
- Hawaii

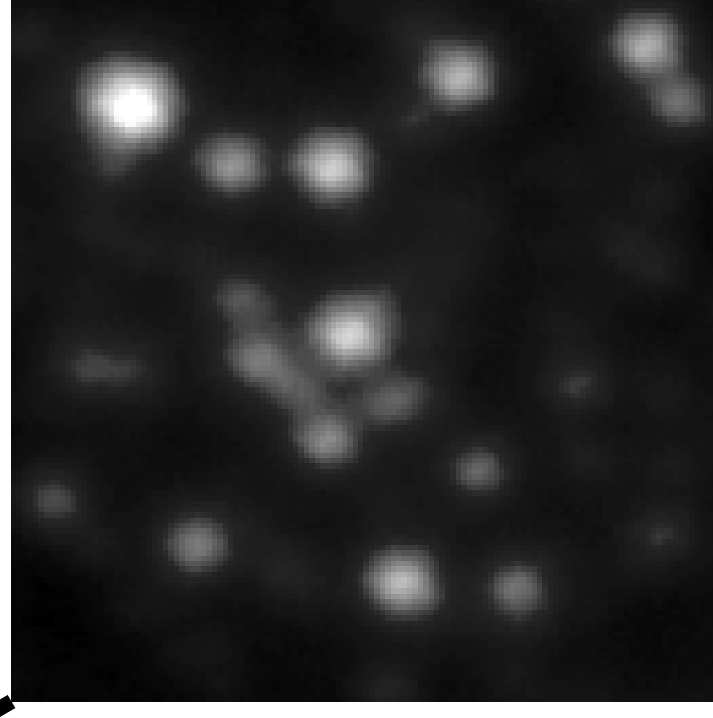
NAOS-CONICA at VLT YEPUN

ESO PR Photo 35l/01 (3 December 2001)

