

Sagittarius A*: Stellar Observations and Analysis



Brett Chizinski

Boston University Department of
Engineering

Overview

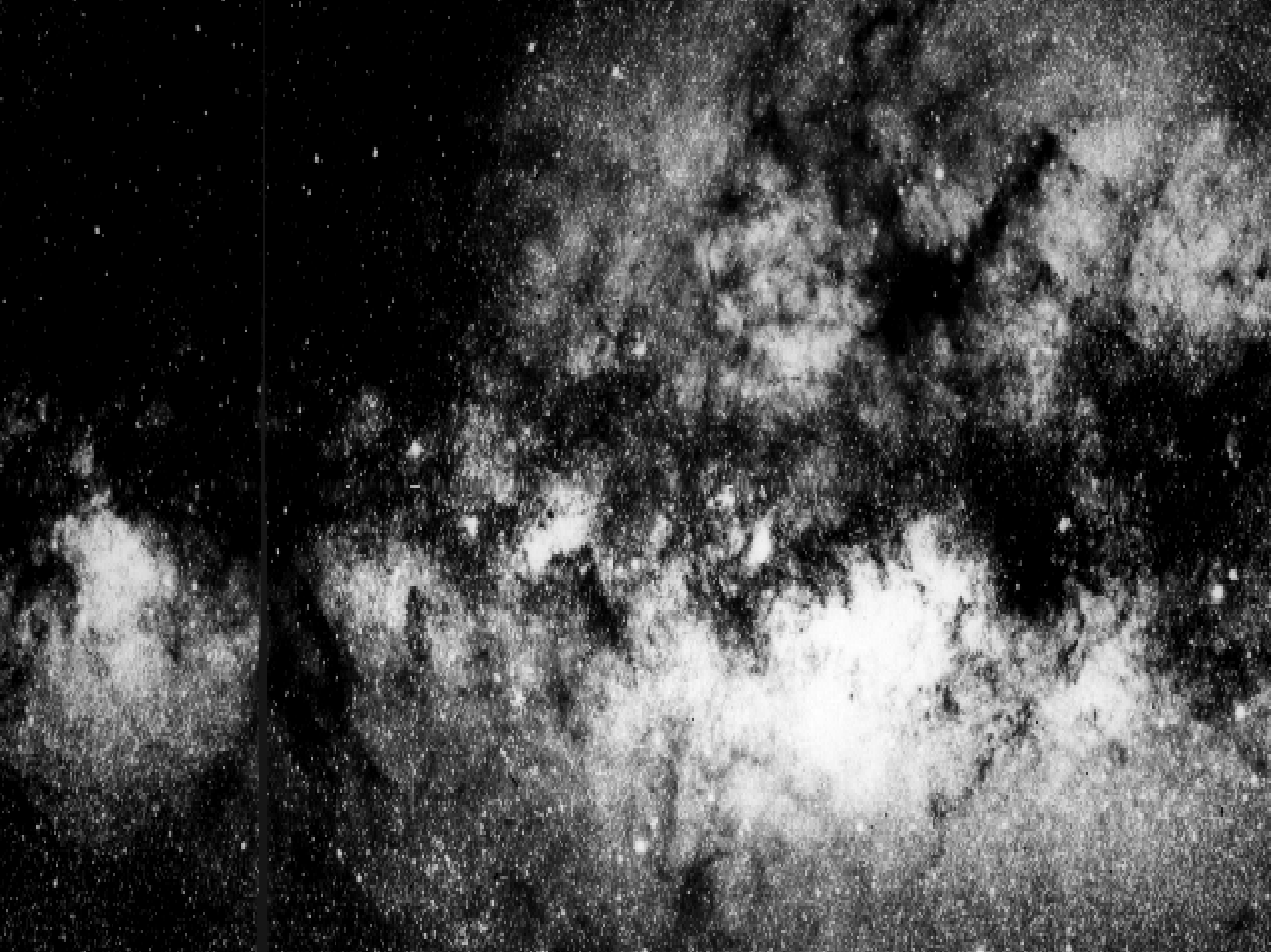
- **General View of Galactic Center**
 - Proposed Models for SgrA*
- **Observational Data**
 - Andrea Ghez
 - Data Reduction
 - Stellar Orbits: Ghez et al.
 - Orbit of S2 with NAOS-CONICA
- **Analysis**
 - Ghez et al.
 - S2
- **Future**
- **Conclusion**

Views of the Galactic Center:

