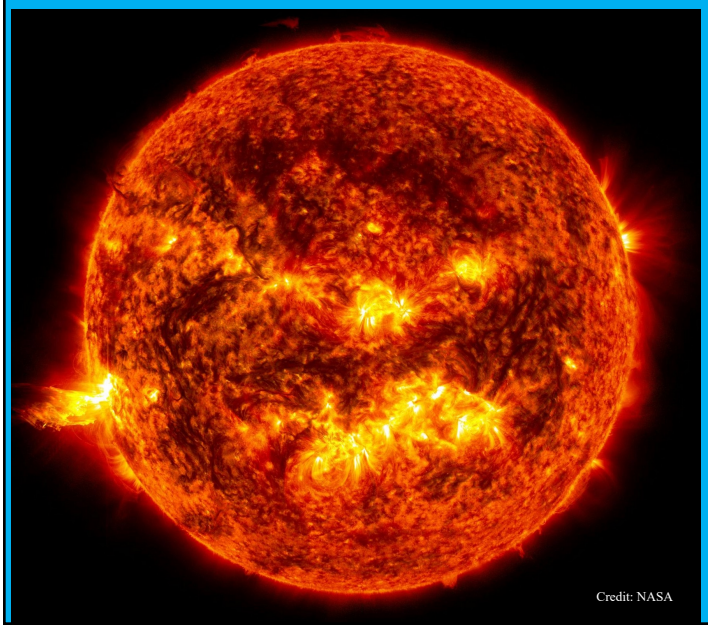
Gravity Wins
or
How the Universe Makes Stuff

- Some nomenclature so we can communicate
- Physical processes that initiate or resist movement
  1. Gravity
  2. Heat/thermal pressure

1

The Sun: A Typical Star



Mass =
300,000 Earths

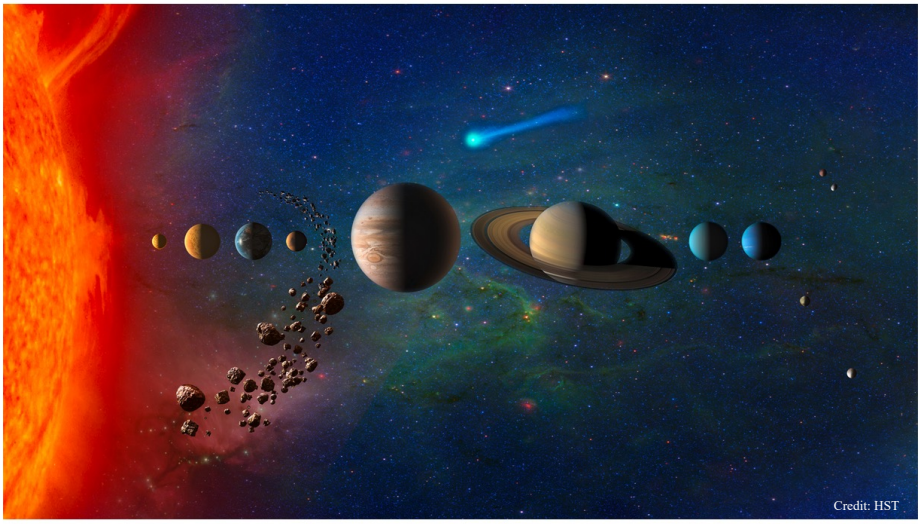
Diameter =
109 Earths

Volume =
680,000 Earths

Made of:
73.46% Hydrogen
24.85% Helium
0.77% Oxygen
0.29% Carbon
0.16% Iron

2

Solar System



An artist's concept of our solar system.