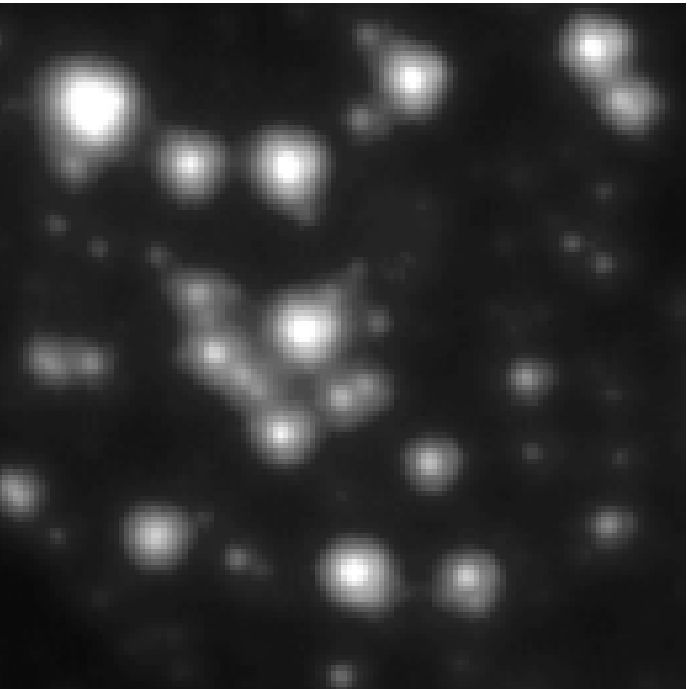
Data Reduction: Speckle Inferometry



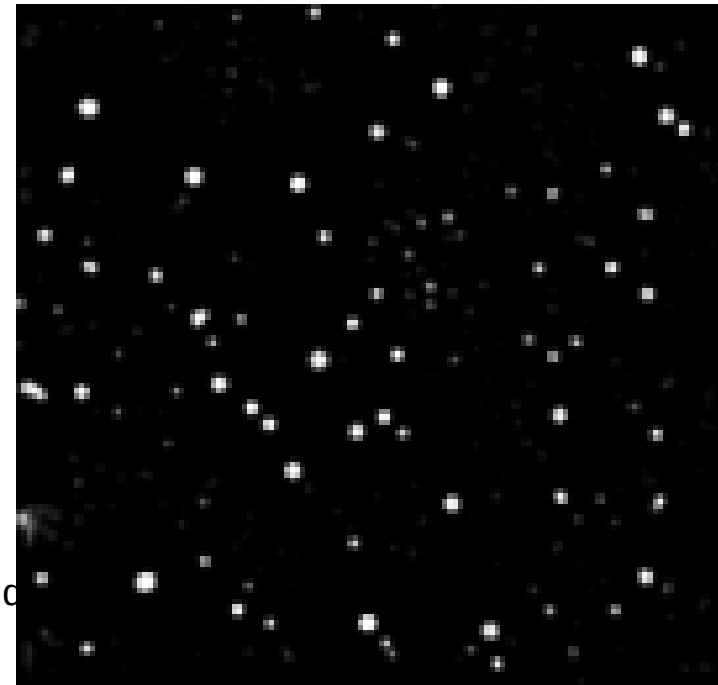
1. Average all short exposures into one long exposure