Radio

X-ray

Infrared

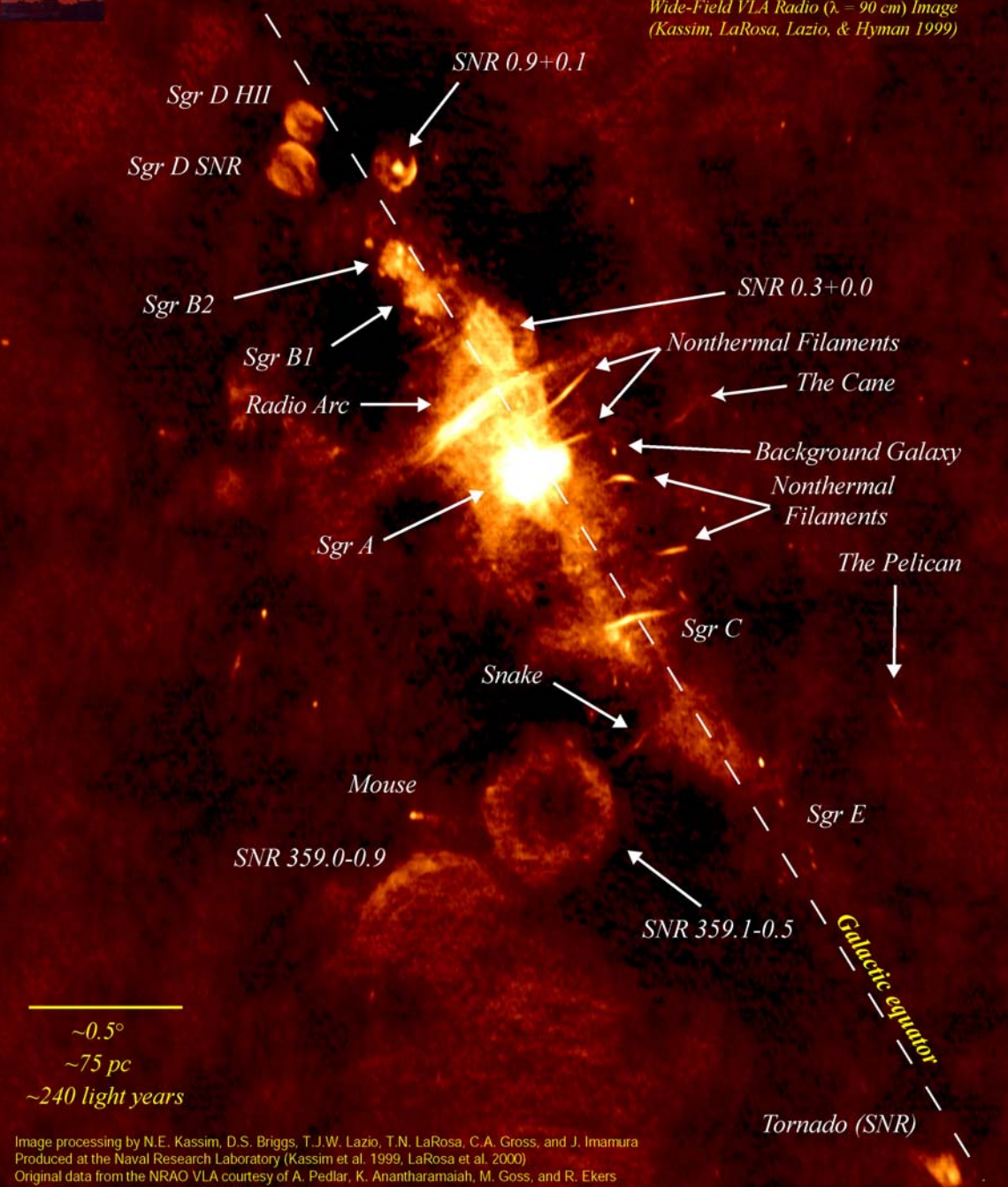




Remote Sensing Division
Naval Research Laboratory
Washington, D.C.

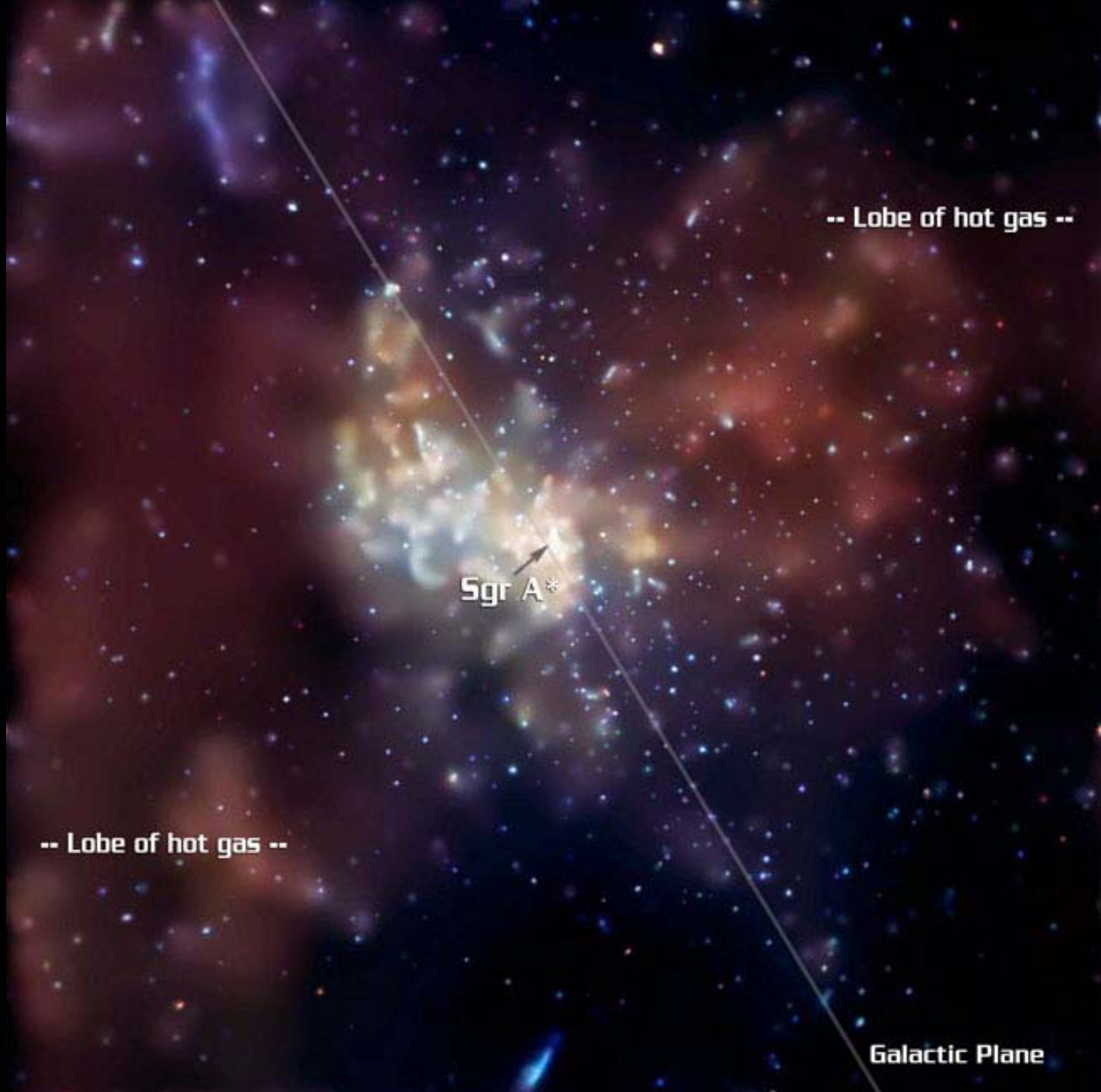
The Galactic Center

Wide-Field VLA Radio ($\lambda = 90$ cm) Image
(Kassim, LaRosa, Lazio, & Hyman 1999)



~0.5°
~75 pc
~240 light years

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://rds-www.nrl.navy.mil/7213/lazio/GC>

