POP III STARS

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OUTLINE

1. Motivation/Definitions

2. Formation

3. Evolution

4. Observational evidence?

MOTIVATIONS

- If the early universe was metal free, how did metals form and spread?

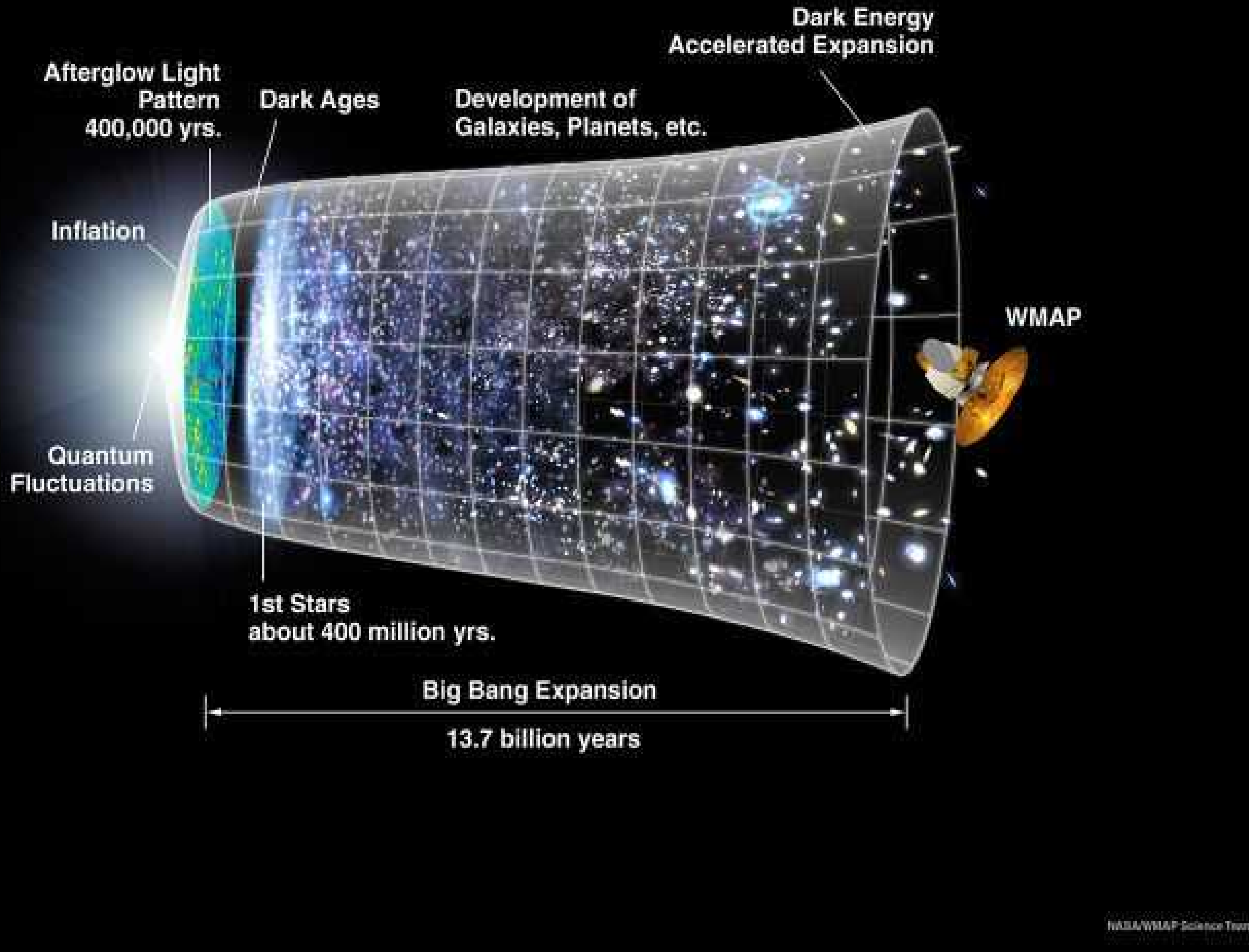
- Metals are observed ~<10% current age of universe, only the supernovae of massive stars could provide such enrichment

Population III Stars

The hypothesized first stars in the universe, and thus metal free.