2. “Shift-and-Add” using brightest star as reference

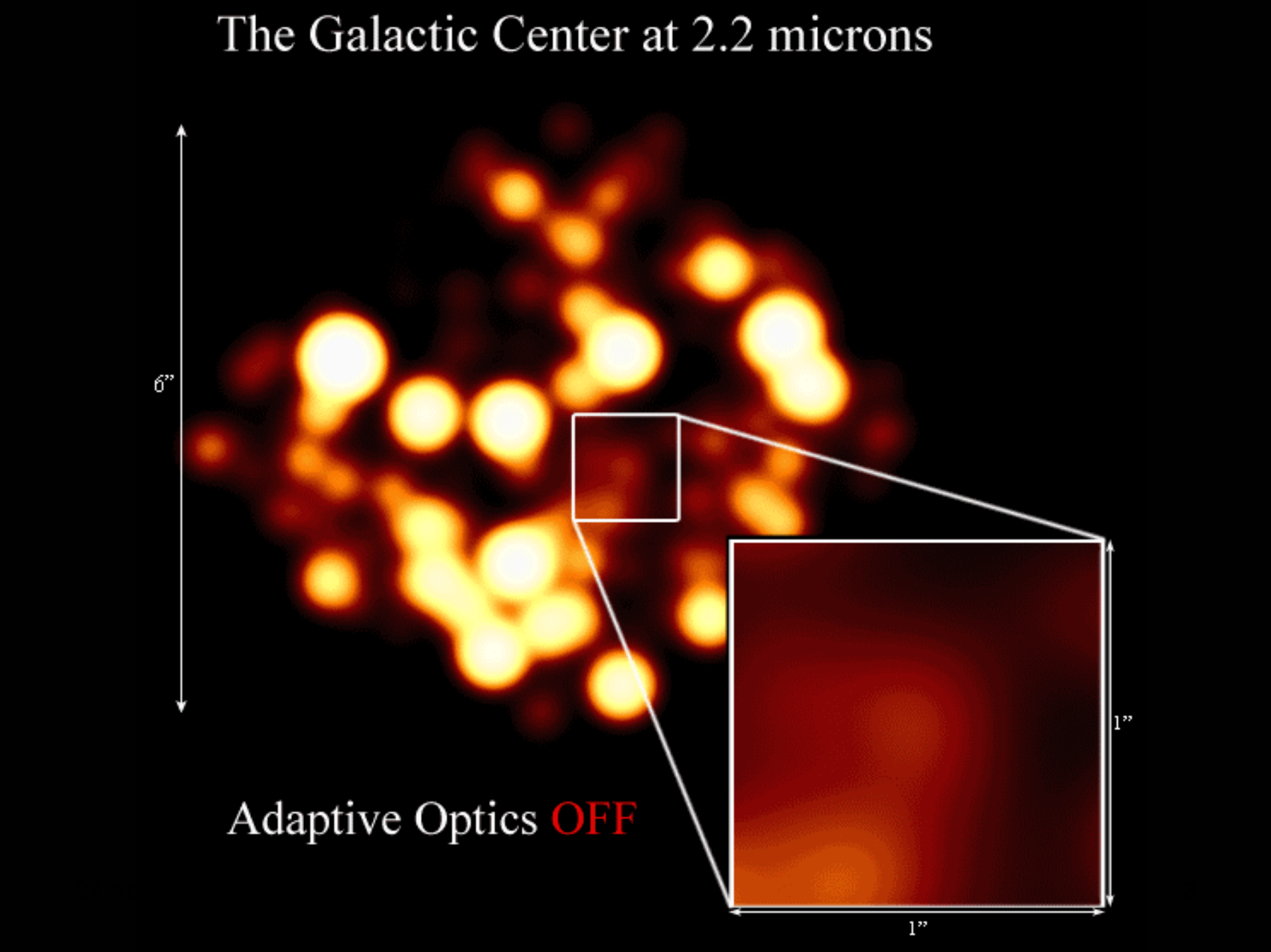