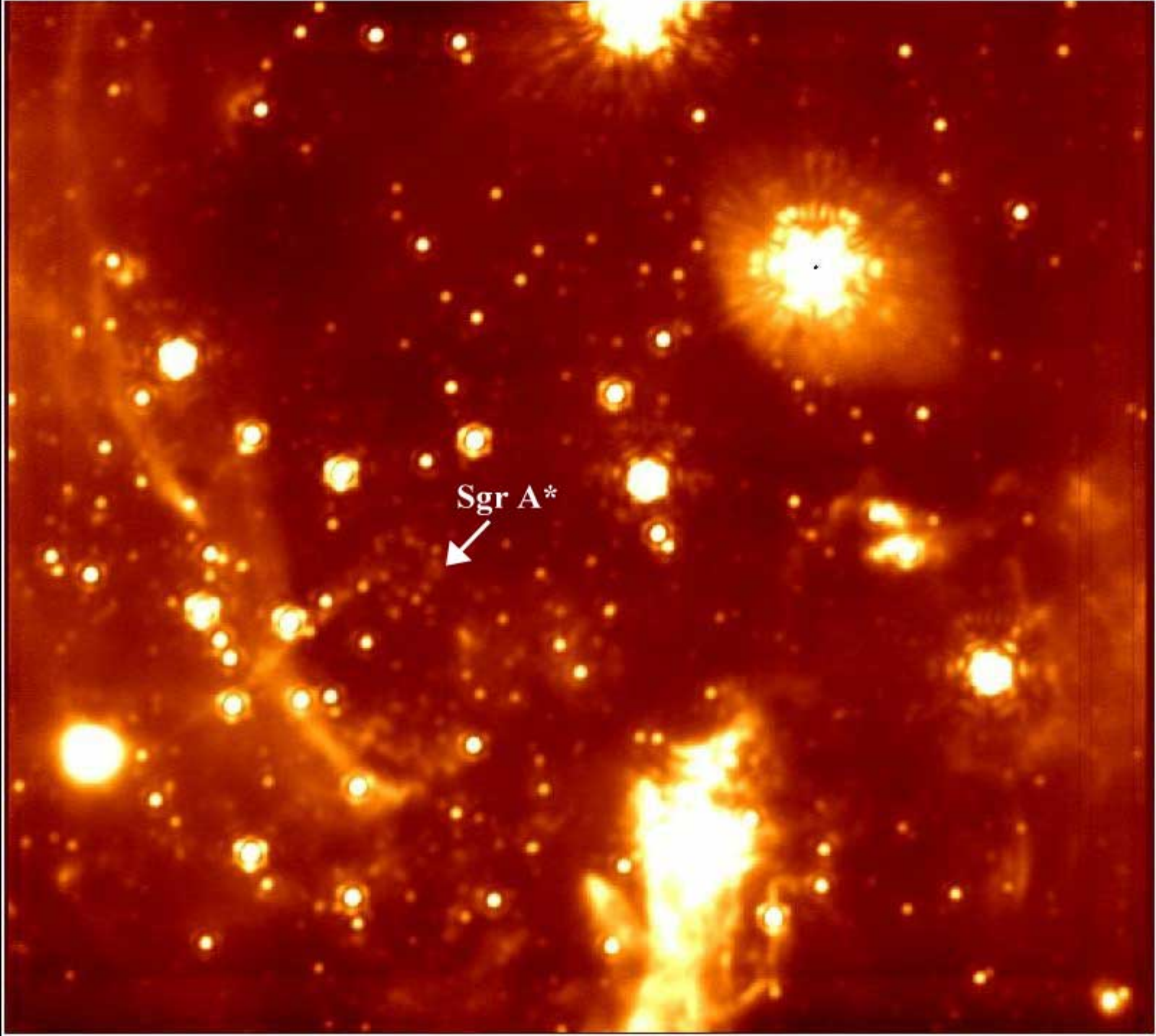


-- Lobe of hot gas --

Sgr A*

-- Lobe of hot gas --

Galactic Plane



Sgr A*

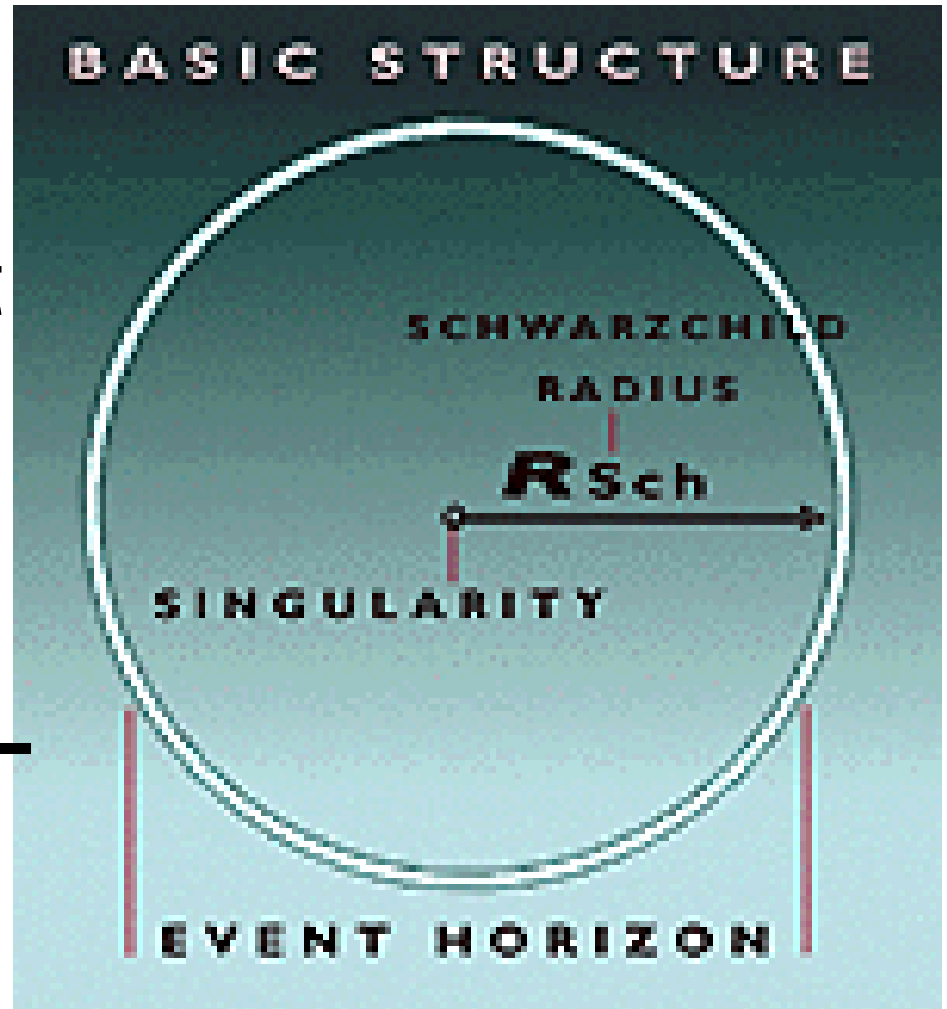


Proposed Models for SgrA*

- 1. Supermassive Black Hole
 - At least $10^5 M_{\odot}$
- 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?