3

Star cluster: Pleiades

A few stars

4

Star cluster: Pismis 26

thousands of stars

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Star cluster: NGC 6440

hundreds of thousands of stars

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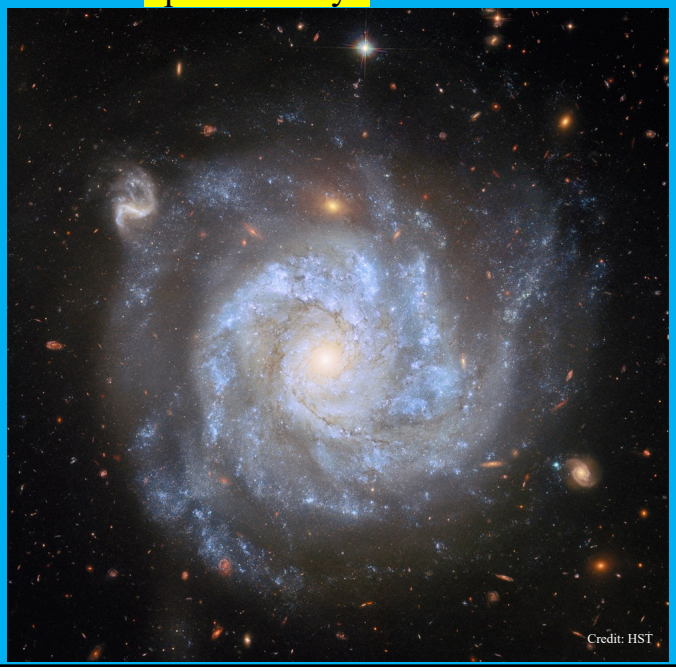
Spiral Galaxy: M81

hundreds of billions of stars + interstellar clouds

7

Spiral Galaxy: NGC 1309



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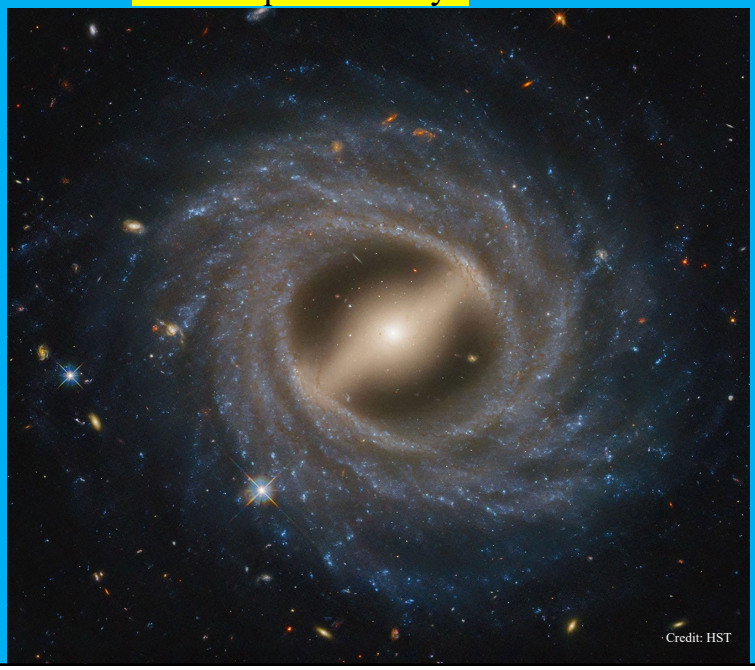
Barred Spiral Galaxy: NGC 5335



9

Edge-on Spiral Galaxy: Sombrero Galaxy

10

Giant Elliptical Galaxy: ESO 306-17

11

Interstellar clouds: Carina Nebula

Milky Way (visible light)

hundreds of light years across; thousands of solar masses

12

Interstellar clouds: CB 130-3

A few light years across; a few solar masses

13

Interstellar clouds: The Orion Nebula

Orion

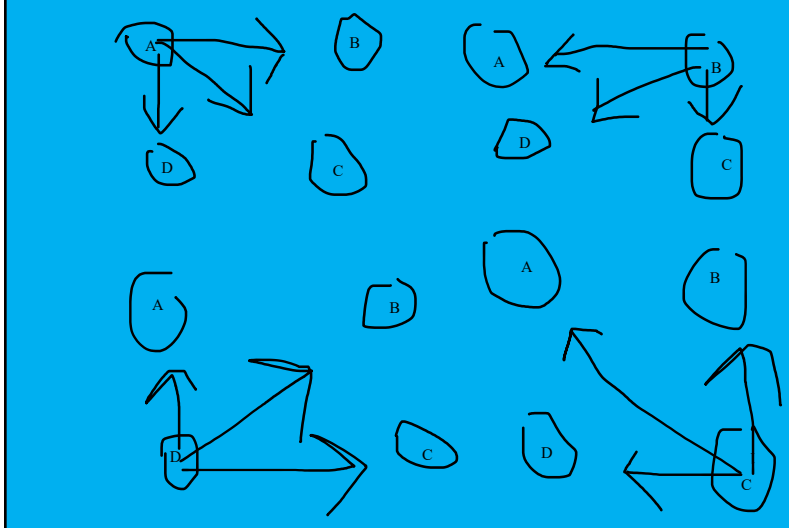
14

Gravity:

