2019 Workshop on Gravitational Waves and High-Performance Computing
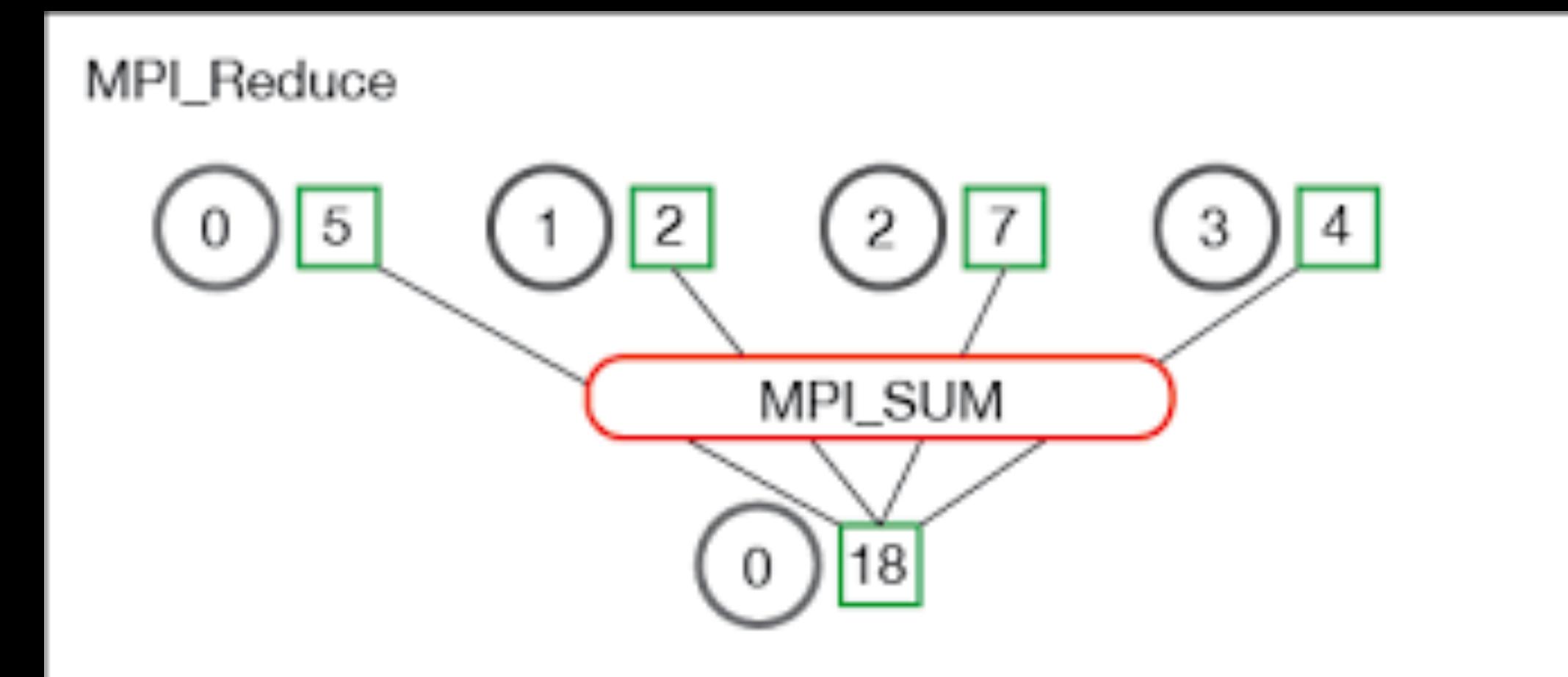
Geoffrey Lovelace
August 19, 2019 – August 23, 2019
Day 3

Paralleizing the dartboard

- **What if we combined results from the whole class's π dartboard?**

- **Even batter**

  - Run lots of copies of the dartboard on lots of cores

  - At the end, each copy tells the others how many hits it had

  - Each copy adds up the number of hits on all processors and computes pi

Parallelizing the dartboard 2

- `cp /home/workshopStudents2019/python_solutions/PiDart.py .`

- `nano PiDart.py`

- `#Add the same mpi4py lines at the top`

```python
from mpi4py import MPI
comm = MPI.COMM_WORLD
rank = comm.Get_rank()
size = comm.Get_size()
```

Parallelizing the dartboard 3

- nano PiDart.py

- #At the bottom, instead of getting pi, print the number of hits on each processor

```
print(str(hits)+" hits on core "+str(rank)+" out of
"+str(throws)+" throws.")
```

- mpirun -np 10 python PiDart.py

- What happens?

Parallelizing the dartboard 4

- nano PiDart.py

- #Divide the darts to throw
  among the processors, instead
  of each processor
  throwing the total

```python
hits = 0
throws = 1e7 // size
i = 0
while i < throws:
    # … rest of program
```

- mpirun -np 10 python PiDart.py

- What happens?