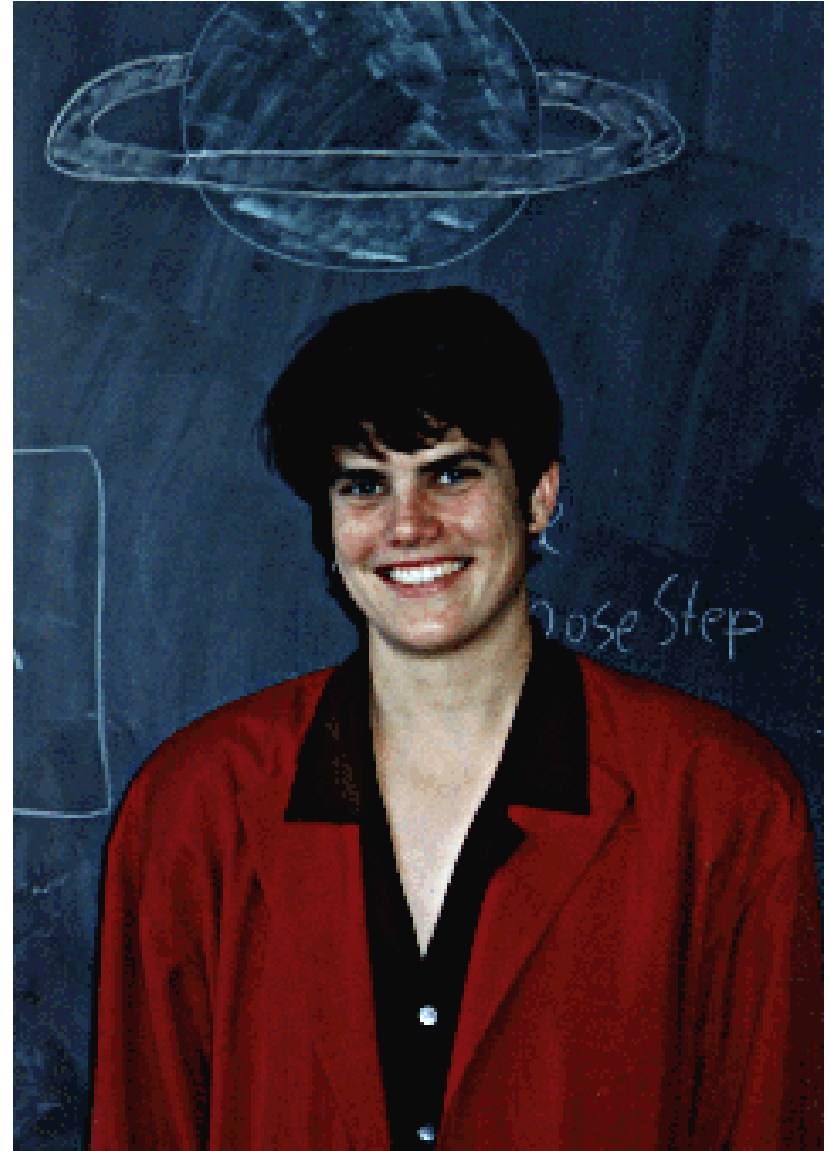
- Mass – for supermassive at least $10^5 M_S$
- Size – Very Dense
- **Event Horizon – only way to prove 100%**



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

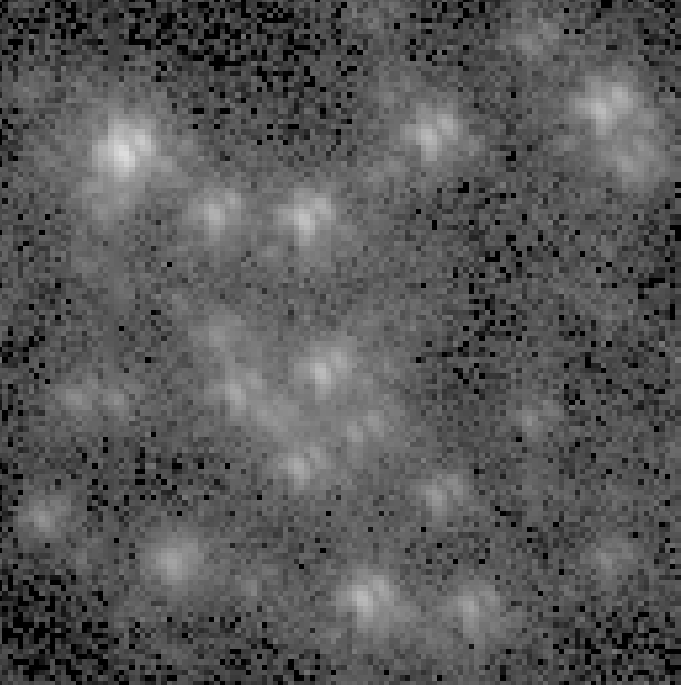
- Two 10m telescopes
- Largest Optical + Infrared
- Hawaii



