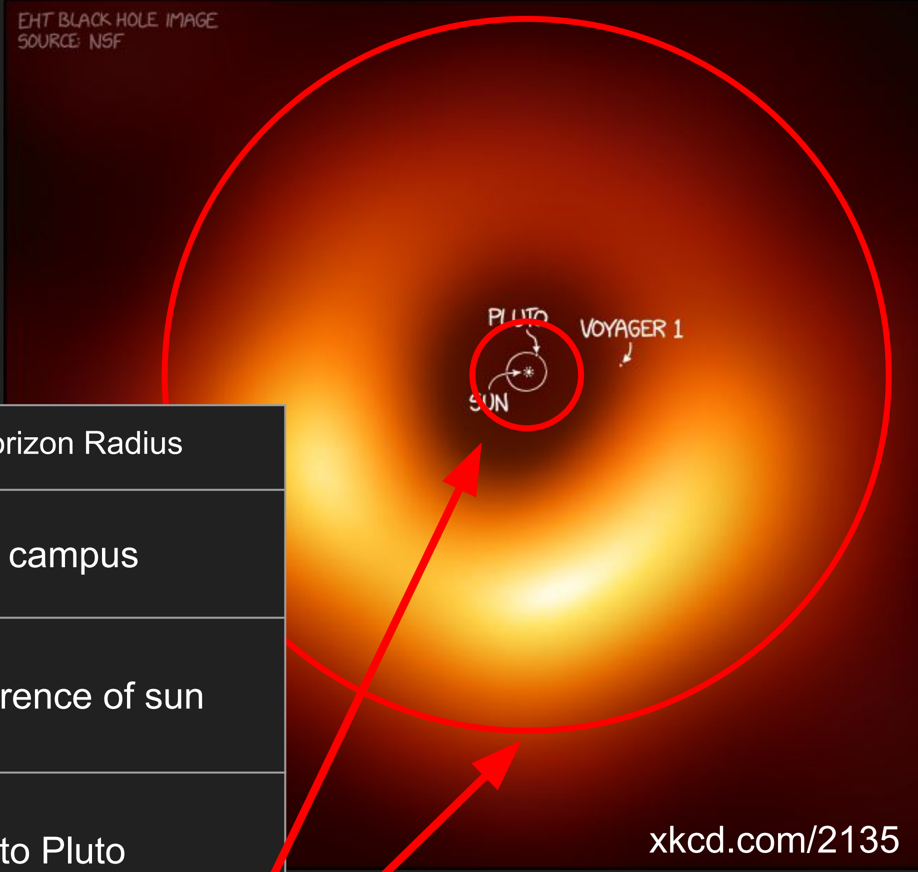
A Search for the Largest Supermassive Black Holes

Supermassive Black Holes

- Unimaginably huge
- Live in centers of most large galaxies

	Mass	Event Horizon Radius
Sun	**1** M_{sun}	Walk around campus
Milky Way Sgr A*	**4 Million** M_{sun}	3 x Circumference of sun
M87	**6 Billion** M_{sun}	3 x distance to Pluto
Holmberg 15A	**40 Billion** M_{sun}	**Huge!**