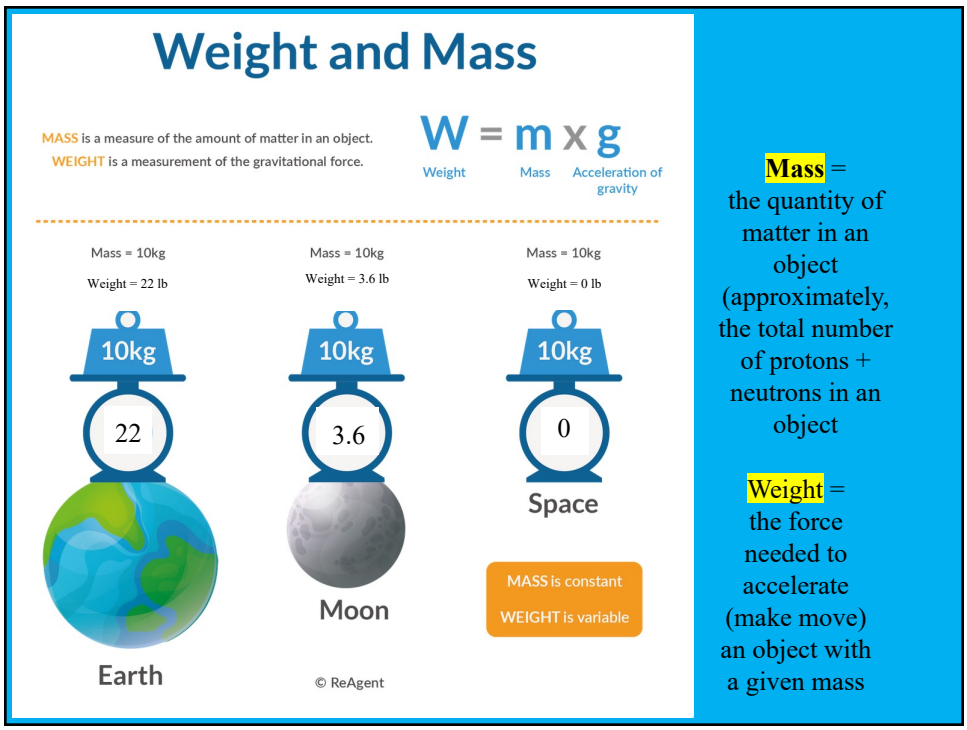
the force of attraction between any two objects in the universe because they have mass

All particles with mass attract all other masses

15



16



Mass = the quantity of matter in an object (approximately, the total number of protons + neutrons in an object

Weight = the force needed to accelerate (make move) an object with a given mass

17

Gravity:

the force of attraction between any two objects in the universe because they have mass

All particles with mass attract all other masses

- **More mass: stronger attraction**
- **Less mass: weaker attraction**
- **Closer together: stronger attraction**
- **Further apart: weaker attraction**

18

$$F_{gravity} = -G\,\frac{Mass_A Mass_B}{(Distance)^2}$$

$F_{gravity}$= force of gravity

The negative sign indicates *attraction*
G is a number (Newton's constant)
$Mass_A$ is the mass of particle A
$Mass_B$ is the mass of particle B
Distance is how far apart A and B are

19

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How far apart must you separate two masses in order to reduce $F_{gravity}$ to zero?

20

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No matter how far apart two masses are,
the force of gravity is always greater than zero!