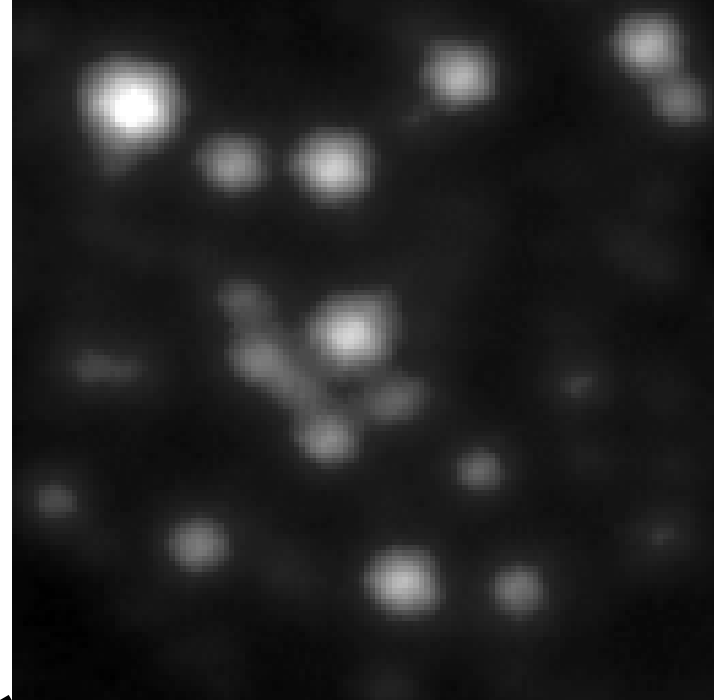


NAOS-CONICA at VLT YEPUN

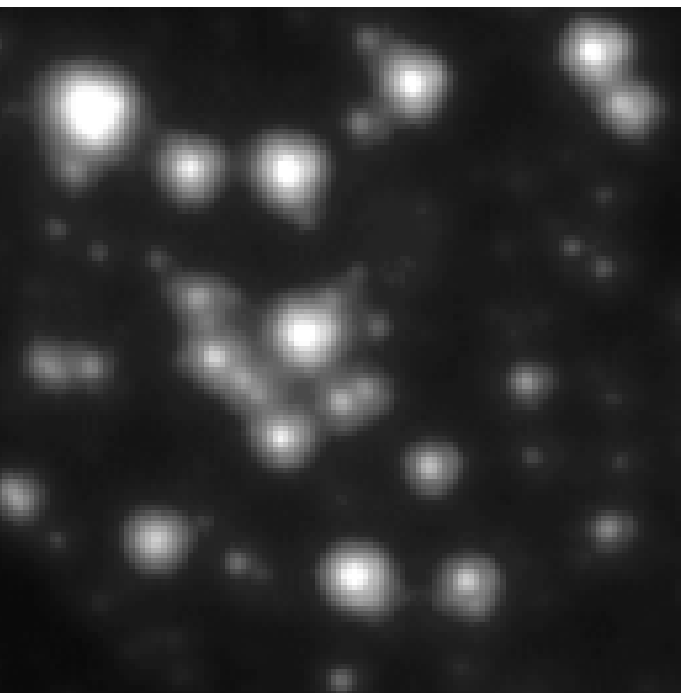
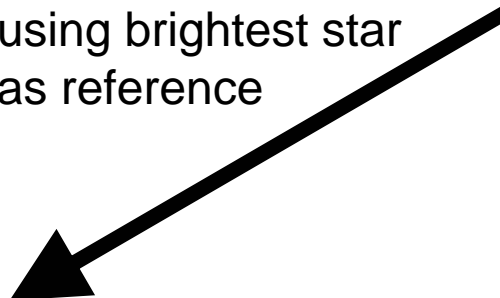
Data Reduction: Speckle Inferometry



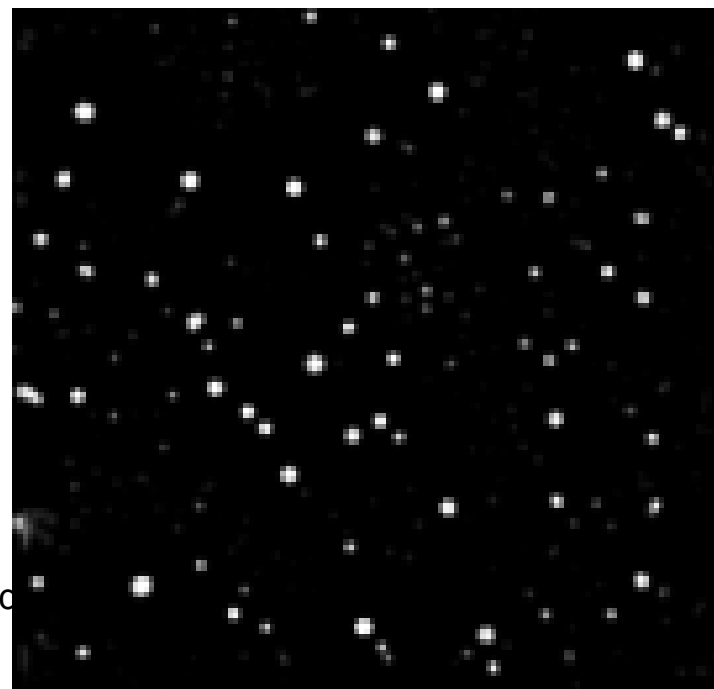
1. Average all short exposures into one long exposure