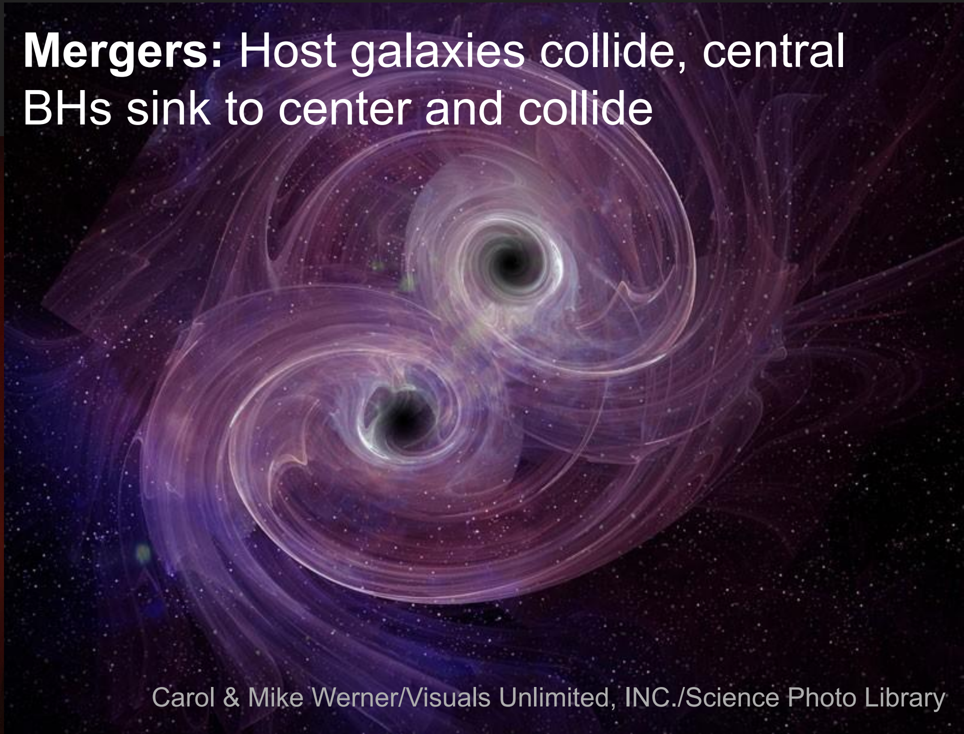
Evolution of SMBHs

- Supermassive black holes become supermassive through **accretion** and **mergers**

Accretion: Gas falls onto the central BH

ESO/M. Kornmesser

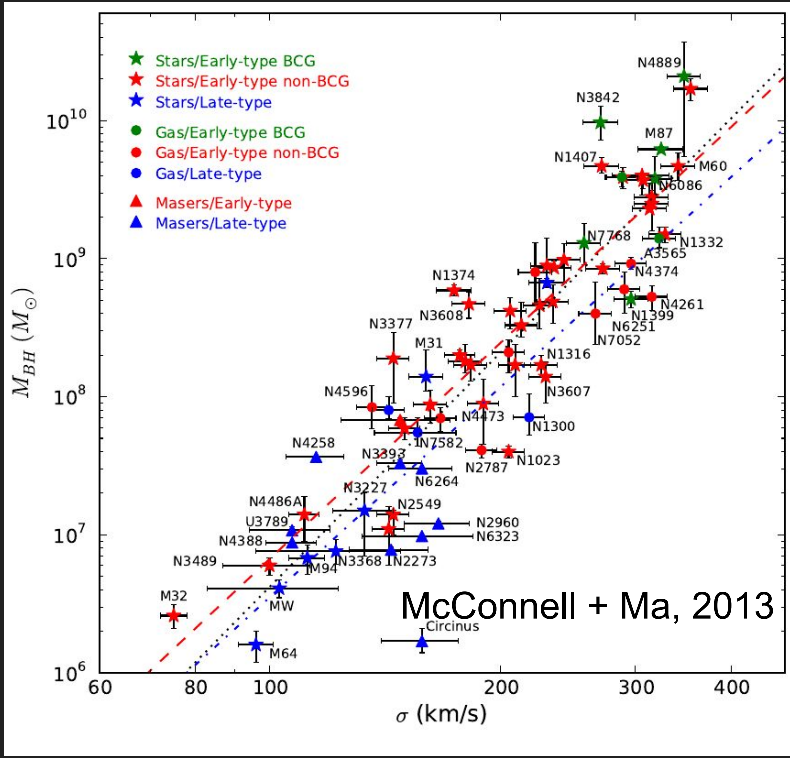
Mergers: Host galaxies collide, central BHs sink to center and collide



Carol & Mike Werner/Visuals Unlimited, INC./Science Photo Library

SMBHs co-evolve with their host galaxies

Measured SMBH Mass (M_{sun})