Parallelizing the dartboard 5

- nano `piEstimate.py`

- #Have on processor add up the totals across all processors

```python
print(str(hits)+" hits on processor "+str(rank)+" out of "+str(throws)+" throws.")




throwsAllCores = throws * size
hitsAllCores = comm.allreduce(hits, op=MPI.SUM)


if rank == 0:
    print(str(hitsAllCores)+" hits on all cores, with "+str(throwsAllCores)+" throws.")
```

-

Parallelizing the dartboard 6

- nano PiDart.py

- #Compute pi

```python
if rank == 0:
    print(str(hitsAllProcessors)+" hits on all processors,
with "+str(throwsAllProcessors)+" throws.")


    pi = 4.0 * float(hitsAllCores) / float(throwsAllCores)
    print(pi)
```

-

Parallelizing the dartboard 7

- nano `piEstimate.py`

- How long does it take?

- At top:

```python
import time
start = time.time()
```

- At bottom

```python
print(pi)

end = time.time()
print("Run in "+str(end-start)+" seconds.")
```

- `mpirun -np 10 python PiDart.py`

How many darts can we run on the entire cluster?

- 1e7 on 1 core

- About 500 cores

- So in the same time, we should be able to run 500e7 = 5e9

Parallelizing the dartboard 7

- srun -p orca-1 --nodes=1 --tasks-per-node=20 --pty /bin/bash

- source /opt/ohpc/pub/apps/anaconda2/bin/activate root
  cd student_folders/YOUR_NAME/PiDart

- How long does it take?

- At top:
```
import time
start = time.time()
```

- At bottom
```
print(pi)
end = time.time()
print("Run in "+str(end-start)+" seconds.")
```

- # Try again with 1e9 darts

Connect to ocean

- Open "PuTTY 64-bit" on the desktop

- Under "saved sessions" select "ocean"

- Click "Open"

- Username: workshopStudents2019

- Passphrase

  - Some computers: workshop2019!!

UNIX command line
crash course activity

- **Commands to know**

  - ls, pwd, cd, mkdir

  - ./, ../, paths

  - cp, mv, rm, rmdir

  - cat, less

  - nano

  - whoami, date, …

- **Play along with me…**

  - mkdir YOURNAME and cd into it

  - Navigate file system: ls, pwd, cd, ./ and ../

  - Use nano to write a text file

  - Copy, rename, remove a file

  - Cat, less, more, head, tail

  - > to redirect output

  - Grab bag: whoami, date, grep, sed, zip…

Unix commands to know

- **Commands to know**

  - ls, pwd, cd, mkdir

  - ./, ../, paths

  - cp, mv, rm, rmdir

  - cat, less

  - nano

  - whoami, date, …

- **Play along with me…**

  - mkdir YOURNAME and cd into it

  - Navigate file system: ls, pwd, cd, ./ and ../

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  - Cat, less, more, head, tail

  - > to redirect output

  - Grab bag: whoami, date, grep, sed, man, …

Clicker question #1.8

- I want to list the files in the directory I'm in. Which command would I use?

A   ls

C   pwd

B   cd

D   nano

Clicker question #1.9

- Which command edits the file "Hello.txt" in the directory I am currently in?

A nano ./Hello.txt

B cat ./Hello.txt

C nano ../Hello.txt

D cat ../Hello.txt

Clicker question #1.9

- Which command makes a new directory called "TestFolder"?

A ls TestFolder

C mkdir TestFolder

B cd TestFolder

D cp TestFolder

Clicker question #1.9

- Which command removes everything in the current directory, which is not empty?

A   rmdir ./

B   rm -r ./*

C   rm -r . /*

D   More than one of these will work

Start your own simulation of merging black holes

- Start from rest, collide head-on

- Choose mass ratio between 1 and 1.2

- Choose spin = 0,0,0 on the smaller black hole (B)

- Choose spin = 0,0,X on the larger black hole (A), where X is between 0 and 0.2

- Set Omega0 = 0, adot0=0, D0=35

```
cd $HOME
cd student_folders/YOURNAME
mkdir BlackHoleMerger
cd BlackHoleMerger
source /home/workshopStudents2019/spec/MakefileRules/
this_machine.env
/home/workshopStudents2019/spec/Support/bin/PrepareID -t bbh2 -no-
reduce-ecc
nano Params.input
# Omega0 = 0.0
# adot0 = 0.0
# D0 = 35.0
# MassRatio = 1.2 #or 1.0, or something in between
# @SpinA = (0.0, 0.0, 0.0) #can make 1 component up to 0.2 instead
of 0.1
# @SpinB = (0.0, 0.0, 0.0)
nano Ev/DoMultipleRuns.input
# MaxLev = 1
./StartJob.sh
```

```
squeue
squeue -j YOURJOBNUMBER
```