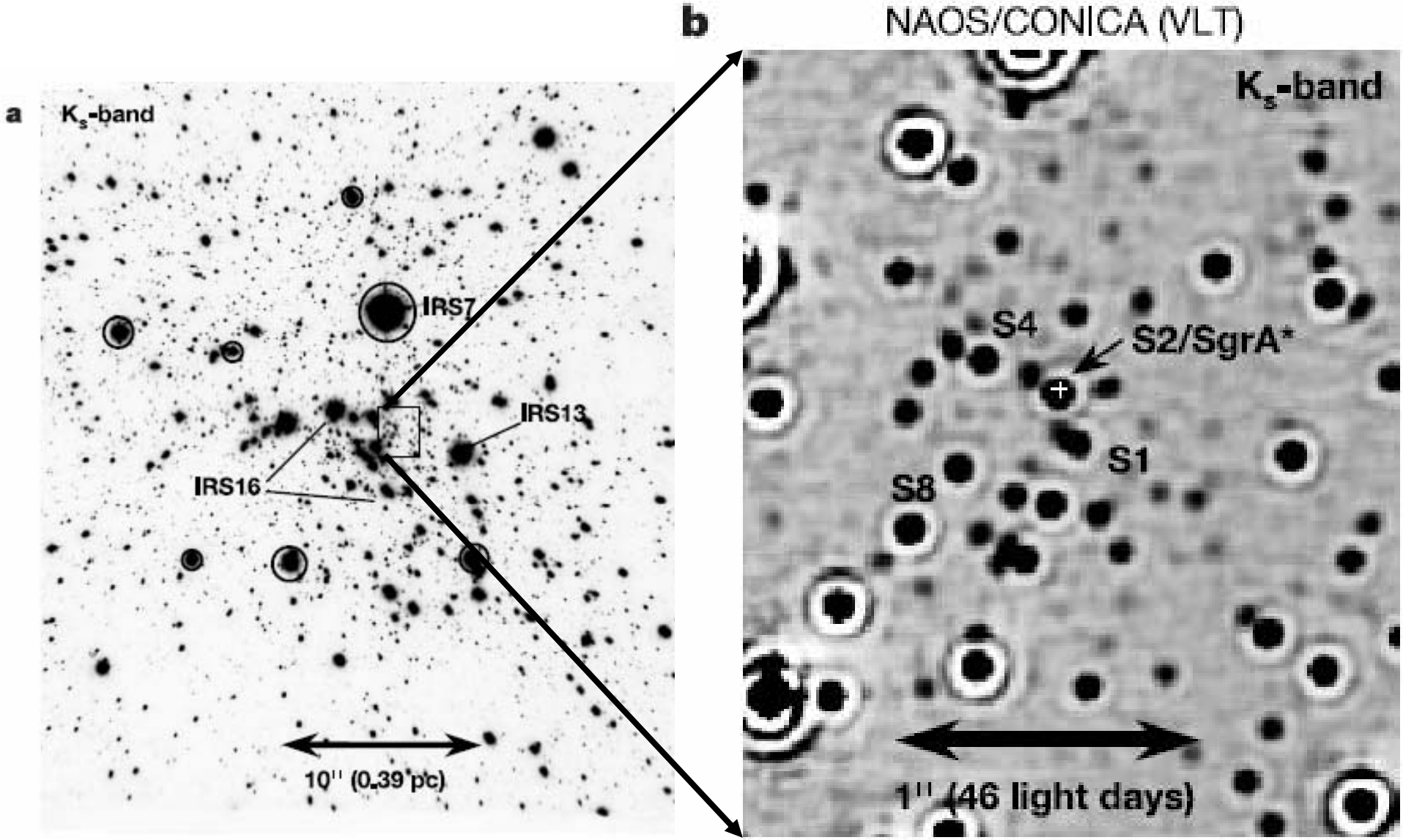
3. Remove Point Spread Function



SgrA*: Stellar Observations and Analysis- Brett Chizinski