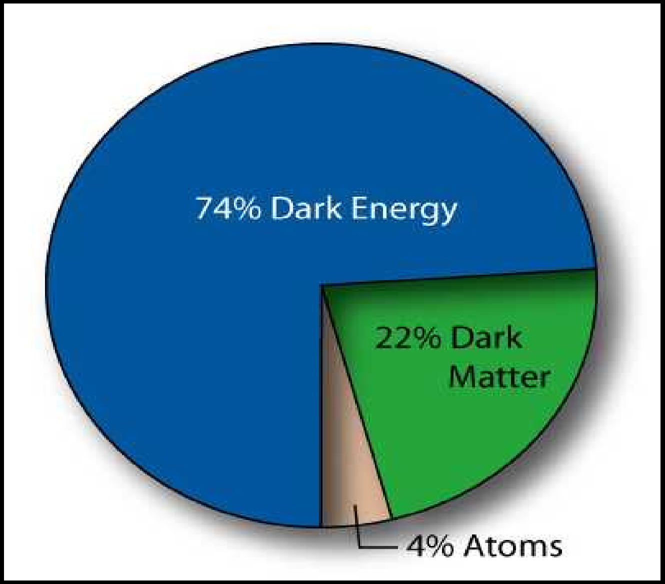
Without any metals, could the gas cool to condense and form stars?

When, where, and how would they have formed?



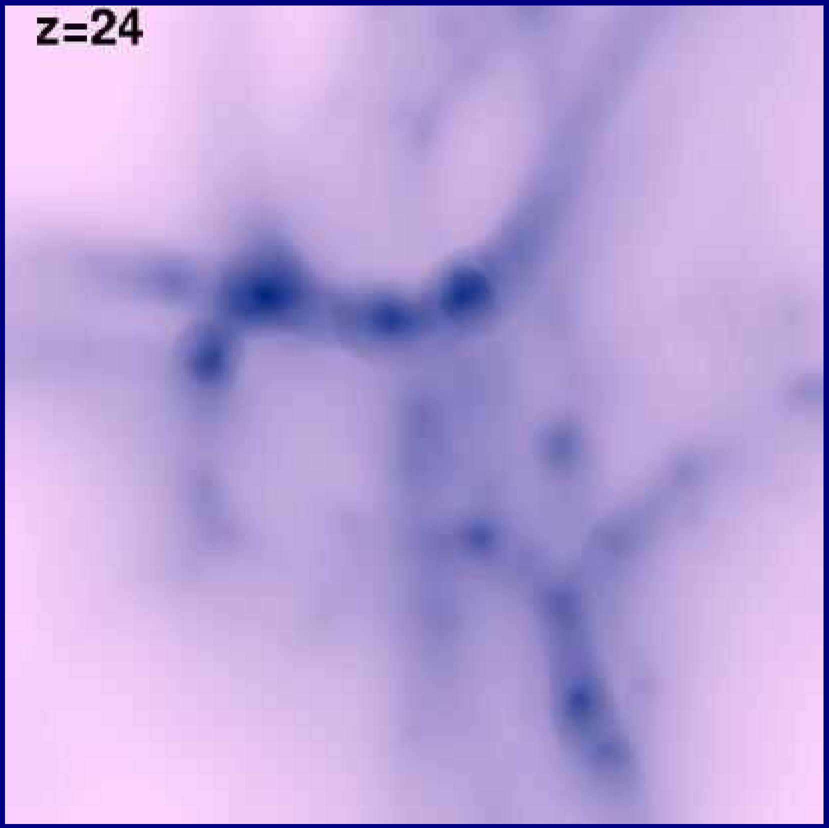
Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
400,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
WMAP
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years
NASA/WMAP Science Team