ocean.fullerton.edu/ganglia
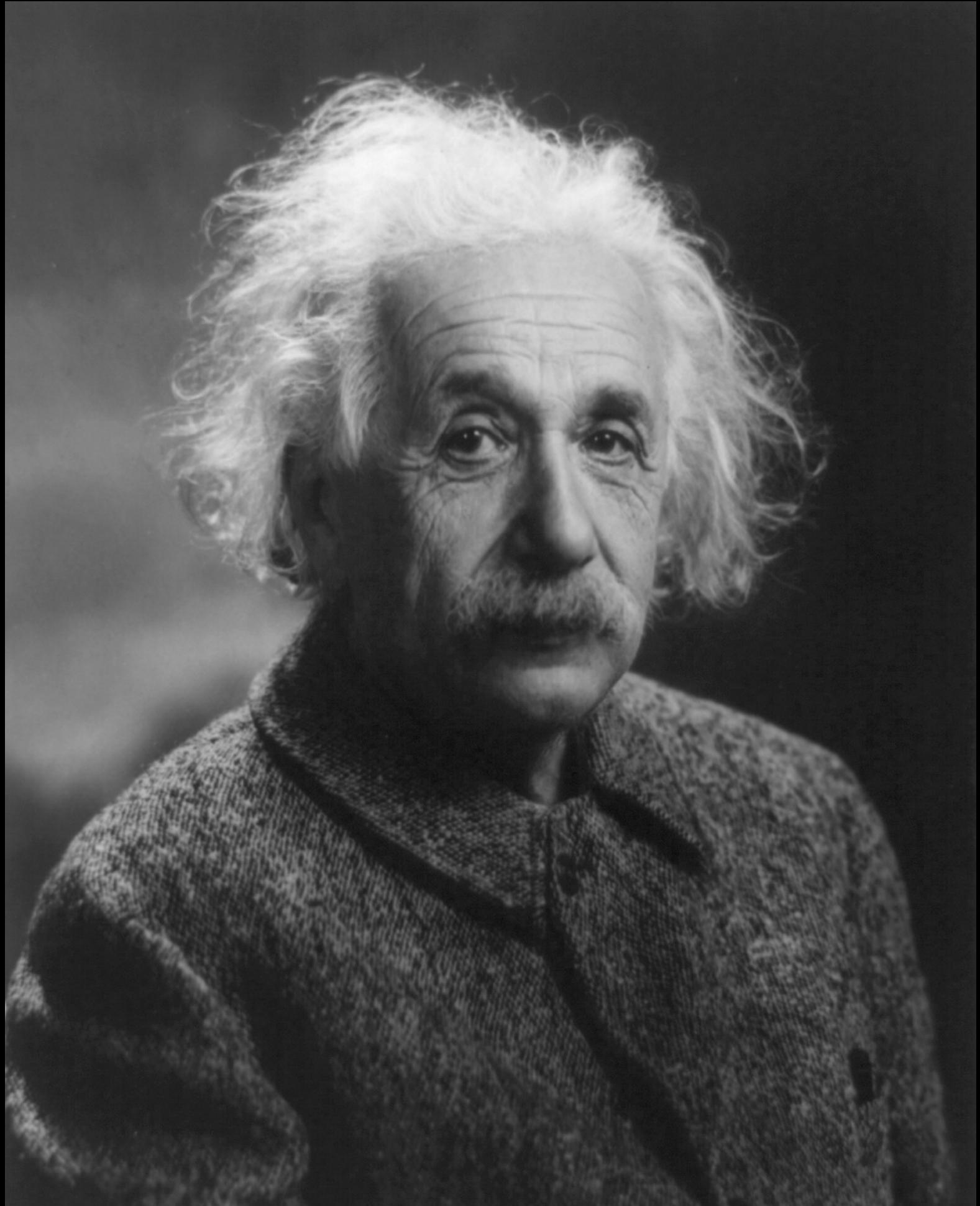
Unix activity

- **Commands to know**

  - ls, pwd, cd, mkdir

  - ./, ../, paths

  - cp, mv, rm, rmdir

  - cat, less

  - nano

  - whoami, date, …

- Use nano to write a bash script (each line is a command like you would enter on the command line)

- The script should…

  - Print the current date and time

  - Print the current directory

  - Copy /proc/cpuinfo into the current directory

  - Get the first line of the copied file, and save it to a file called FirstLineOfProc.txt

  - Bonus: Use grep to only show the line with "cpu cores"