21

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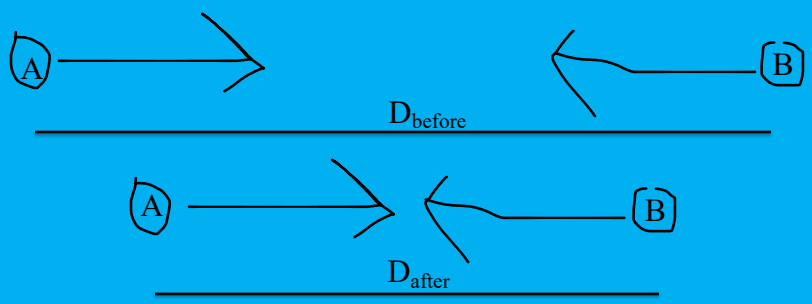

How does the force of gravity change if the particles are moved closer together?

22

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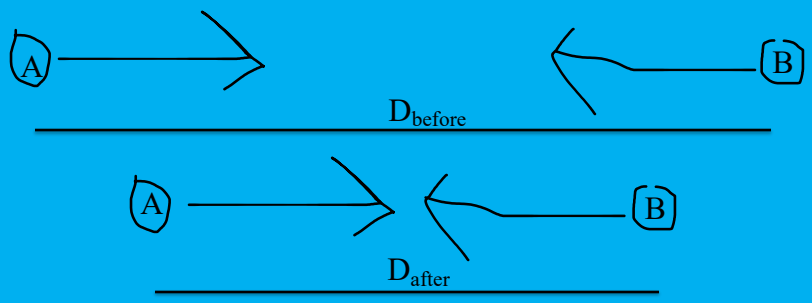
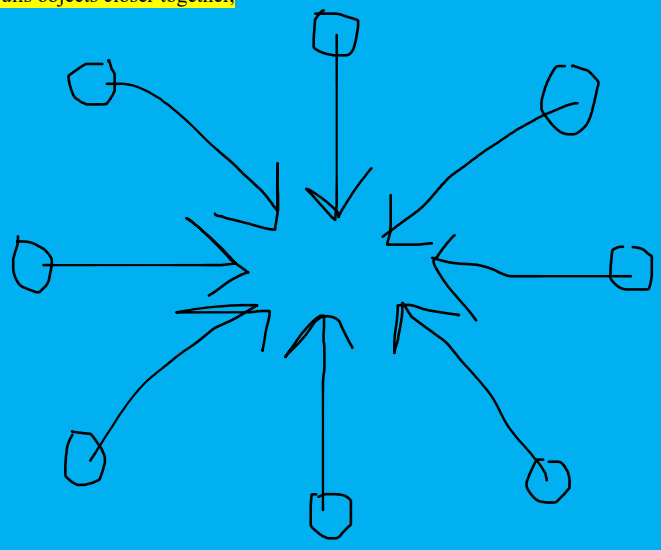


If: "Distance" changes to a smaller number ($D_{after} < D_{before}$)
Then: $F_{gravity}$ gets bigger

23

So:

As gravity pulls objects closer together,

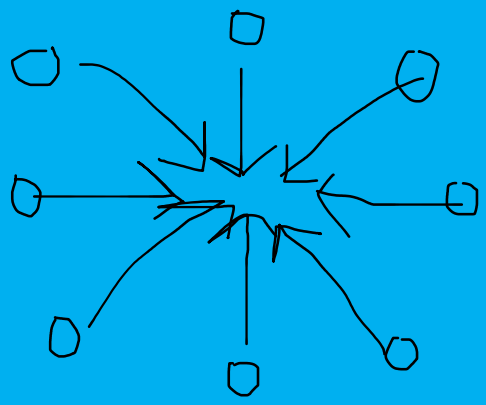


24

So:

As gravity pulls objects closer together,

the force of gravity gets stronger,
which pulls objects closer together even more strongly!