The Early Universe



H,
He/H~0.25,
2H/H~10^-3,
Li/H~10^-9
(in mass)

100 million years after Big Bang

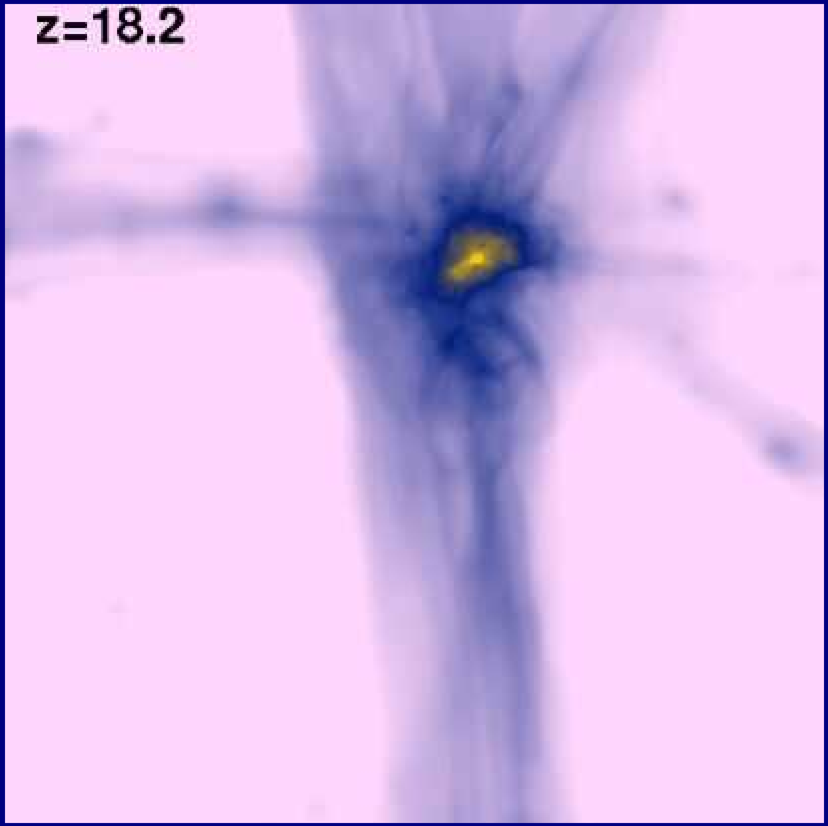


High resolution, 'cosmological hydrodynamic' simulations show the filamentary nature of dark matter