  - Bonus: use sed to remove all but the core number

  - Bonus: instead of copying the /proc/cpuinfo file, copy whatever file users specify as an argument (google bash arguments)
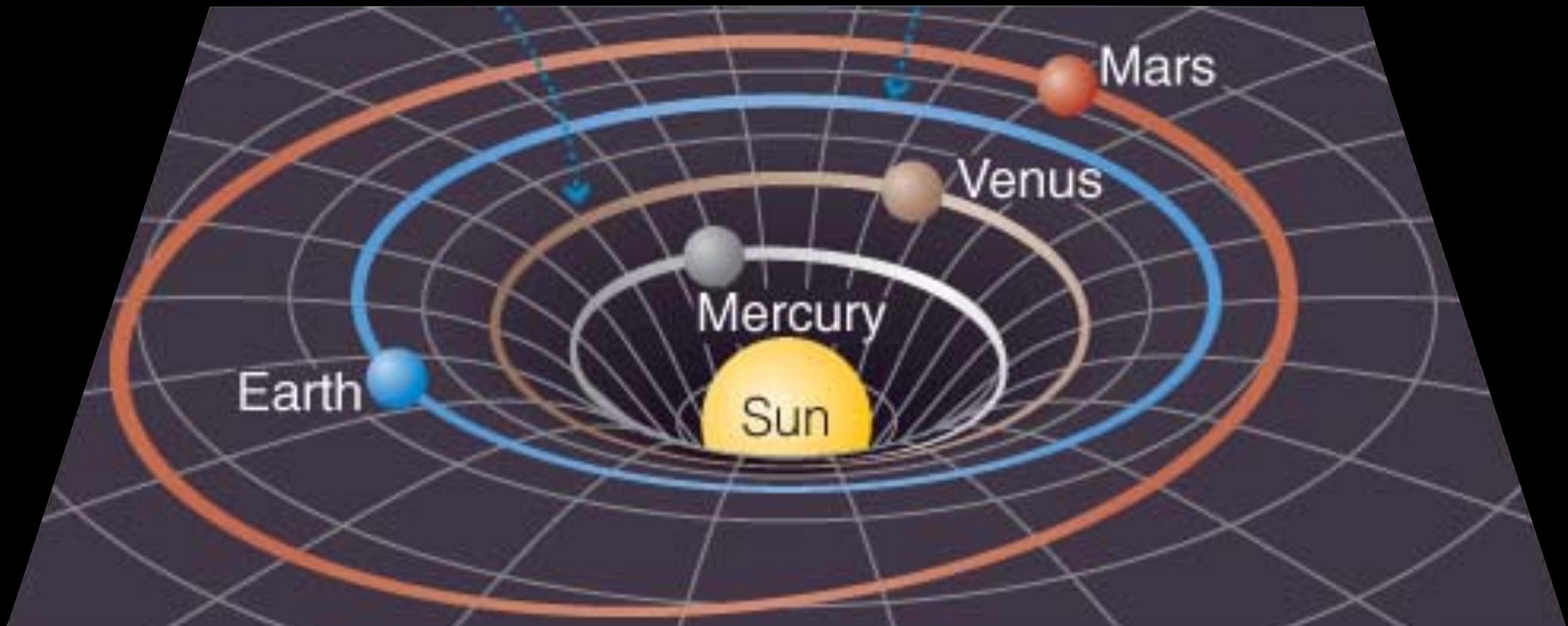
LITERARY CHARACTER AP'S	BEATLES PEOPLE	OLYMPIC OODITIES	NAME THE DECADE	FINAL FRONTIERS	ALTERNATE MEANINGS
$200			$200	$200	
$400	$400	$400	$400	$400	
$600	$600	$600	$600	$600	$600
	$800	$800	$800	$800	$800
$1000	$1000	$1000	$1000	$1000	$1000