σ ~ speed of stars far away from BH ~ tracer of galaxy mass

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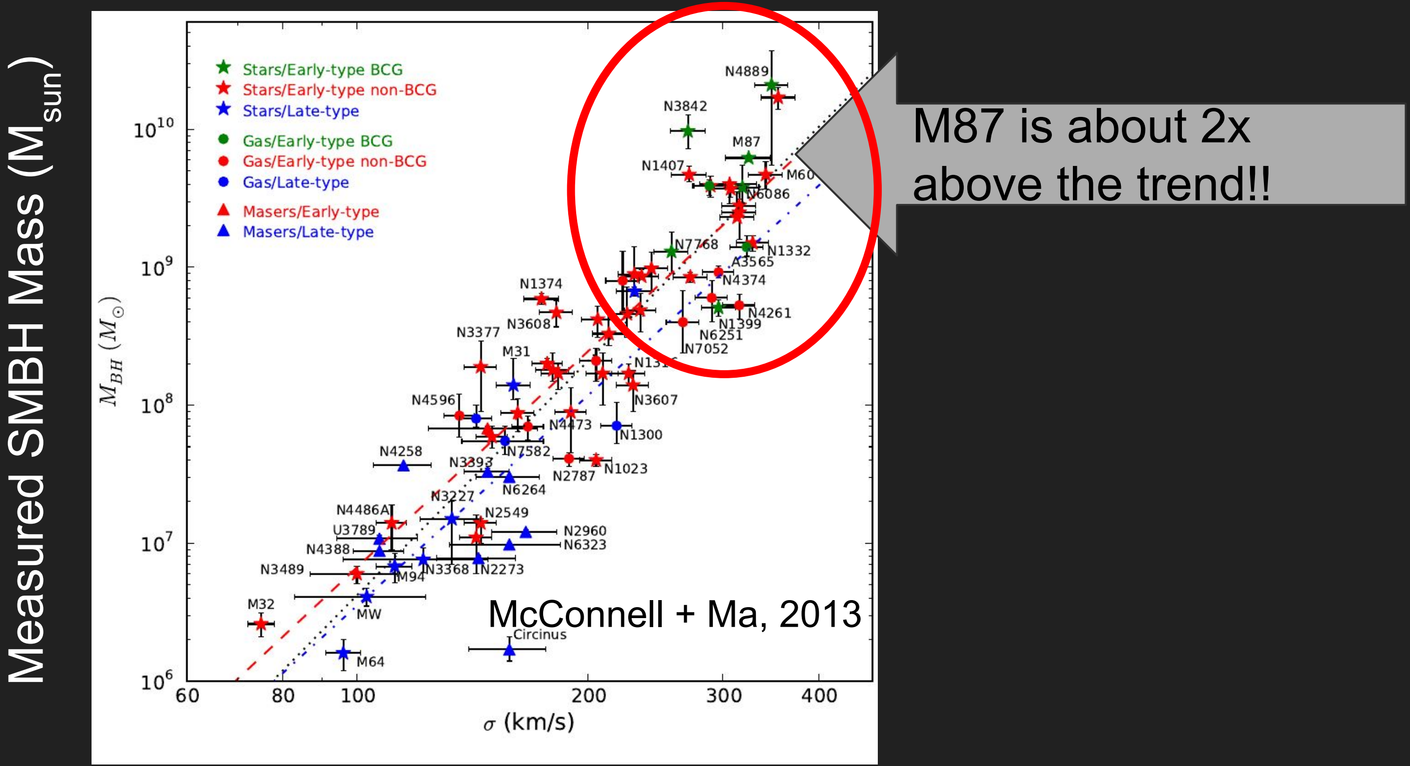

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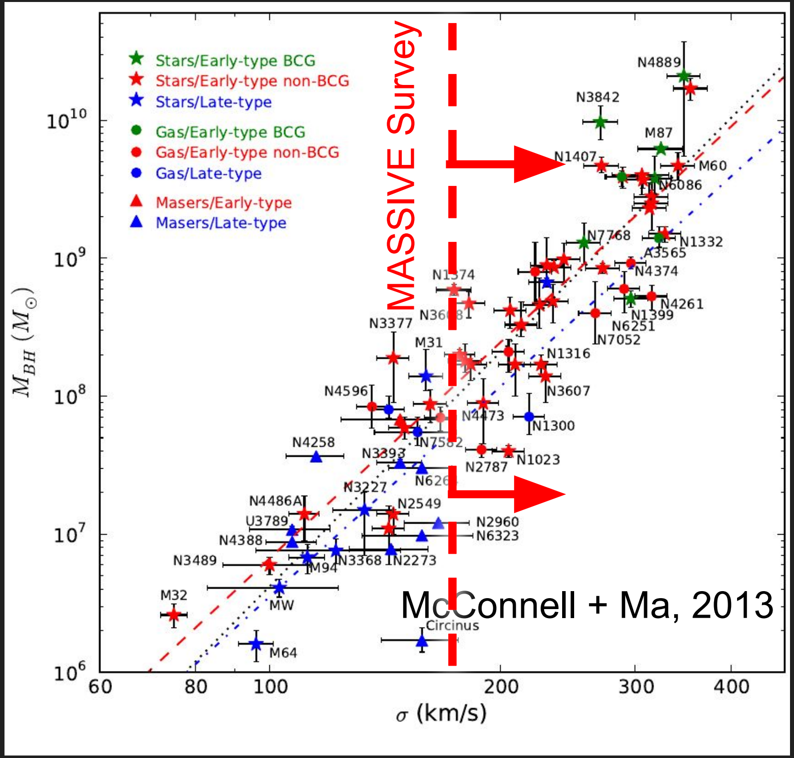

MASSIVE Survey explores **~100** most massive early type galaxies in our neighborhood

(Note: MASSIVE selects targets by M_*, not M_{BH}, so vertical line is not representative of real cuts)

σ ~ speed of stars far away from BH ~ tracer of galaxy mass

Finding Black Holes: Observables (stars!)