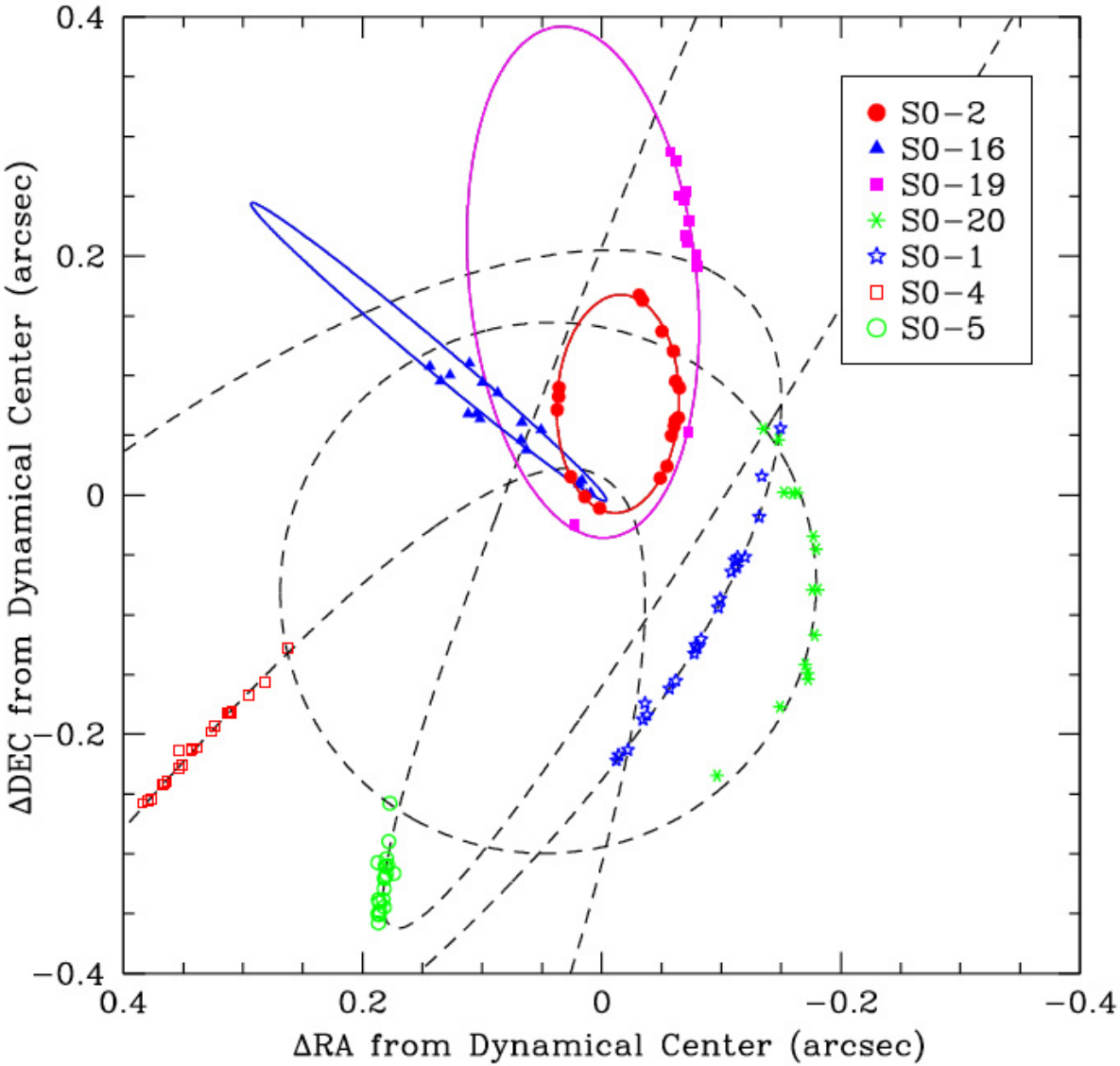
Data Reduction: Adaptive Optics


The Galactic Center at 2.2 microns
6”
1”