23
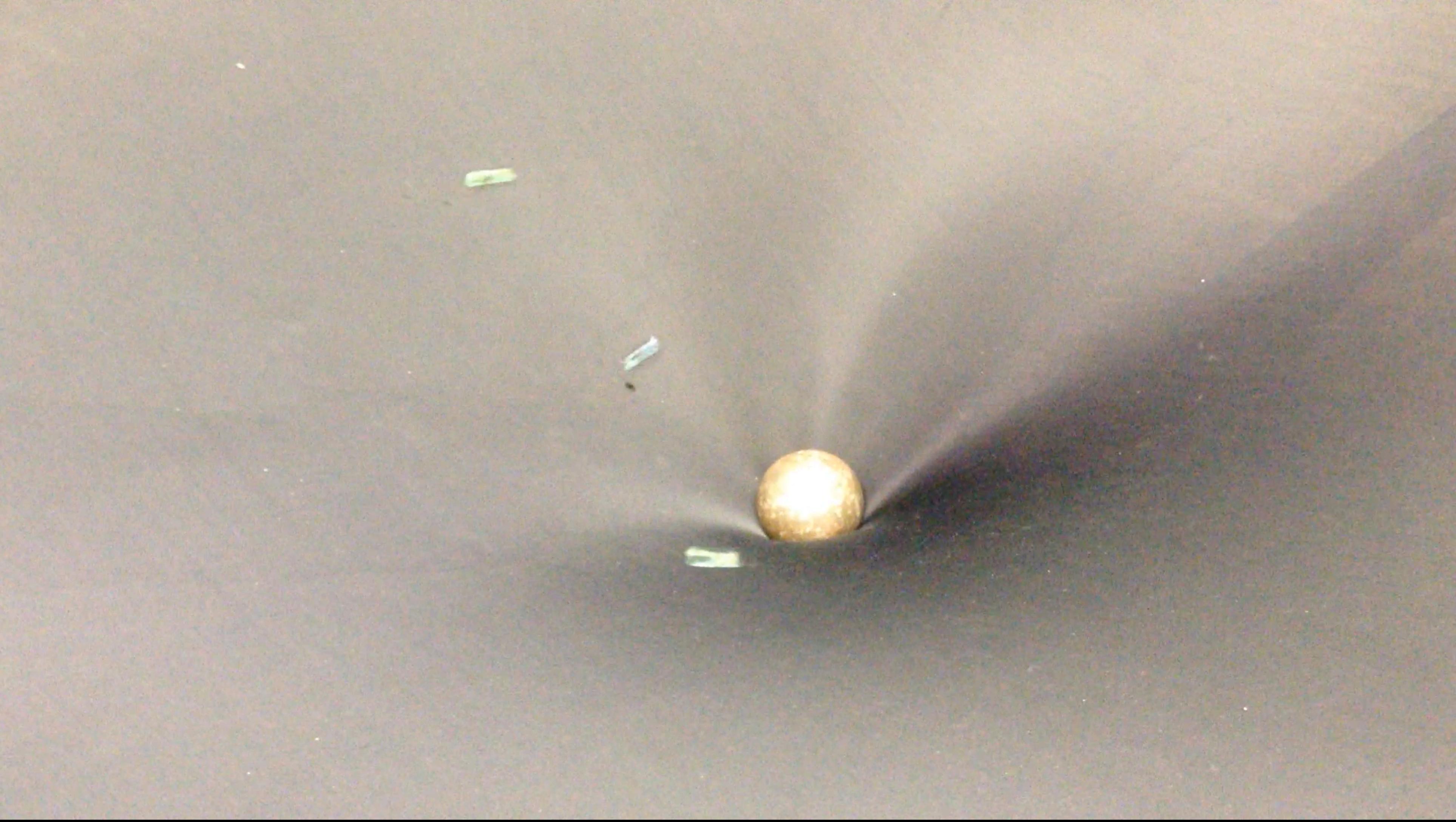
Curved spacetime

"Matter tells space-time how to curve and space-time tells matter how to move."
— John A. Wheeler
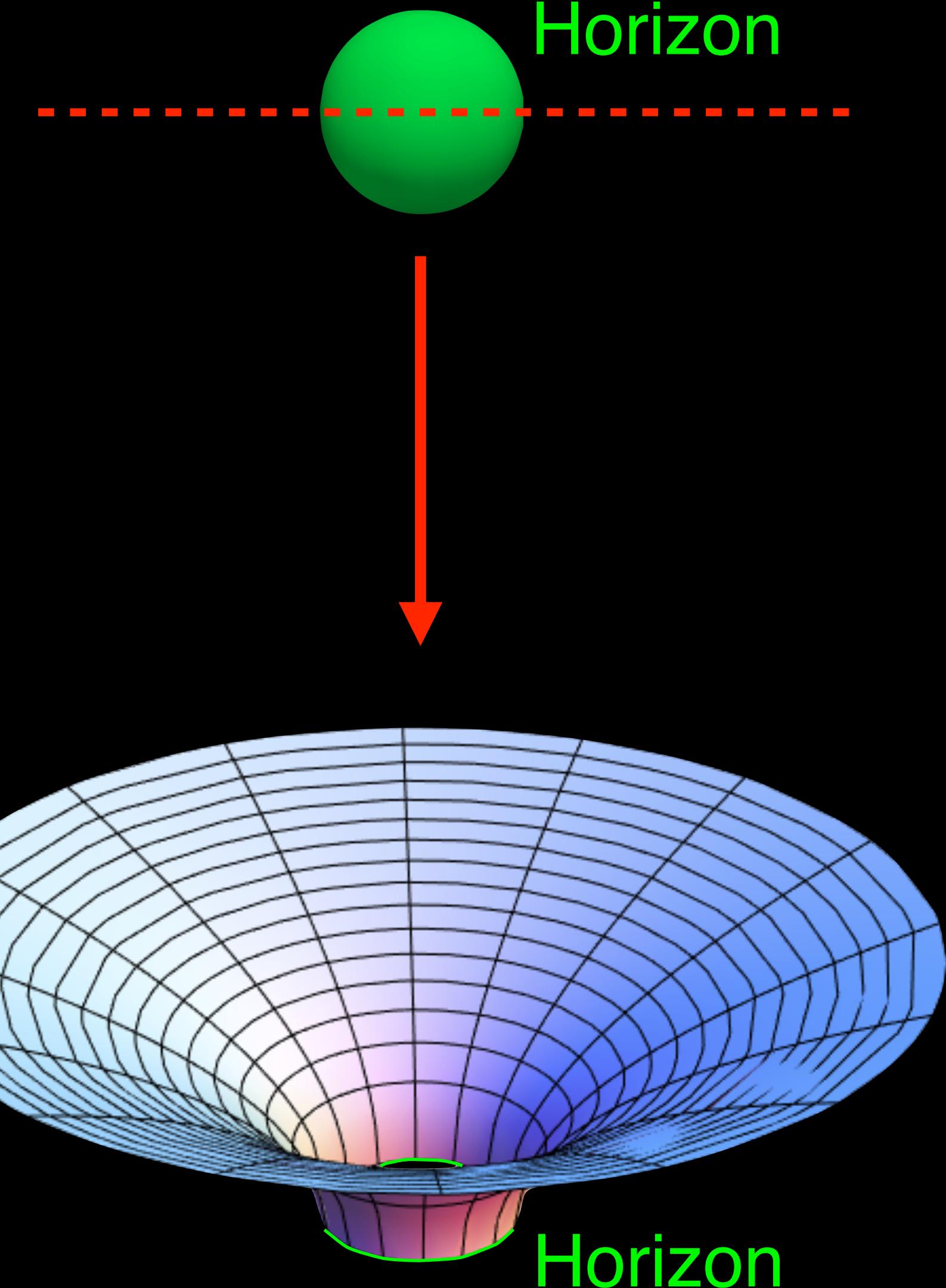
Credit: The Library of Congress