Photometry (photos)

Where are the stars?

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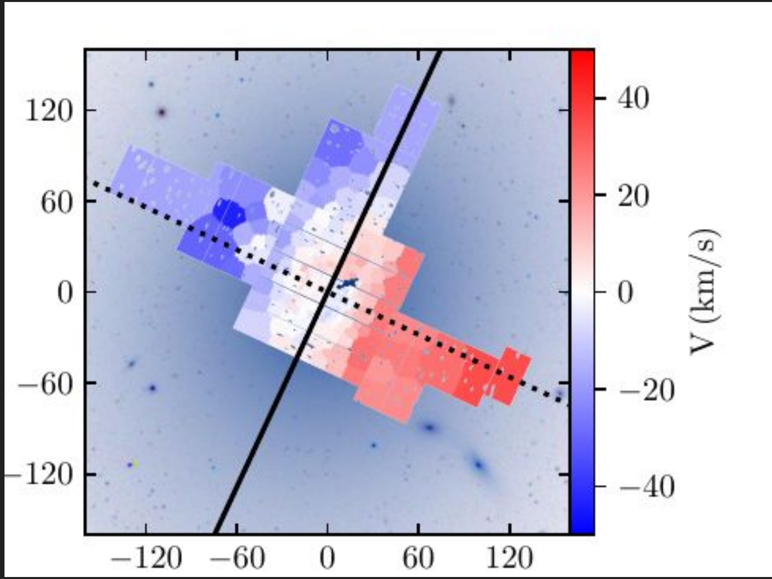
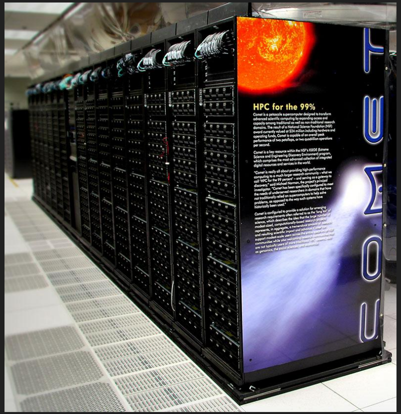


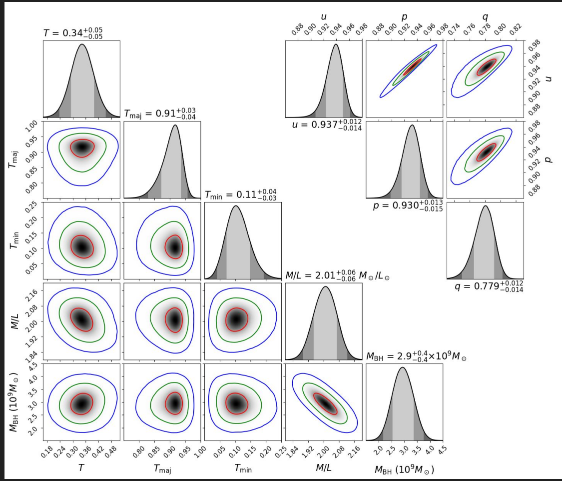
Liepold+ (in prep)

- We only measure quantities in **projection** -- 3D positions and velocities can’t uniquely be reconstructed from the data

Finding Black Holes: Modelling

1. Assume a **deprojection** of the photometry and a **mass model**
2. Integrate **>100k** representative stellar orbits in that potential
3. Combine those orbits to match the measured kinematics
4. Repeat 1-3 to find the best mass model and deprojection





NGC 1453, Quenneville+21

Digression: Deprojecting Ellipses

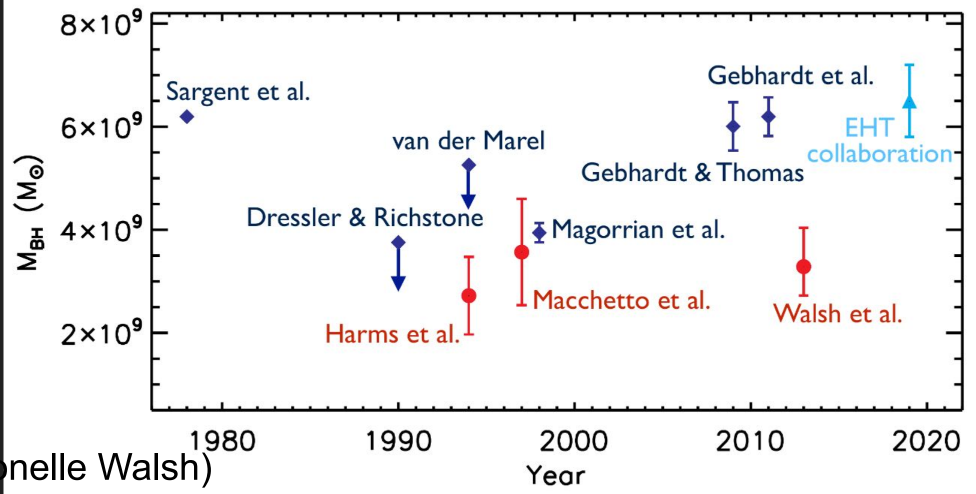
- Elliptical galaxies are Elliptical!
- 3D ellipsoids look like ellipses when projected on the sky
- In general, 3D ellipsoids can be **triaxial** with 3 different axis lengths
- Mis-modelling the 3D shape can **significantly** bias the measured BH mass