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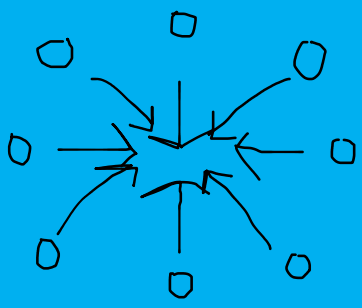

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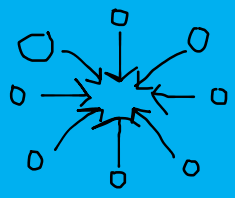

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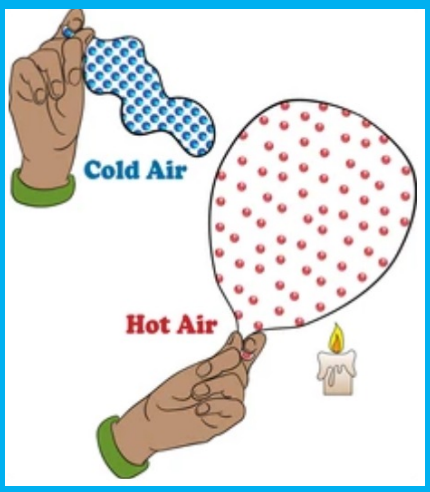
CAN ANYTHING STOP GRAVITY?

29

YES

thermal pressure can resist gravity

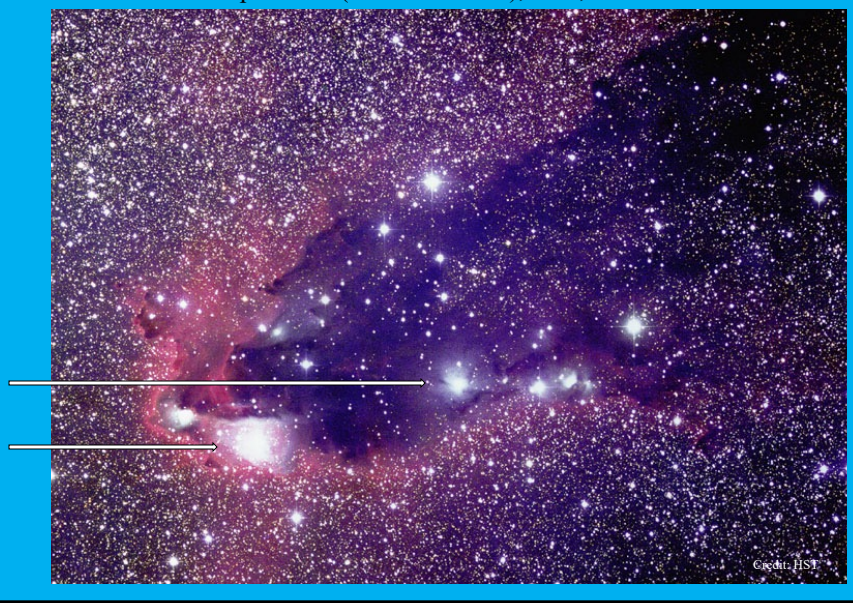


Images: shutterstock

30

Stellar Wombs

Stars are born deep in cold (10 K = - 440°F), dark, dense interstellar clouds



31

Gravity starts to make a star

- Turbulence and random processes fragment an interstellar cloud
- Within each fragment, all parts of the cloud fragment attract all other parts of the fragment
- result: each cloud fragment squeezes itself, with all atoms pulled toward that fragment's center

32

Think of a collapsing interstellar cloud fragment as a huge "balloon" of gas that can expand or contract

Gasses are characterized by pressure, temperature and volume (Ideal Gas Law: PV = nRT)

As gravity squeezes the cloud …

V gets smaller

P goes up faster than V goes down, so T goes up

Higher P resists gravity (gravity loses, for now)

But since T went up, the cloud becomes hotter than its surroundings

Now the cloud is too warm; it radiates heat and cools off (T goes down)

If T goes down, P goes down

If the P goes down, gravity squeezes the cloud and makes it smaller …

33

The Birth of a Star

- Initially, the collapsing core is transparent --- light can get out. So it radiates away the excess heat.
- core gets smaller, denser, but not much hotter

34

- Finally, density is high enough that cloud becomes opaque
- Since light can't easily escape, cloud starts to heat up
- As it heats up, pressure increases, starts to push back against gravity