1”
Adaptive Optics OFF



(Schodel *et al.)*

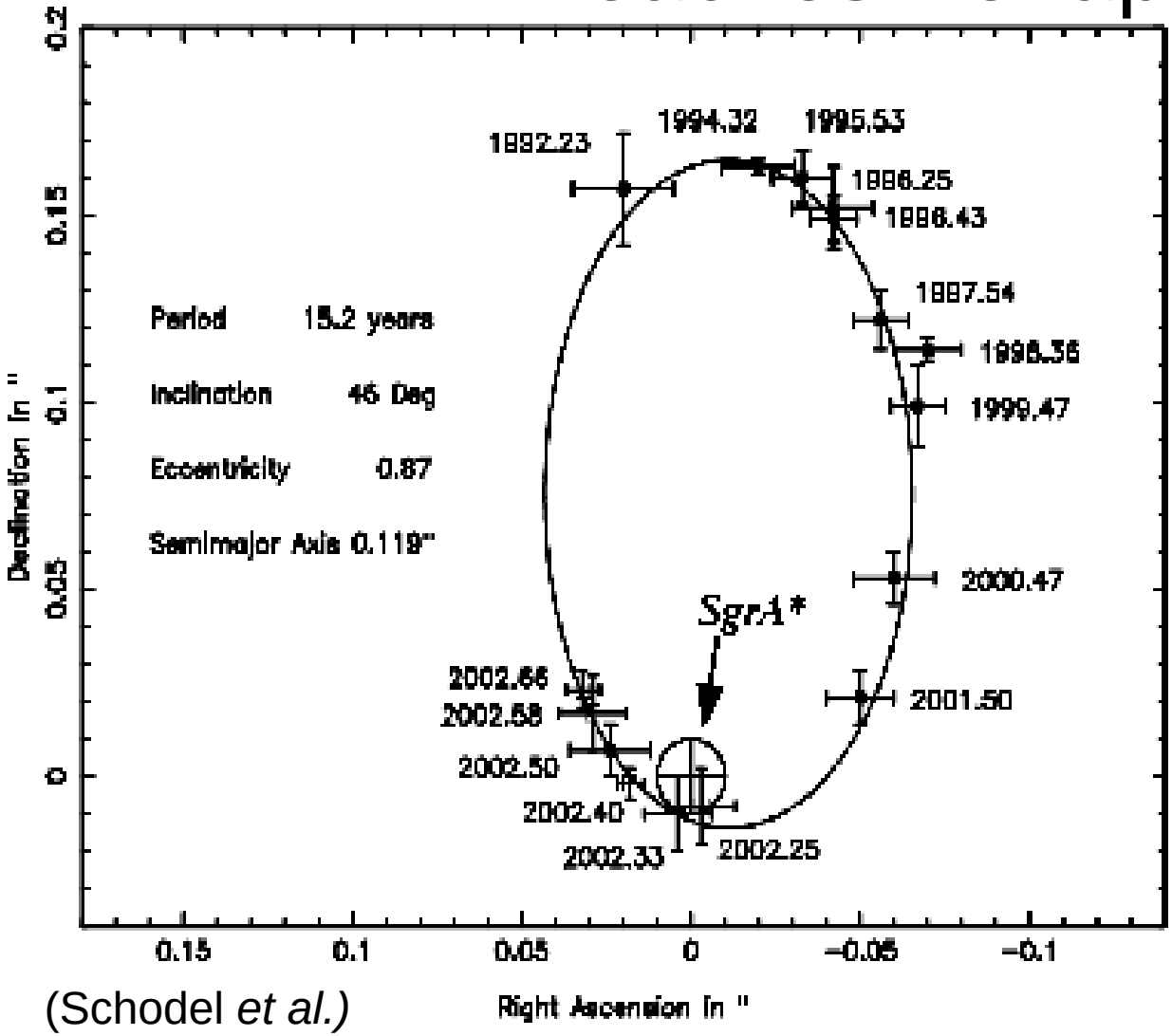
Stellar Orbits: Ghez et al.