Is frisbee viewed obliquely?

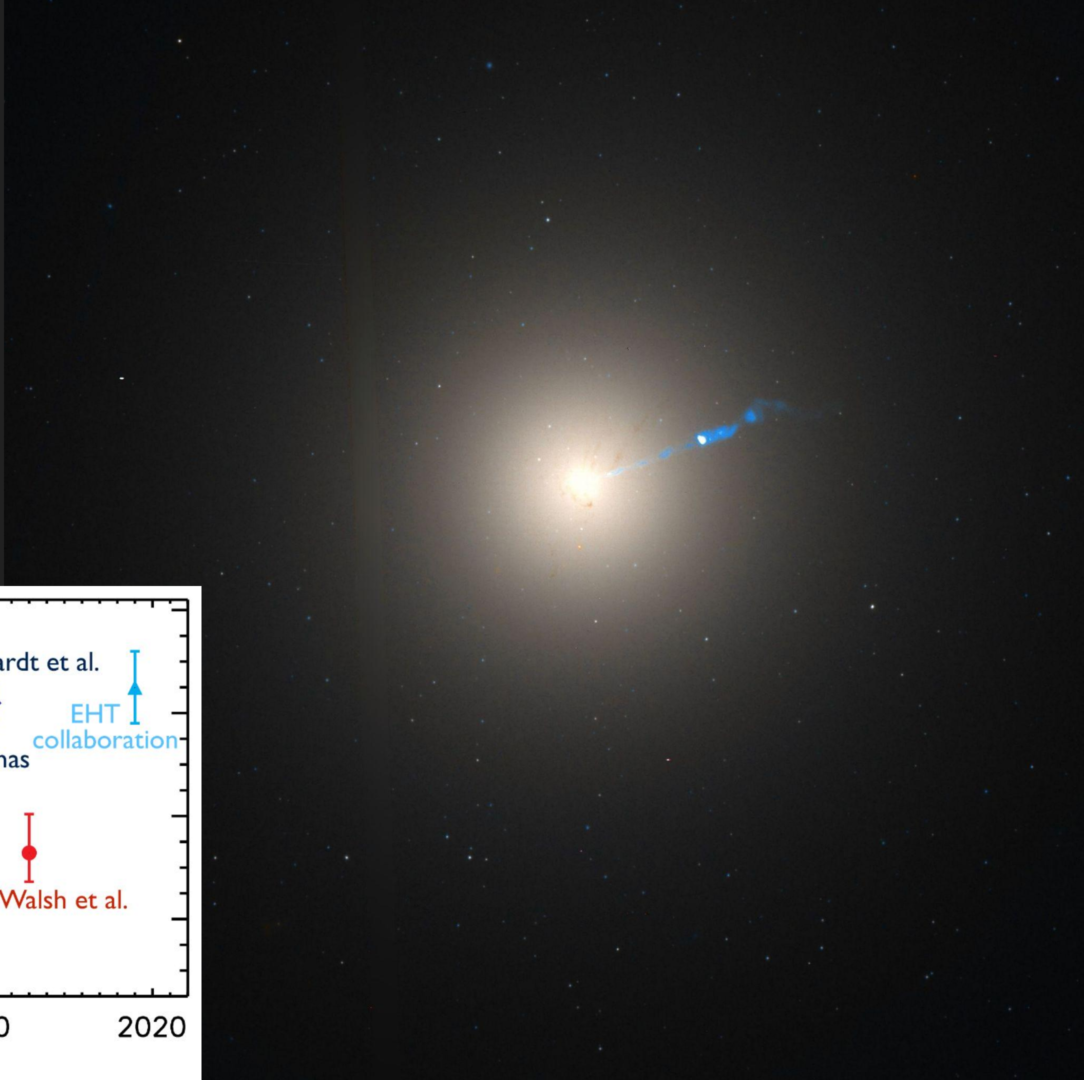
Or edge on and a bit more thick?