Abel et al, 2000

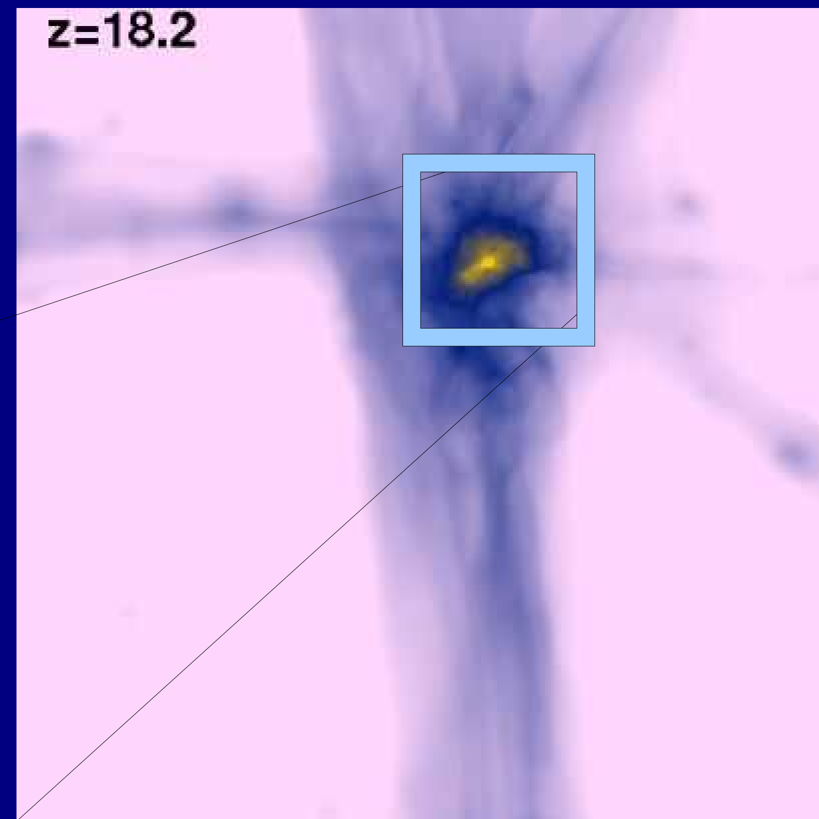
155 million years after Big Bang

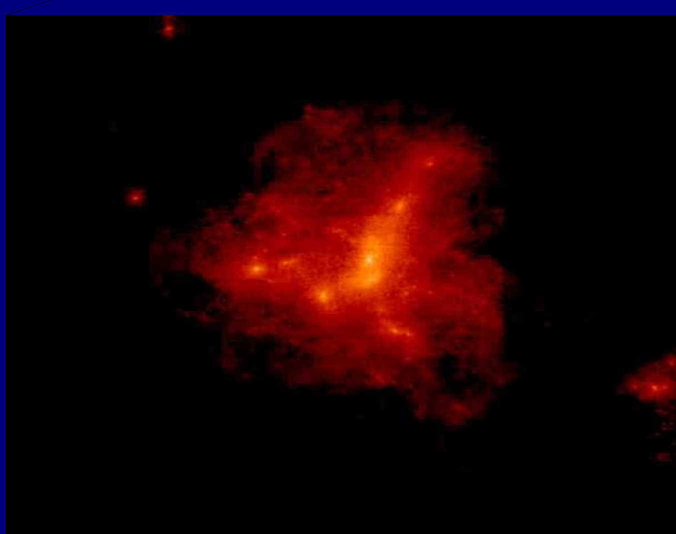
Primordial gas condenses in the nodes of these dark matter filaments



Abel et al, 2000

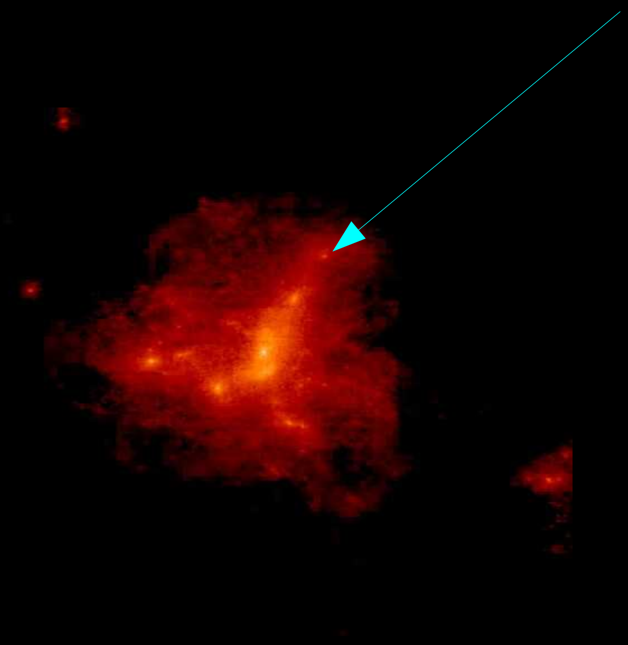
Mini-halo:
T~1000 K
M~ (10^6-10^8 sol M)