Analysis: Ghez et al.

- Velocities measured by red-shift
- 7 orbits deemed accurate for simultaneous fitting
- Fitted orbits infer center point mass of **(3.7 ± 0.2) x 10^6 M_S**
- Radius < 10 light days

Observational Data: S2's Orbit Reaches Periapse



(Schodel *et al.)*

When:

Spring 2002

Where:

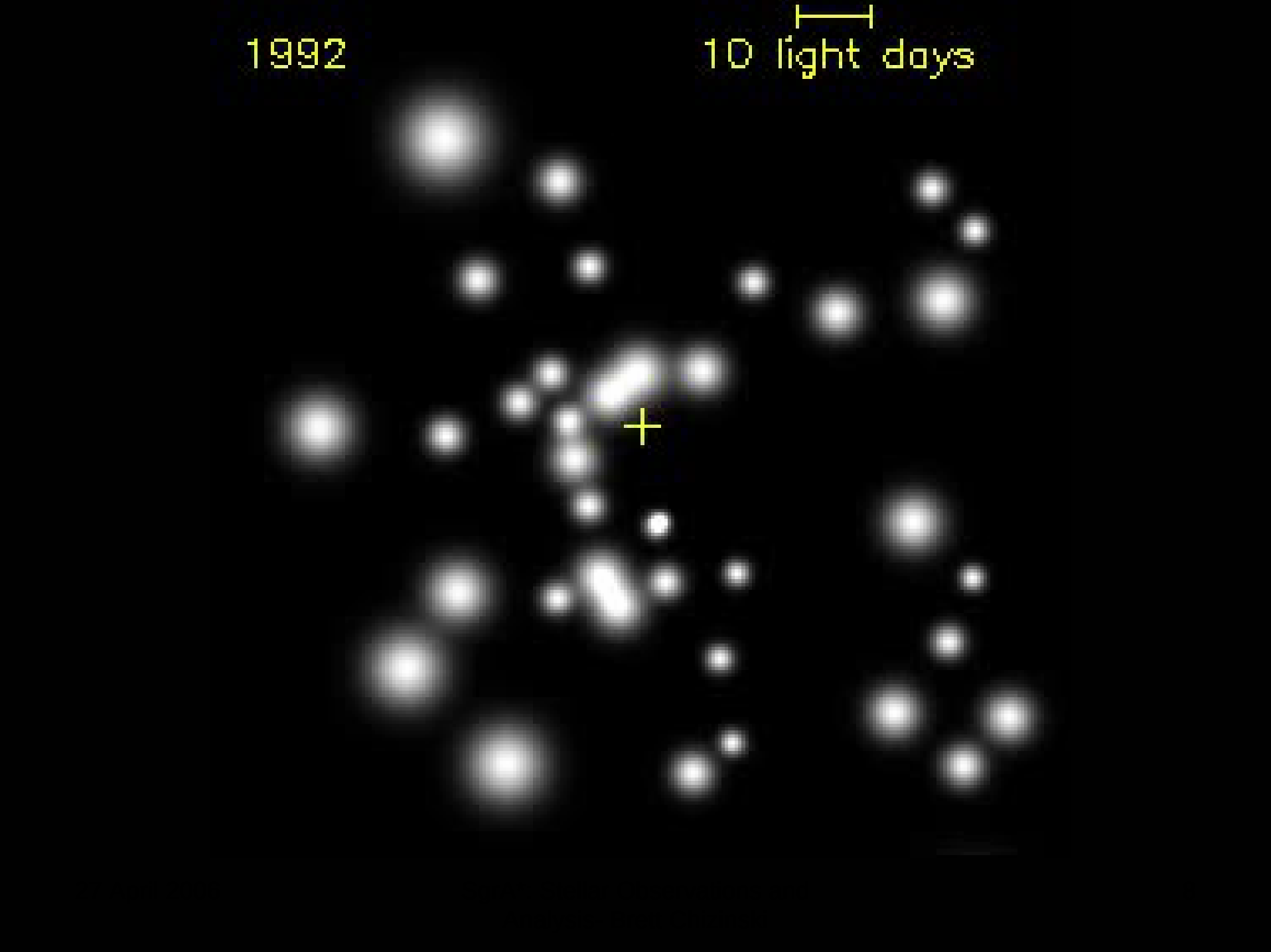
17 light hours from SgrA*

Speed:

over 5000 km s^{-1}

Measured By:

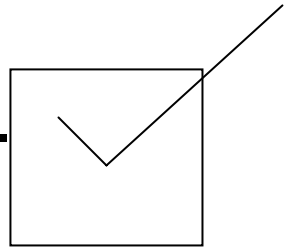
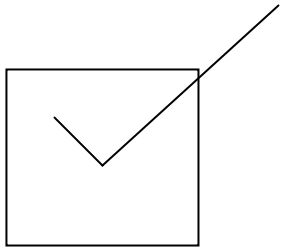
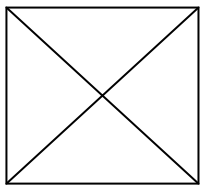
NACO


1992
10 light days

Analysis: S2 Orbit

- $3.7 \pm 1.5 \times 10^6 M_S$
- Radius < 17 light hours
- Fermion Ball Model: fermion mass > 74 keV (100000 times greater than most massive neutrino recorded)
- Cluster cosmic objects: lifespan of ~10^5 years, Milky Way ~10^9 years old, extremely unlikely
- Ball of Bosons: Would collapse into black hole eventually

So…is it a black hole?