M87: A (brief) history

- (Axisymmetric) Orbit modelling suggests $M_{BH} \sim 6 \times 10^9 M_{sun}$
- Gas modelling suggests $M_{BH} \sim 3 \times 10^9 M_{sun}$
- EHT suggests $M_{BH} \sim 6 \times 10^9 M_{sun}$

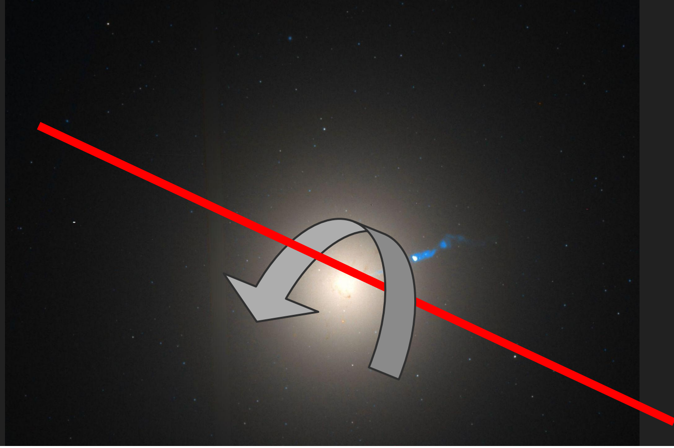


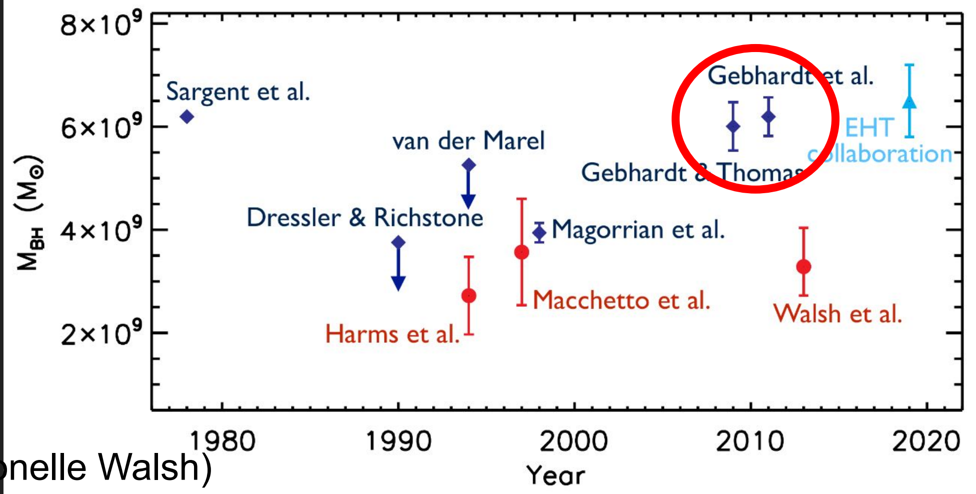
(Jonelle Walsh)



M87's puzzling shape

- Axisymmetric modelling **only** allows rotation about the symmetry axis
- Our recent observations find that the rotation is 90 degrees misaligned!
- M87 is not axisymmetric!
- Is the mass really **6 Billion**?





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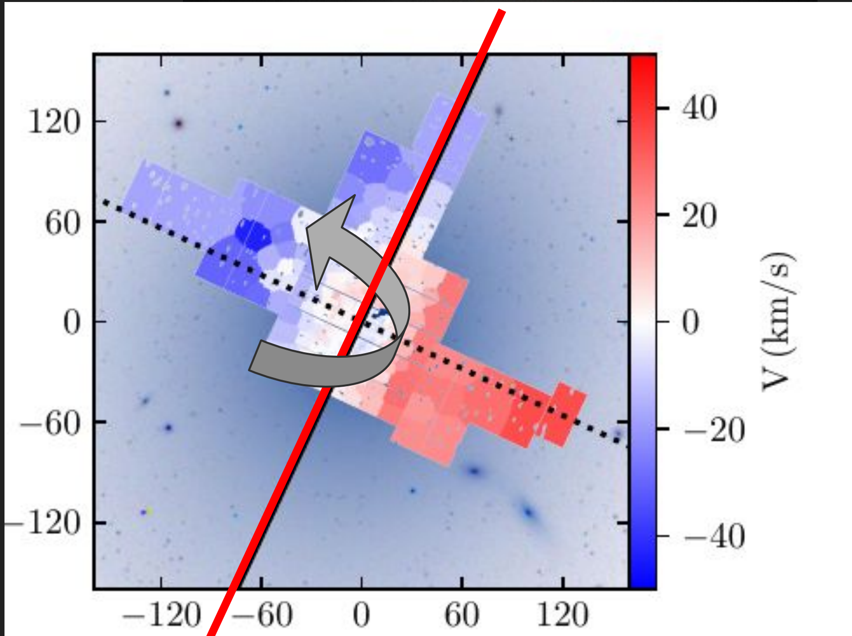