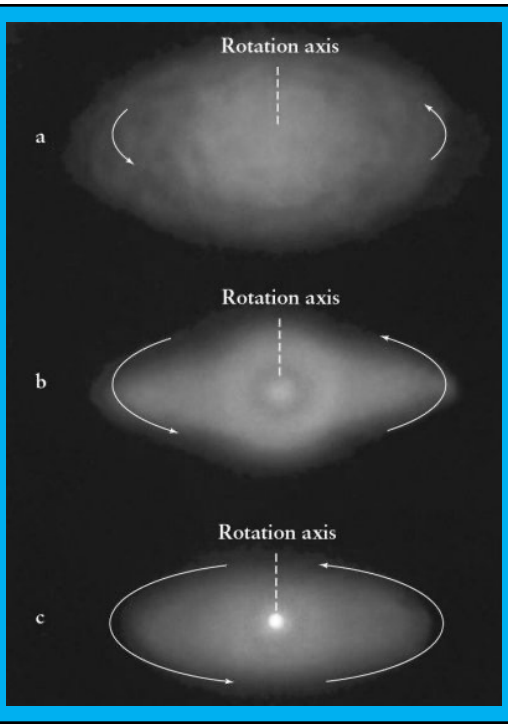
35

Collapsing cloud core bursts into view as a visible **protostar**

McNeil's nebula

36

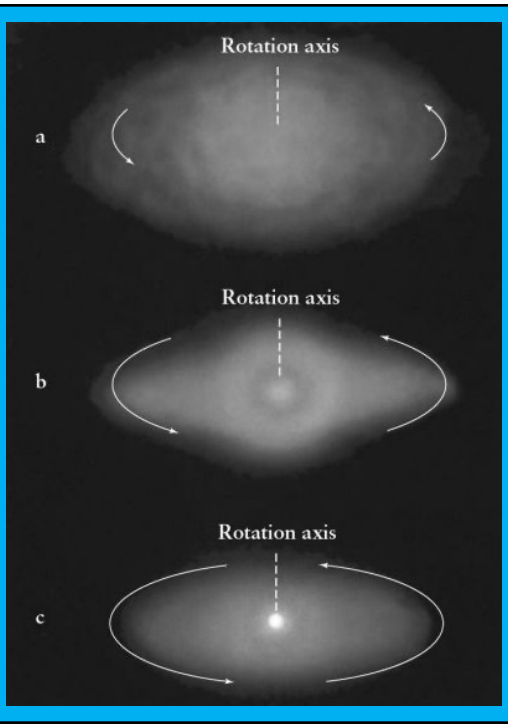
What if the cloud, which is collapsing due to gravity, is spinning?