Larry Kiwano, Astrocamp, November 7, 2013

What are black holes?

- Gravity so strong...
  - Nothing (even light) can escape from inside hole's horizon (surface)
- Formed when the most massive stars die

Horizon

Horizon
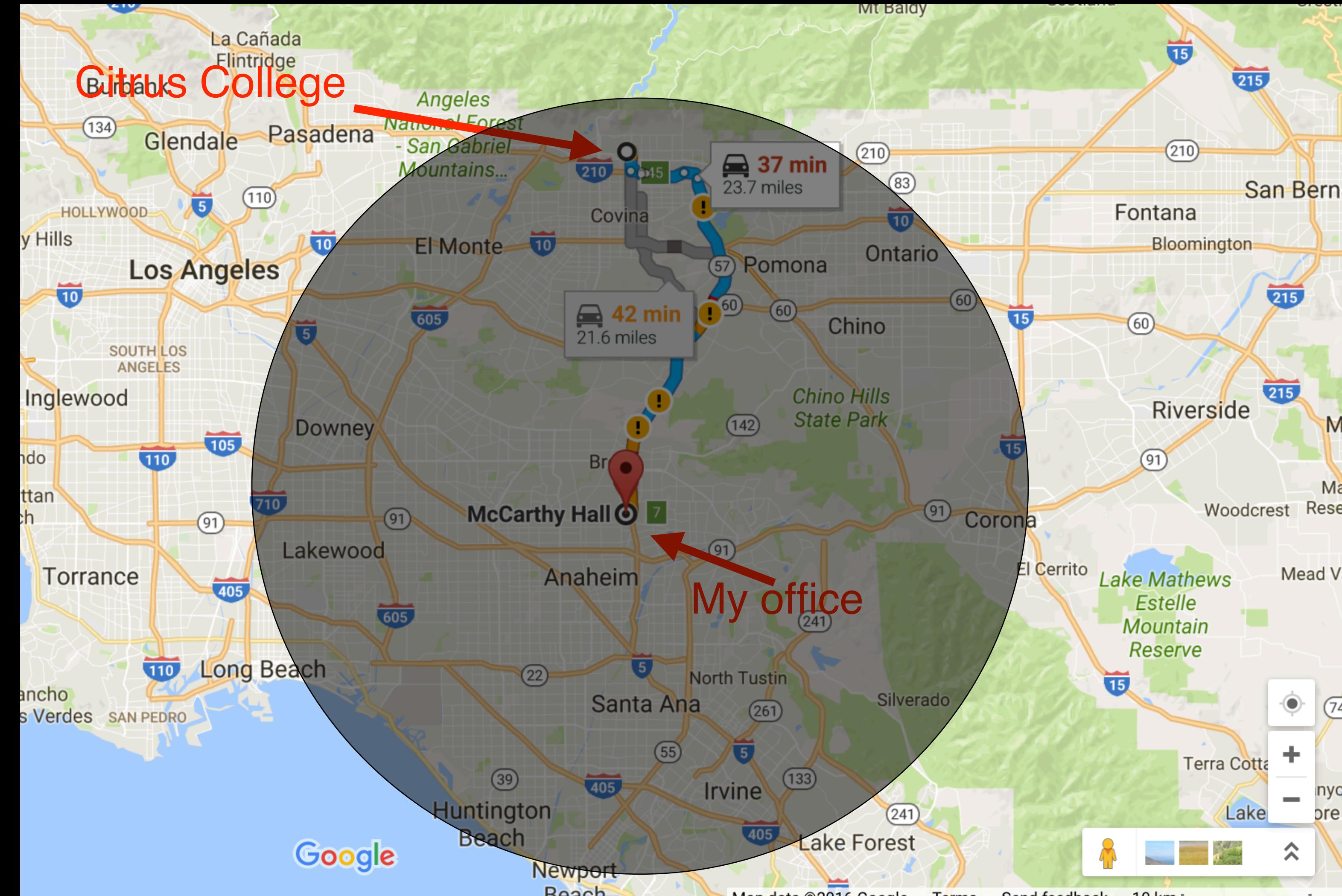
How big are black holes?