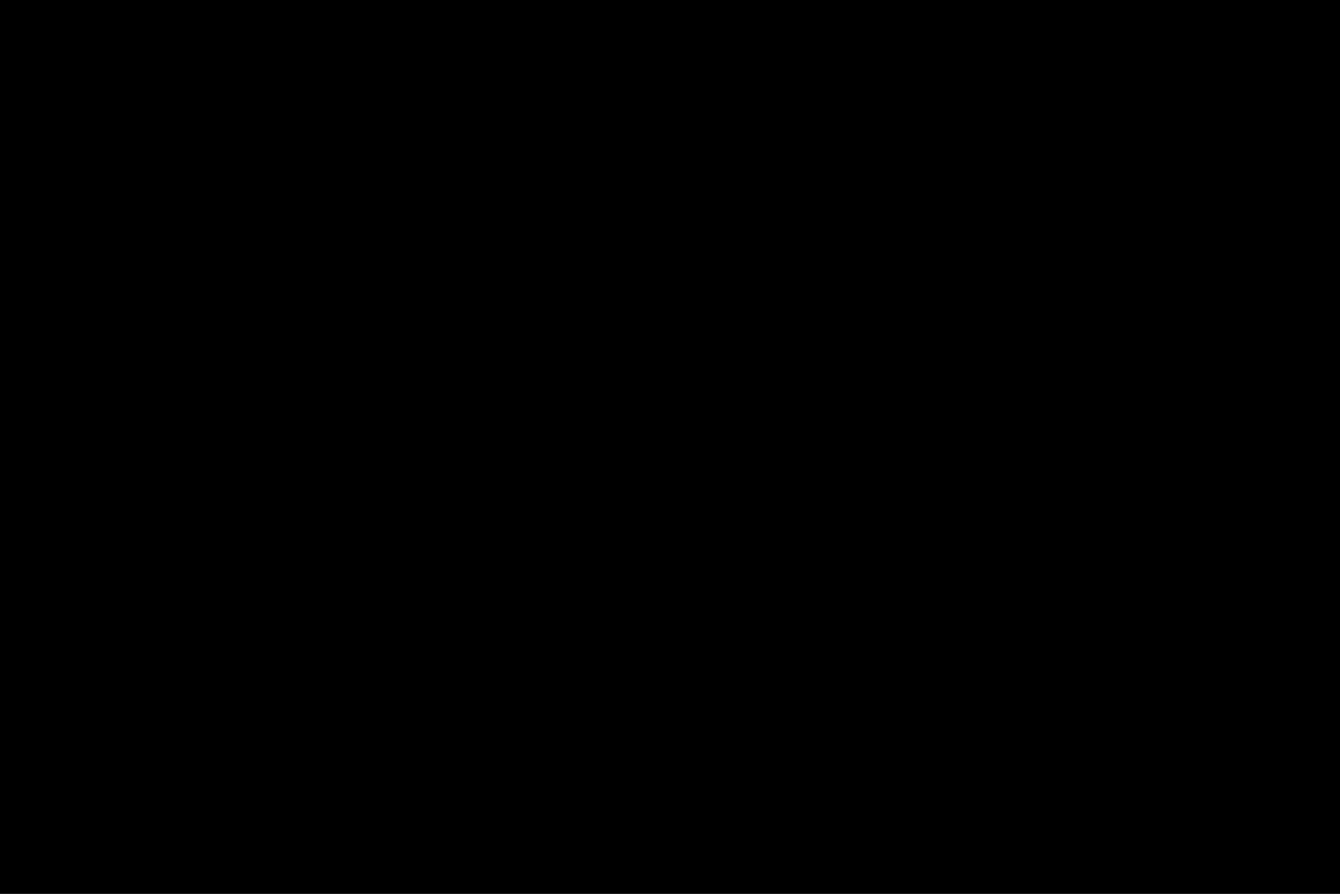
- Mass------- 
- Size-------- 
- Event------ Horizon 

Future: Further Investigations

- Data Refinement
  - Distance estimate = 19% mass uncertainty
- Event Horizon
  - Observe mass being “eaten”
- Star Formation
  - Young stars in unhospitable region

Conclusion

- $3.7 \times 10^6 M_S$ object
- Radius no more than 10 light days
- Density of at least $6.5 \times 10^{21} M_S/pc^3$
- Supermassive black hole model most fitting
- Evidence of event horizon needed



Works Cited

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- Shen, Zhi-Qiang. “A size of ~1 AU for the radio source Sgr A* at the centre of the Milky Way.” Letters to Nature. 11/03/05; 62-64.
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