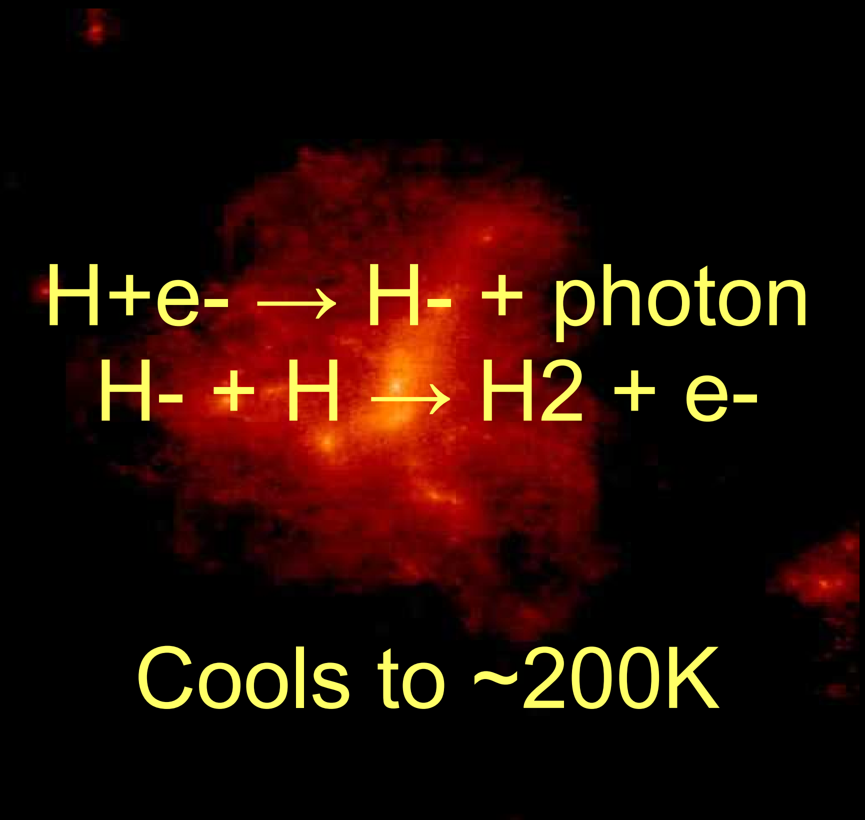
Abel et al, 2002

Cooling leads to proto-stellar collapse



At these temperatures, the dominant coolant is
~H2~
rotational/vibrational transitions