The Instruments

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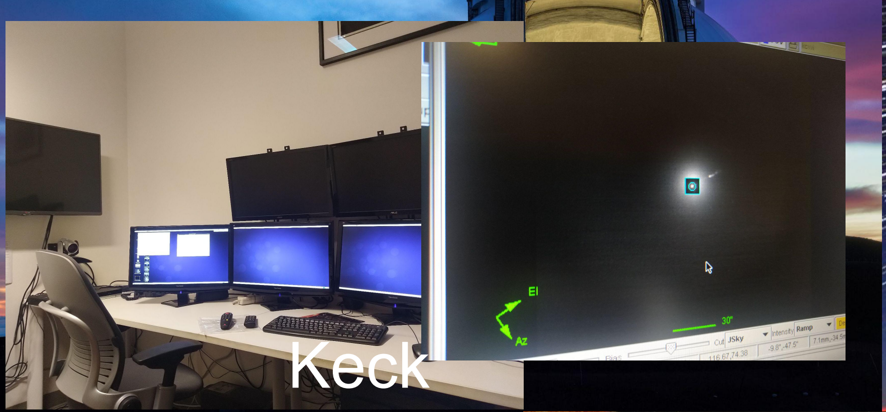
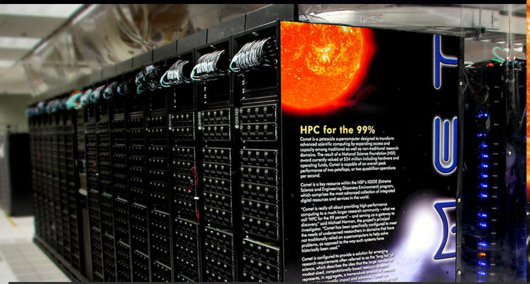


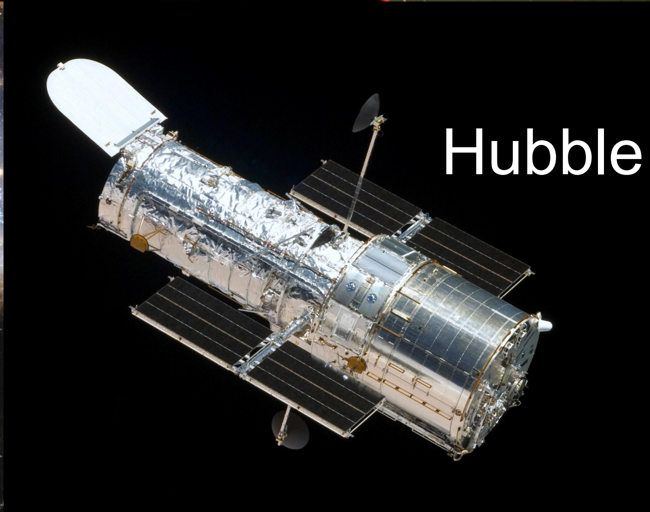
Keck

Gemini



San Diego
Supercomputer Center
(UCSD)

James Webb



Hubble

The People

Melanie Veale

Chung-Pei Ma

Jen Ito

Matthew Quenneville

Jacob Pilawa

Shaunak Modak

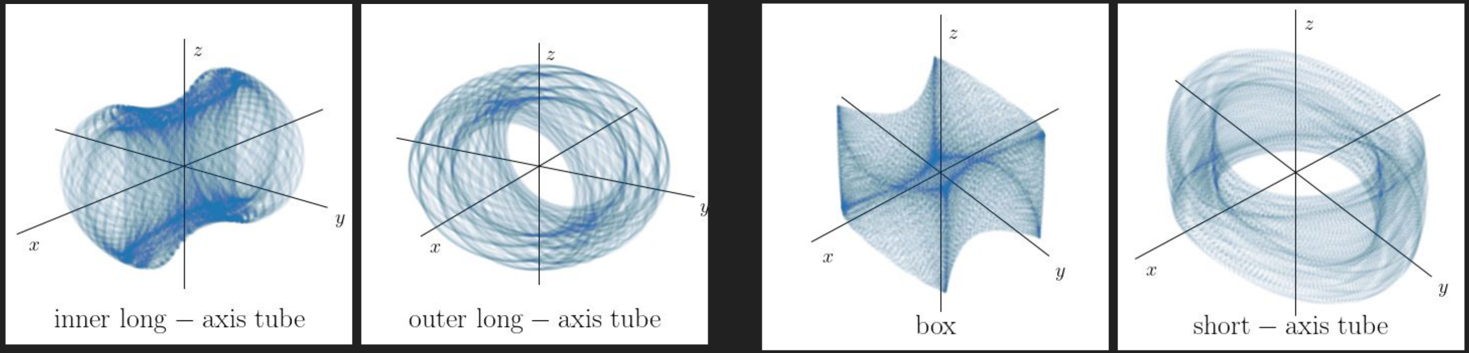
Myself!

