Plan of Lecture

Galactic Center and Stellar Populations

Review of galaxies.

Center of Milky Way.

Sagittarius A*.

The case for a supermassive black hole.

Puzzles about the center.

Review

In the time BSB (Before Spring Break), we determined:

Galaxies contain $\sim 10^{9-13}$ stars.

Spiral/elliptical/irregular.

For MW, disk/halo distinction.

Spiral arms are forming stars.

Rotation suggests dark matter.

Now we'll focus on the center of our galaxy.

Characteristics of Center and Bulge

The center of the Milky Way is obscured by dust and gas.

Need non-optical observations.

Radio, IR, hard X-rays.

Most bright X-ray sources are in bulge region.

Much higher fraction of high-mass stars.

Stars are higher metallicity than locally.

Excess of gamma radiation from e^-–e^+ annihilation.

Near GC, you'd see $> 10^6$ stars brighter than Sirius!

Sagittarius A*

There is one particular radio source of great interest...

Detected by Grote Reber in 1944; first radio telescope.

Strong IR emission from Sgr A, grouping of several sources.

Sgr A* is powerful radio source; synchrotron radiation.

But what is it?

Star?

Pulsar?

Supernova remnant?

Clues to the Nature of Sgr A*

What other information can we find out about this object?

Many bright stars are nearby.

Observe in IR.

Speckle interferometry.

Over years, can actually see the stars move.

Proper motion and radial velocities.

Can use these to estimate mass interior to orbits.

Result: $\sim 3 \times 10^6\, M_\odot$ inside 60 AU!

Alternatives to a Black Hole

A black hole could explain this, but we need to be careful.

Must rule out other possibilities!

Being creative, what other semi-realistic possibilities are there?

Cluster of normal stars?

Cluster of NS or WD?

Concentrated dark matter?

Other object with very high mass?

Dynamical Evidence for a Black Hole

First let's consider clusters of objects.

How about a cluster of stars?

Say, 3×10^6 **in** $r < 60$ **AU.**

Average sep: ~ 0.4 **AU**$\sim 80\ R_\odot$**.**

Plenty of room!

Normal stars, though, would be bright; what about NS or WD?

Would self-eject in few thousand yr!

Graininess of interactions.

Exotic Possibilities

What about a very concentrated halo of low-mass dark matter particles?

If there are many, don't self-eject.

Problem: have to cut off sharply at <60 AU.

Stellar interactions.

Dark matter would spread.

Also considered: "boson stars", "fermion stars".

Specific models fail.

Overwhelmingly best choice is $\sim 3 \times 10^6 \, M_\odot$ black hole.

A Starving Black Hole

If there really is a $\sim 3 \times 10^6\, M_\odot$ black hole powering Sgr A*, why isn't it brighter?

Luminosity $< L_\odot$!

Feeding only from ISM; not much mass.

Even less may get to hole!

Reasons for this are debated.

Proof positive that black holes don't "grab" matter!

The Stars Near the Galactic Center

But there are more puzzles than just the supermassive black hole (aka SMBH).

We can infer the mass because of bright stars near the center.

But bright stars are massive and young!

How did they get there?

They must have formed recently.

Did they form at current location?

Did they form somewhere else?

The SMBH has probably been there a long time...

Problems With Local Formation

The simplest idea would be for the stars to have formed right where they are, as an OB association.

But this doesn't work.

These stars formed from a molecular cloud.

To form stars, gravity needs to overcome molecular motion.

One type: thermal.

Another type: relative rotation.

Too much motion prevents collapse and star formation.

Near SMBH, rotation gradient is too great, so stars couldn't form!

Could the Stars Form Elsewhere?

If the stars formed elsewhere, how did they get close to SMBH?

Individual star takes a long time to sink to center.

Cluster gets there a lot faster.

What happens when cluster sinks towards SMBH?

Ripped apart when gets close.

Loose cluster disrupted far away.

Tight cluster survives longer.

But tight cluster self-ejects too rapidly!

Somehow, need dense stellar cluster that does not wipe itself out.

A Shepherd Black Hole

This leads to a suggestion by Hansen and Milosavljevic.

Imagine a dense cluster with a $\sim 10^3\, M_\odot$ black hole at its center.

Massive main sequence stars sink towards BH.

Move fast as a result.

Take longer to affect each other.

Little self-ejection.

This dense core of BH+stars sinks towards SMBH.

Get close before shredded.

$10^3\, M_\odot$ **BH still floating around!**

Intriguing idea, but no direct confirmation.

Summary

The center of our galaxy has active star formation.

Sgr A*, radio source, is almost certainly a $\sim 3 \times 10^6\, M_\odot$ black hole.

Not very bright!

Continued observation of dynamics is ongoing.

Challenge: what is the mass of the black hole in the center of M31?