2. "Shift-and-Add" using brightest star as reference

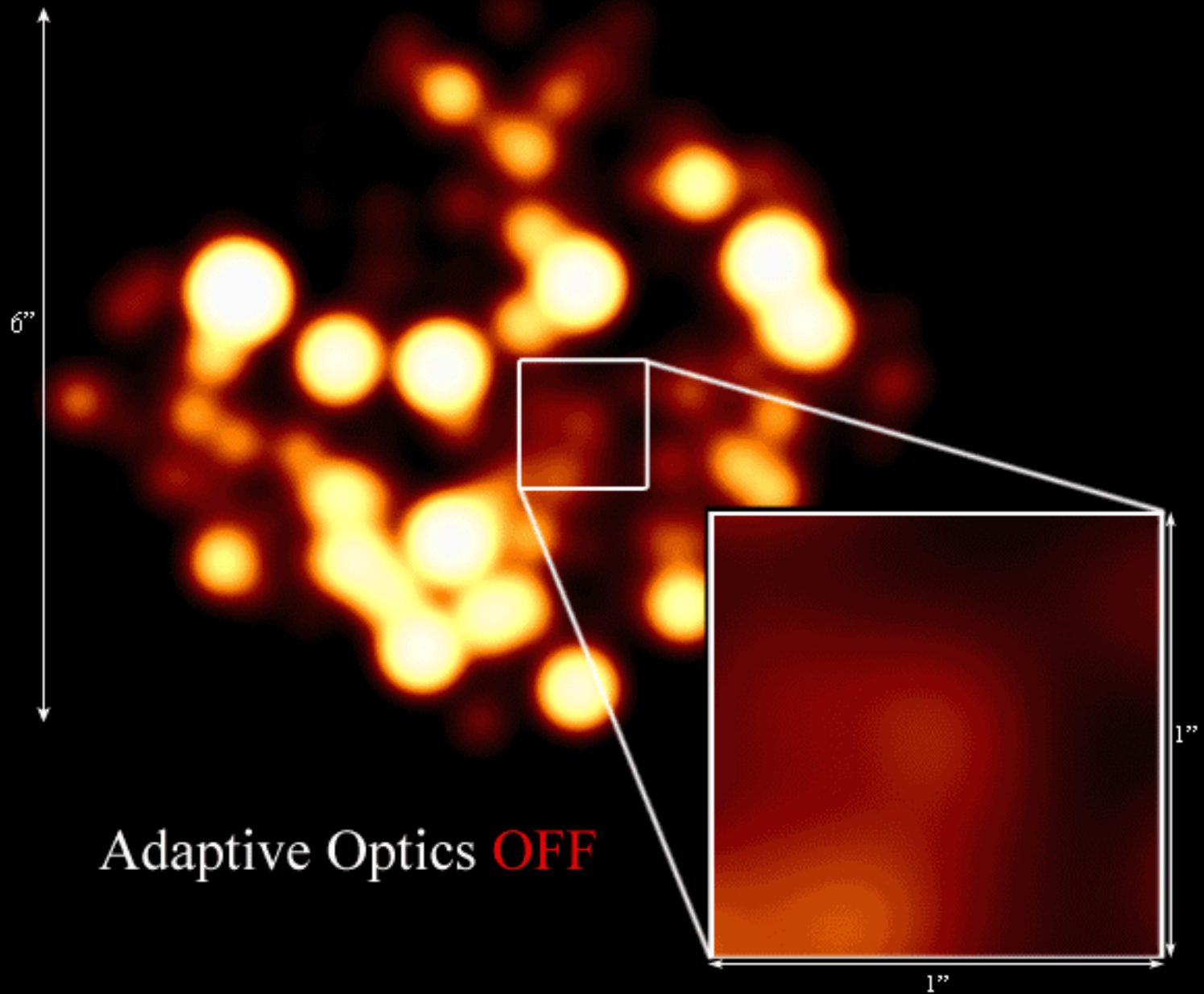


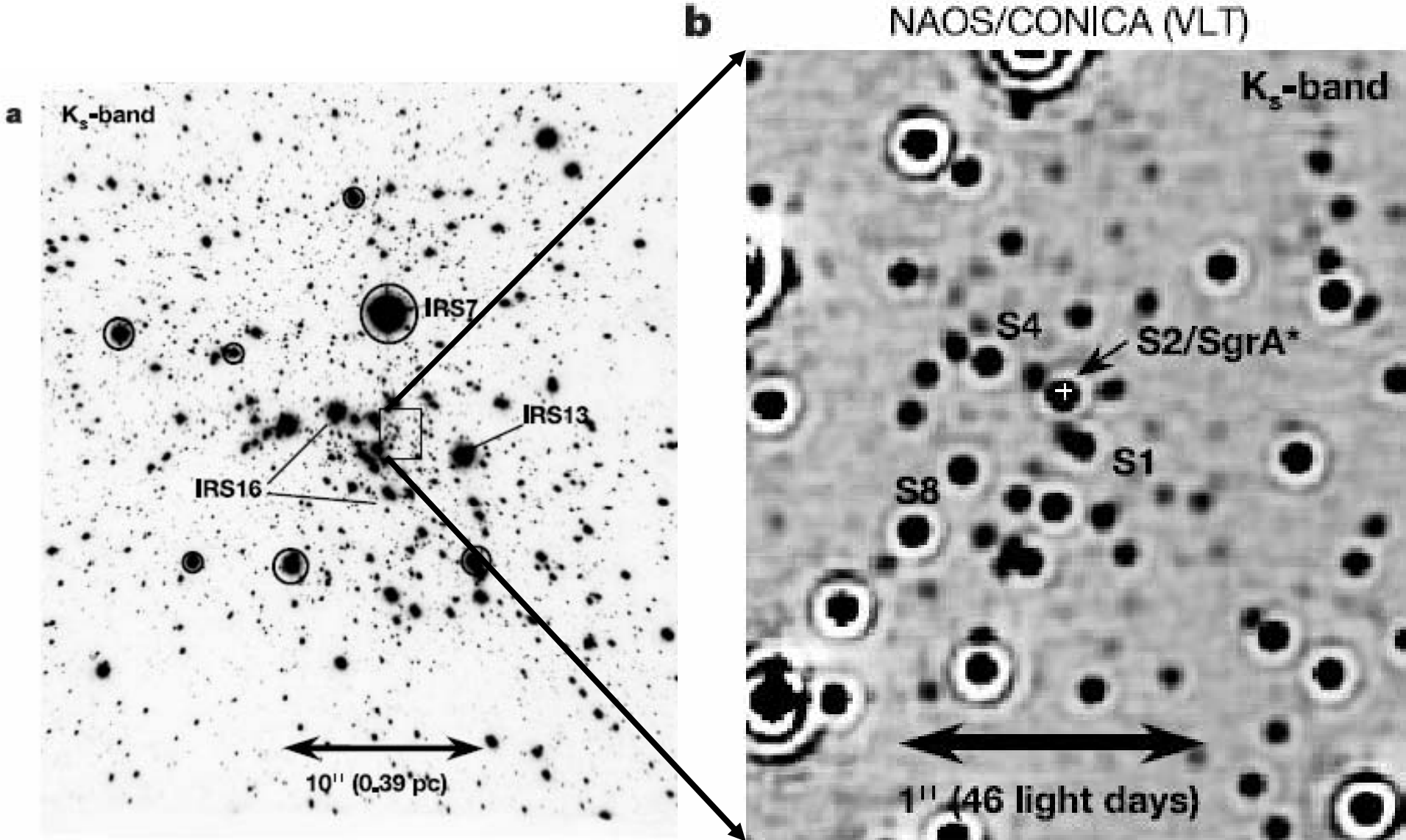
3. Remove Point Spread Function



Data Reduction: Adaptive Optics

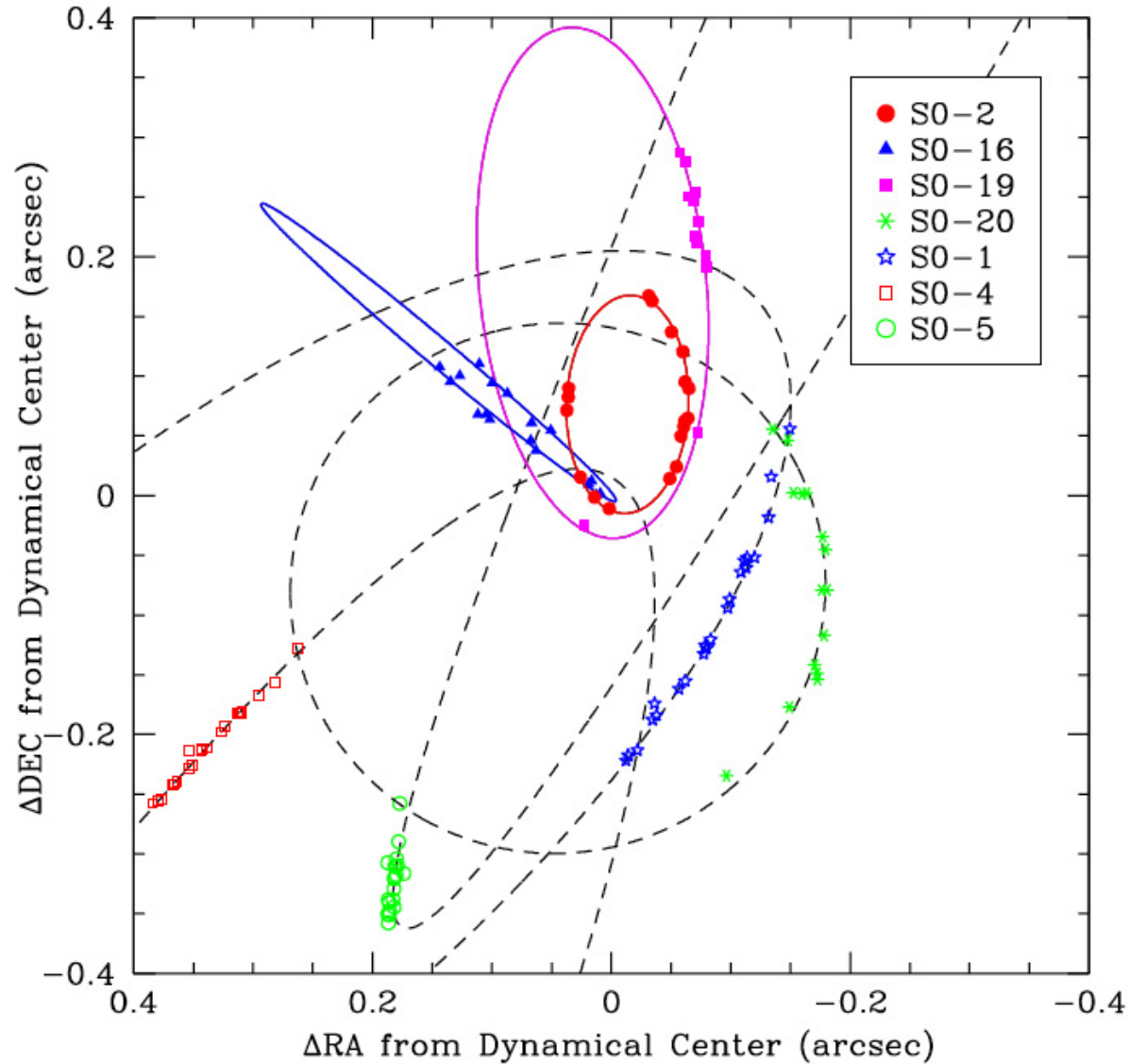