37

It pancakes

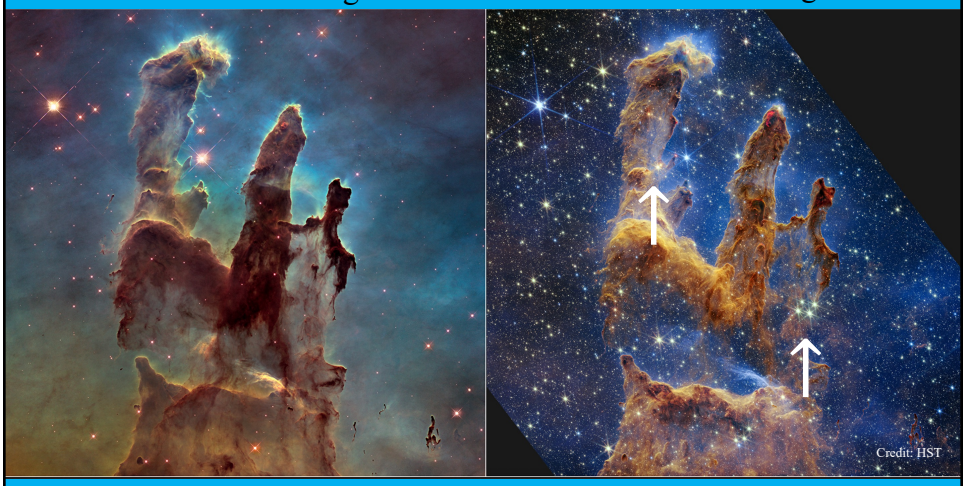
With the protostar at the center



38

HST: visible light

JWST: infrared light

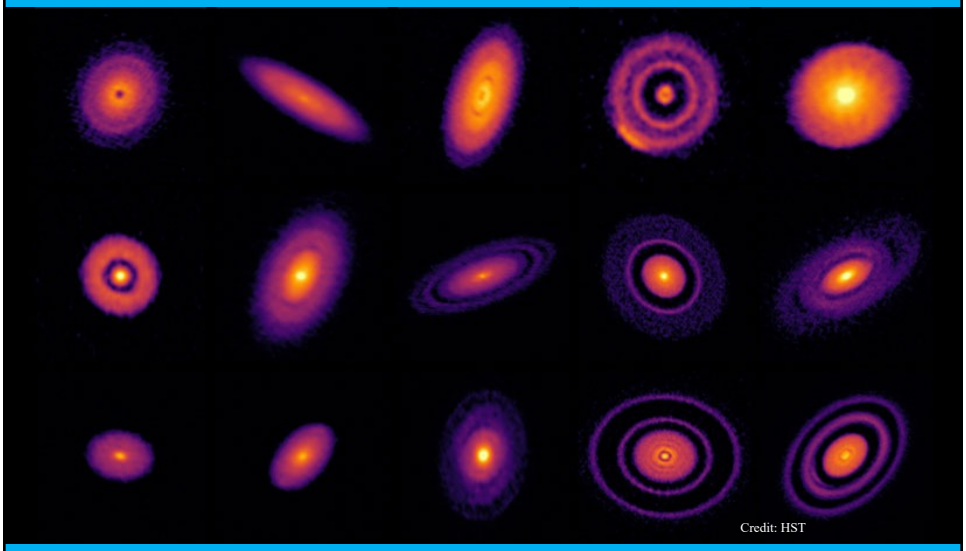


HST: visible light

Newborn stars!

39

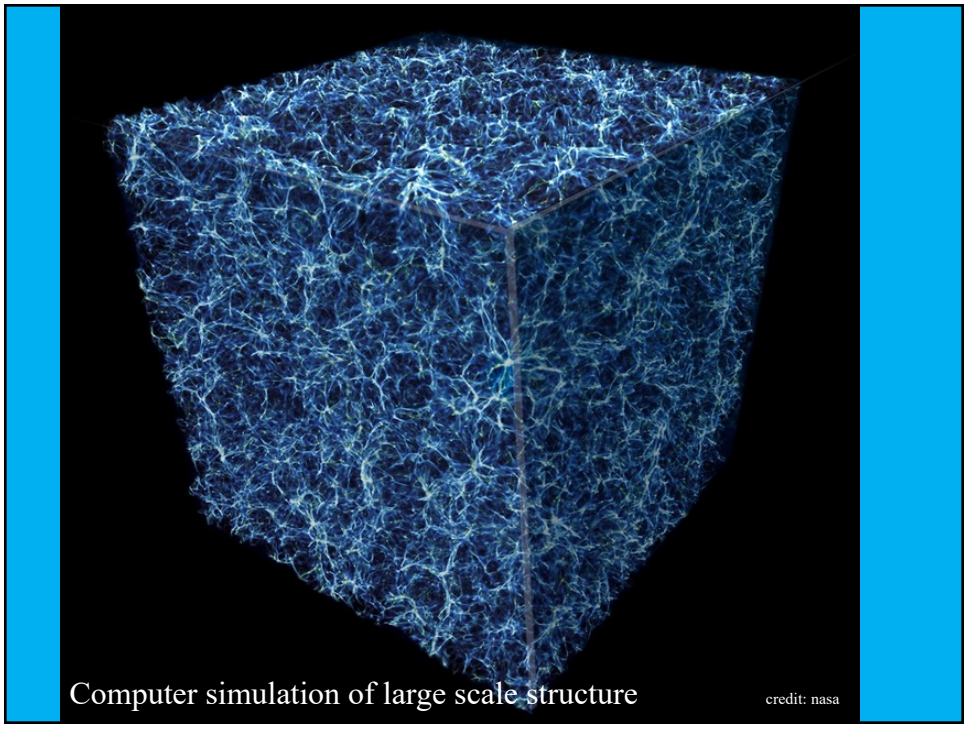
protostars, still surrounded by their disks



40


Whirlpool galaxy
Disk around forming protostellar system
Ecliptic plane of solar system
Saturn with rings

41


Computer simulation of large scale structure
credit: nasa

42