- Mass: huge!
  - Two kinds
  - 3 to 70 ☀️☀️
  - Millions+ ☀️

- Radius: small!

$$r = \frac{2G}{c^2}M = 3 \text{ km} \left(\frac{\text{mass}}{☀️} \right)$$

Images courtesy wikipedia

Size of earth-mass black hole

Citrus College

🚗 **37 min** 23.7 miles

🚗 **42 min** 21.6 miles

McCarthy Hall

My office

Google

Size of 10- ☀️ black hole

Image courtesy Google maps

Clicker question #3.1

- A black hole's circumference has doubled. The hole's mass has _____.
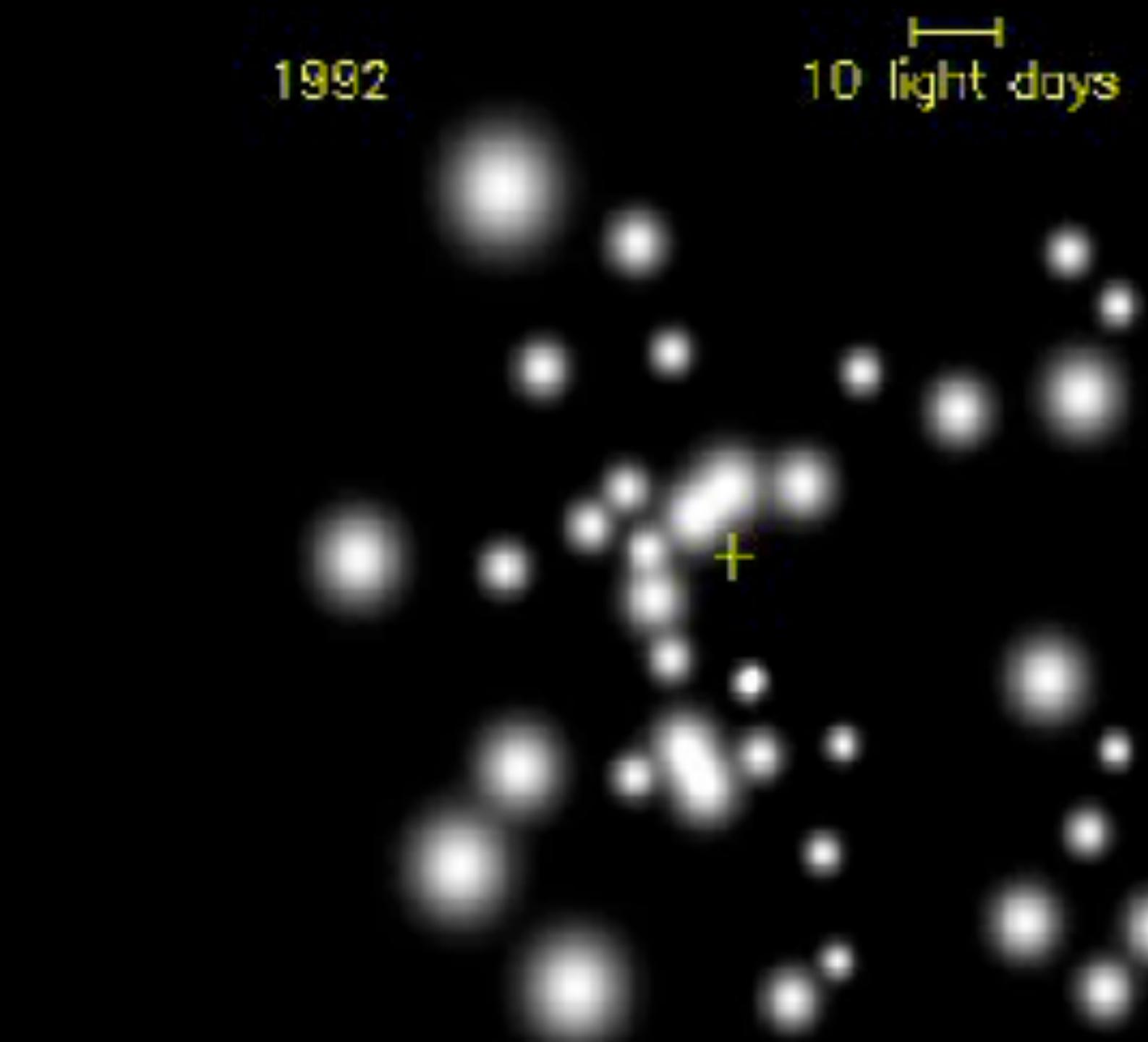
A halved

B not changed

C doubled

D quadrupled

How to observe black holes?