The Galactic Center at 2.2 microns





(Schodel *et al.*)

Stellar Orbits: Ghez et al.



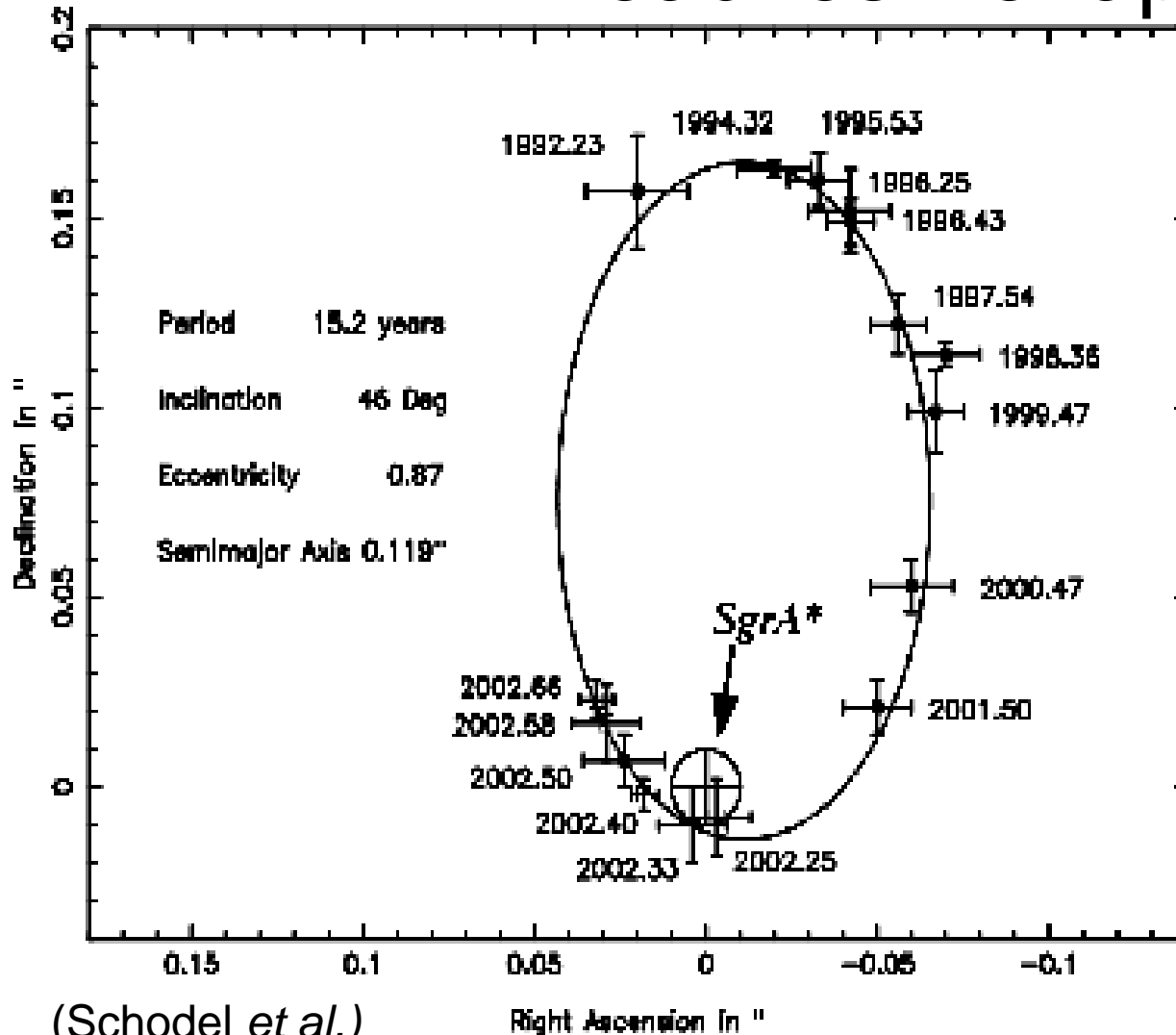
27 April 2006

SgrA*: Stellar Observations and
Analysis- Brett Chizinski

Analysis: Ghez et al.