Questions?

Additional slides (TBD)

The importance of shapes

- **Axisymmetric** models only allow orbits about the symmetry axis
- **Triaxial** models allow orbits around **short** or **long** axis and orbits which pass through center (**boxes**)
- **Box** orbits can mimic the kinematic signatures of a black hole
- Mis-modelling the 3D shape can bias the BH measurement by a factor of >**2**



Ch 14, Dynamics and Astrophysics of Galaxies, Bevy

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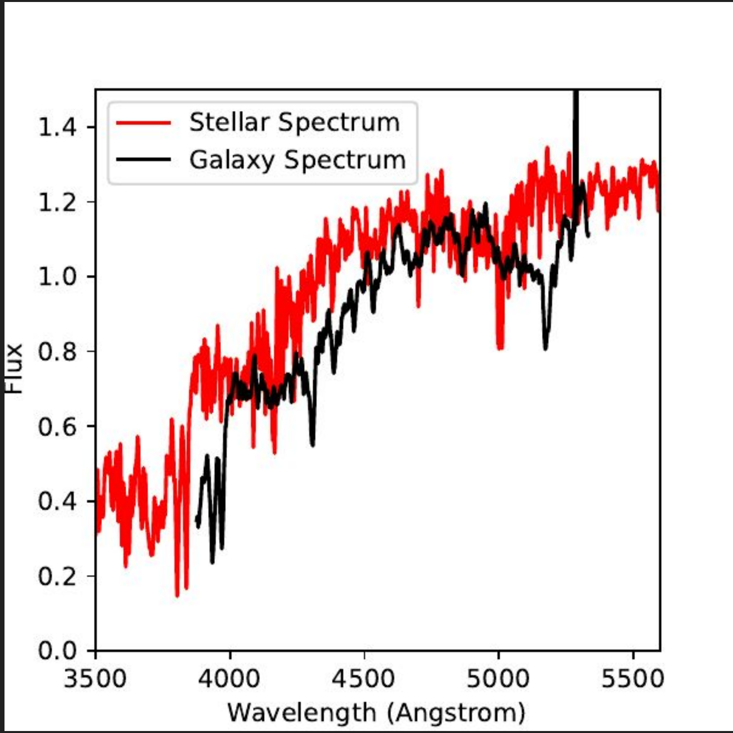

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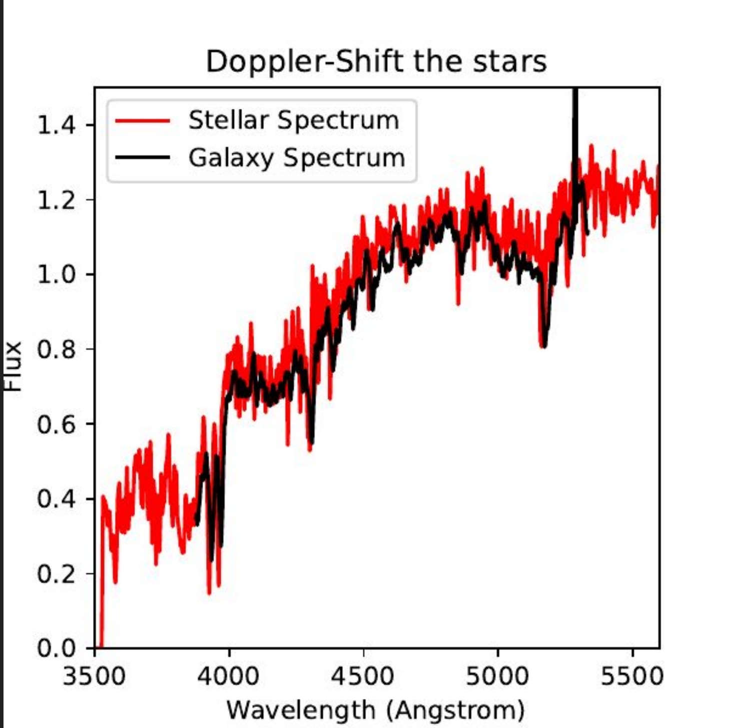

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