• Indirectly

– Gravity affects motion
of objects nearby: infer mass

– Gas heats up & glows as
it falls in: infer spin (uncertain!)

Cygnus X-1

1992   10 light days

Sagittarius A*

First black hole discovered

$M/M_{\mathrm{sun}} \approx 15$

$\chi \gtrsim 0.983$ — Gou *et al.* (2014)
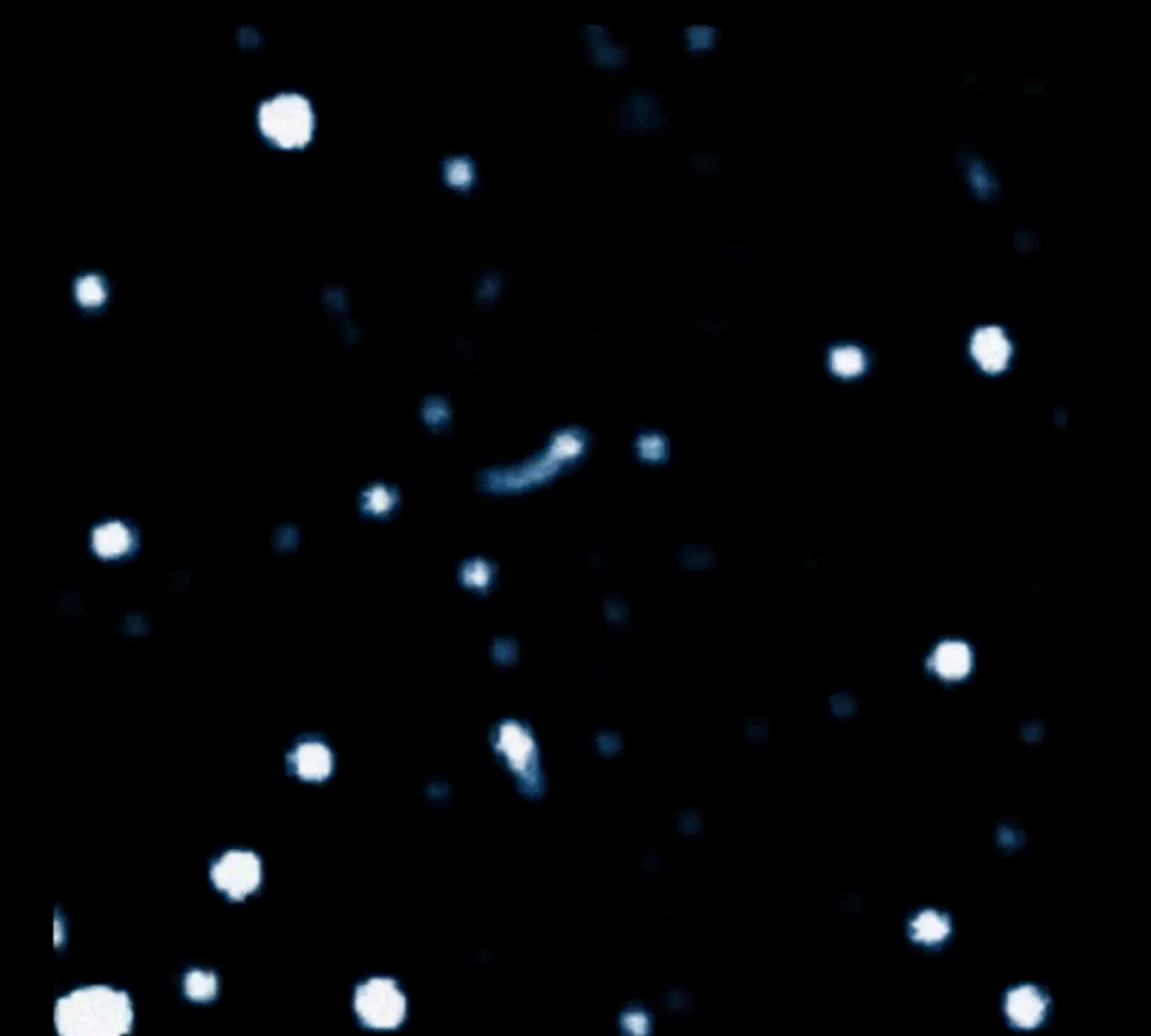
Black hole at center of our galaxy

$M/M_{\mathrm{sun}} \approx 4 \times 10^{6}$

$\chi \approx 0$ — Broderick *et al.* (2010)

20-year time lapse

ESO very large telescope

Movie courtesy ESO…2 weeks ago