- Velocities measured by red-shift
- 7 orbits deemed accurate for simultaneous fitting
- Fitted orbits infer center point mass of **$(3.7 \pm 0.2) \times 10^6 M_{\odot}$**
- Radius < 10 light days

Observational Data: S2's Orbit Reaches Periapse



(Schodel *et al.*)

27 April 2006

SgrA*: Stellar Observations and
Analysis- Brett Chizinski

When:

Spring 2002

Where:

17 light hours from
SgrA*

Speed:

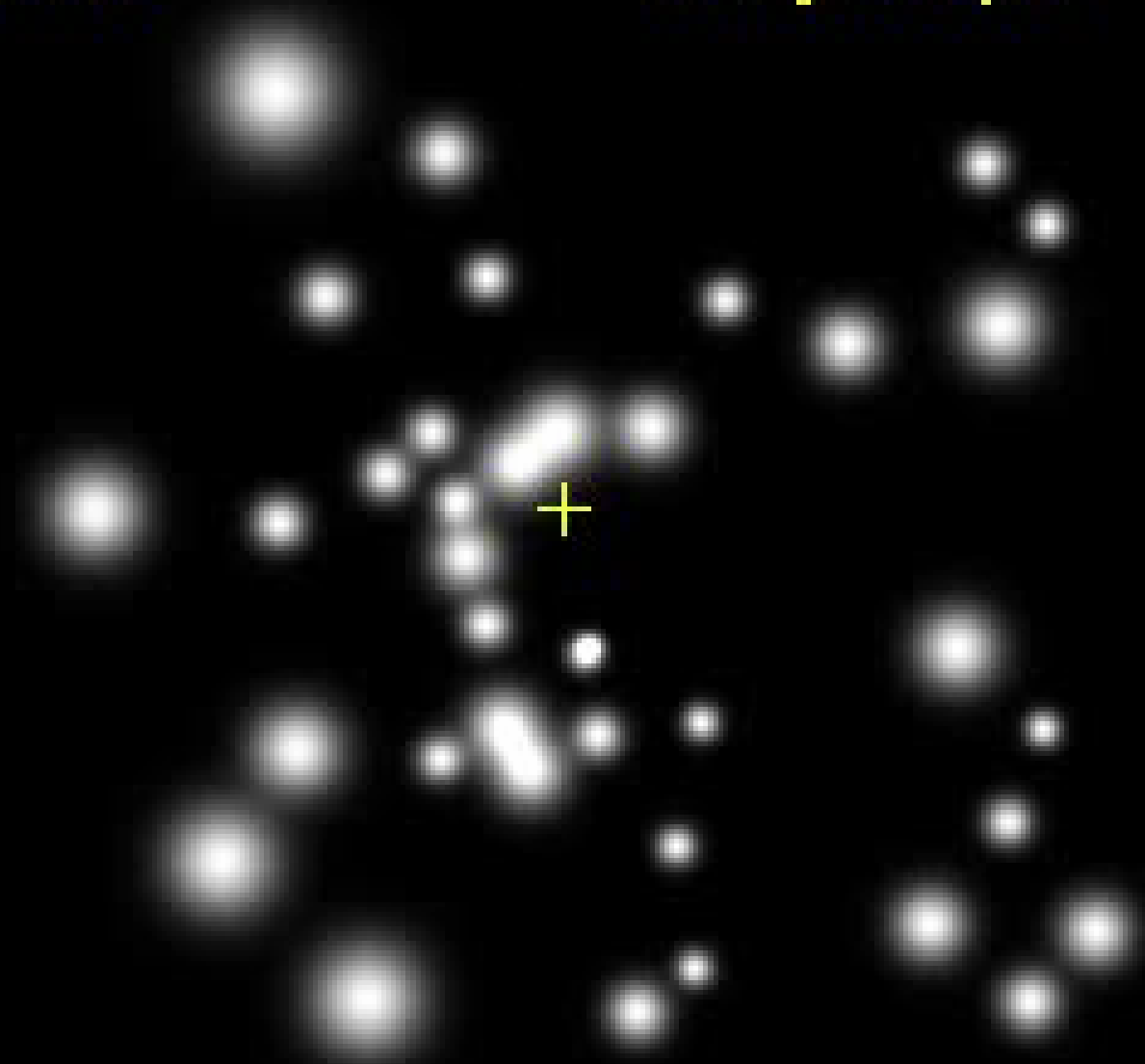
over 5000 km s⁻¹

Measured By:

NACO

1992

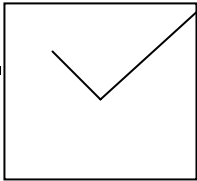
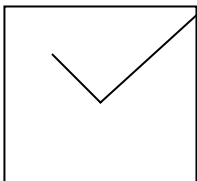
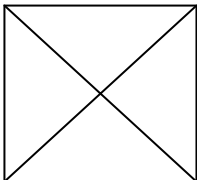
10 light days



Analysis: S2 Orbit

- $3.7 \pm 1.5 \times 10^6 M_{\odot}$
- Radius < 17 light hours
- Fermion Ball Model: fermion mass > 74 keV (100000 times greater than most massive neutrino recorded)
- Cluster cosmic objects: lifespan of $\sim 10^5$ years, Milky Way $\sim 10^9$ 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 inhospitable region

Conclusion

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

Works Cited

- Schodel, R et al. “A star in a 15.2-year orbit around the supermassive black hole at the centre of the Milky Way.” Letters to Nature. 10/17/02; 694-696.
- 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.
- Ghez, A. M. et al. “Stellar Orbits Around the Galactic Center Black Hole.” Astrophysical Journal. 02/20/05; 744-757.
- Hawking, Stephen. The Universe In a Nutshell. New York: Bantam Books, 2001. Pages 110-122
- Schodel, R et al. “Stellar Dynamics in the Central Arcsecond of our Galaxy.” Astrophysical Journal. 10/20/03; 1015-1034