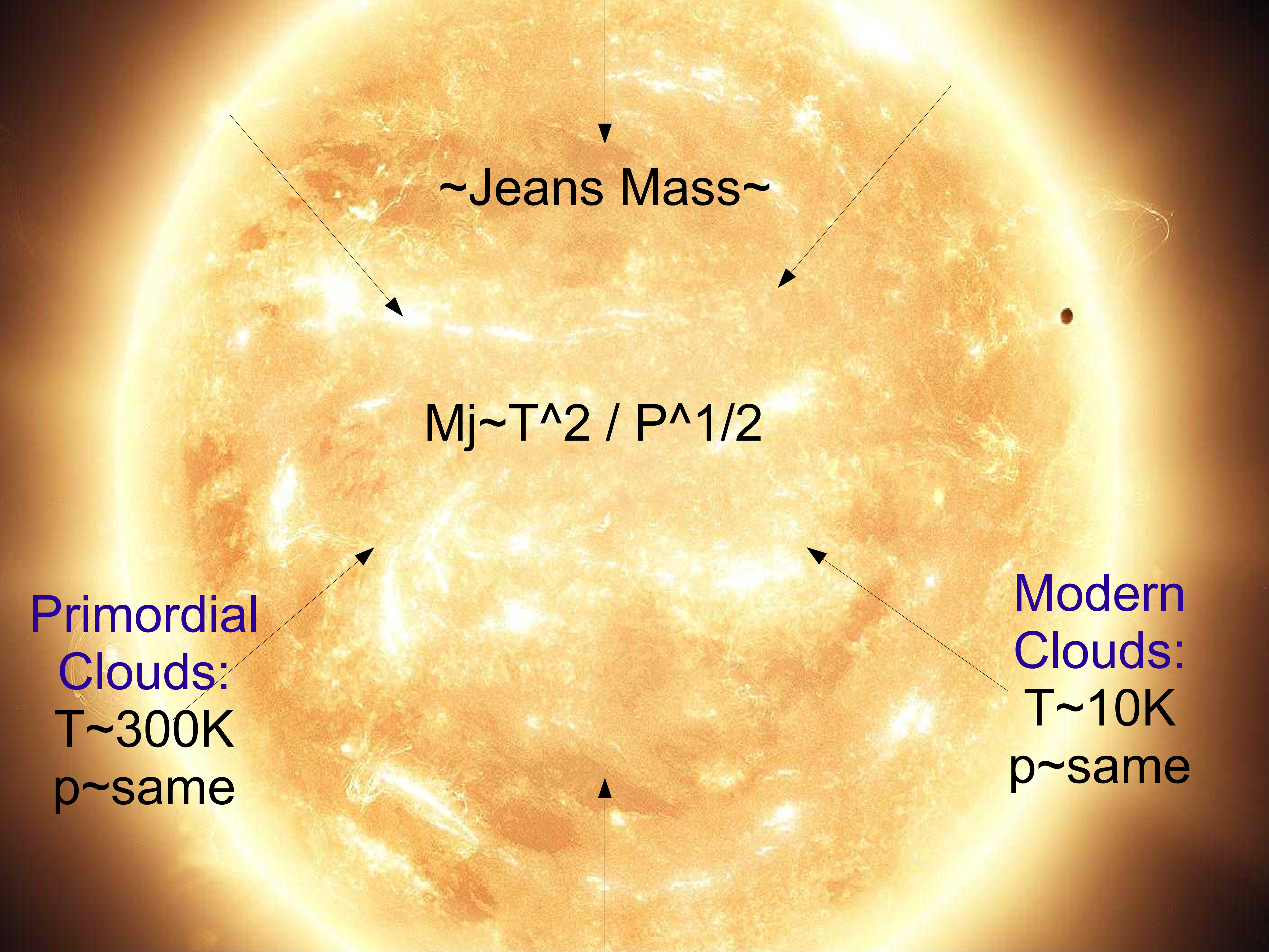
H2 formation in gas phase:

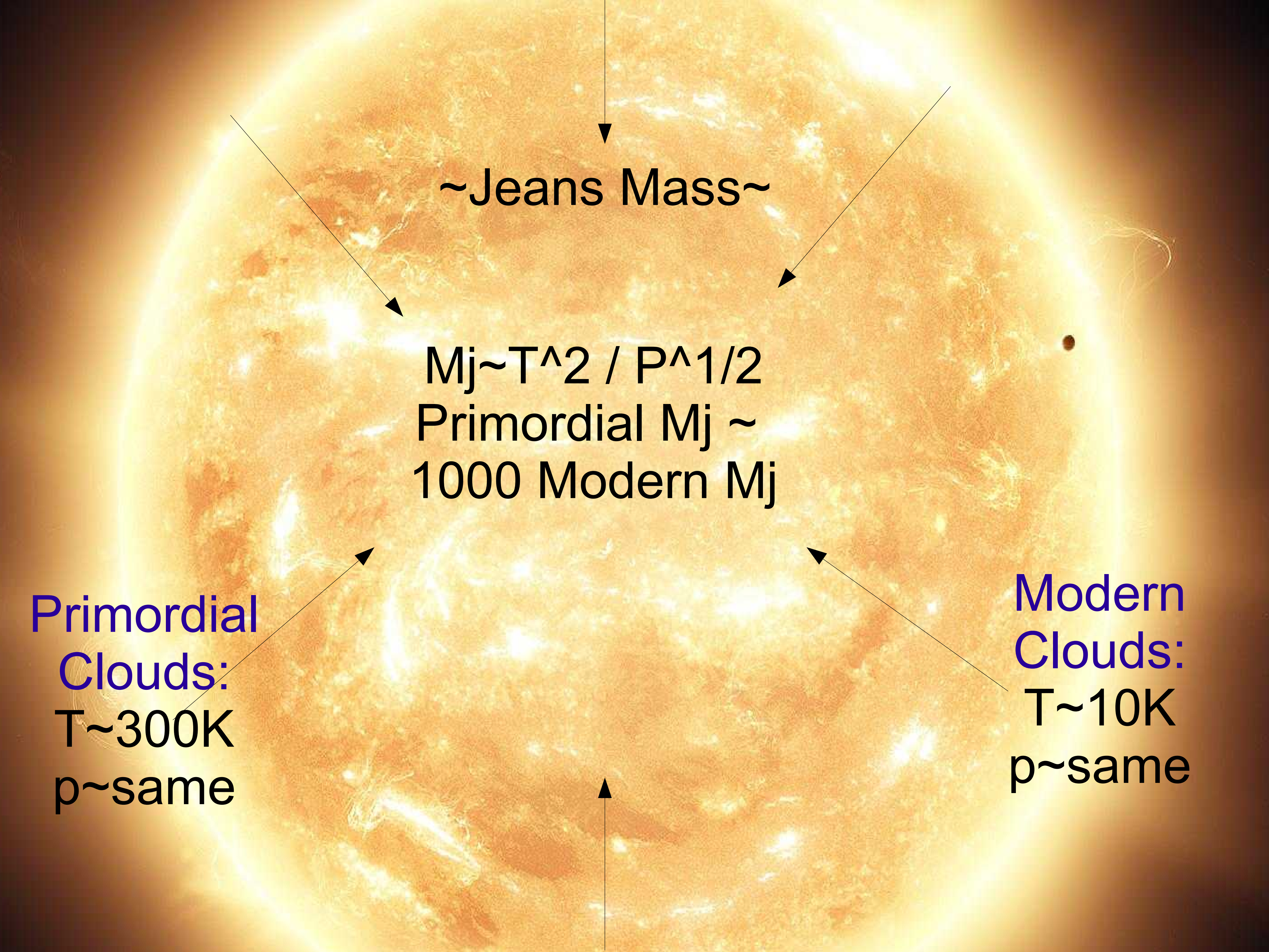


H+e- → H- + photon

H- + H → H2 + e-

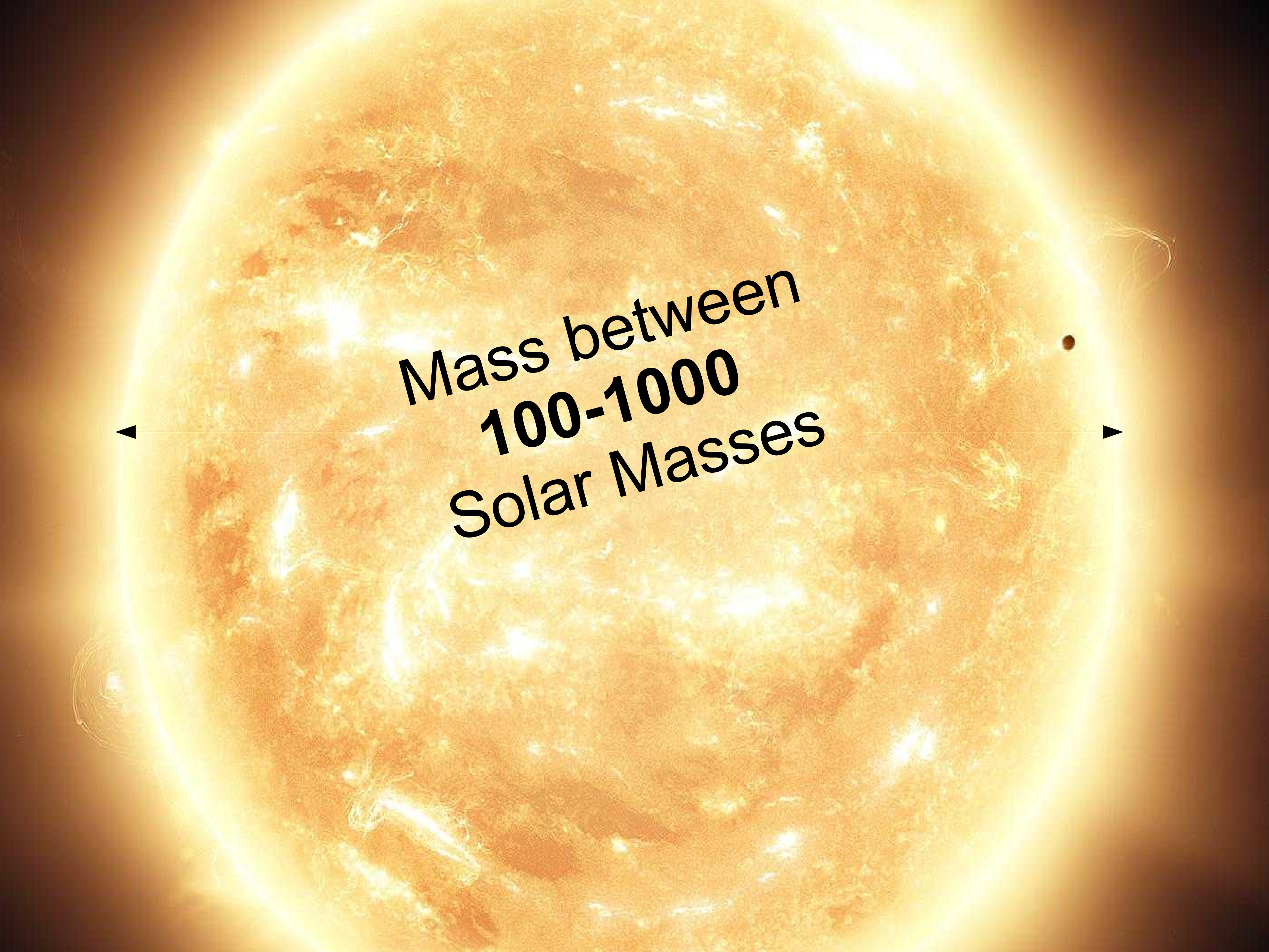
Cools to ~200K


~Jeans Mass~
Mj~T^2 / P^1/2
Primordial Clouds:
T~300K
p~same
Modern Clouds:
T~10K
p~same


~Jeans Mass~
Mj~T^2 / P^1/2
Primordial Mj ~
1000 Modern Mj
Primordial
Clouds:
T~300K
p~same
Modern
Clouds:
T~10K
p~same

~Accretion Processes~
To determine final mass

- Similarity soln's (e.g. Larson-Penston, Shu)
- Simulation set
- Other pieced-together soln's


Mass between
100-1000
Solar Masses

Main Sequence Evolution of POPIII stars (Super-massive)

In H(80%) and He(20%) stars of M>20 sol M,

PP-chain is not enough to balance contraction – stars continue to contract and heat … to ~10^8K!

Pop III stars MUCH hotter and smaller than POP I/II counterparts

TABLE I
The physical characteristics of the models at the zero-age main-sequence

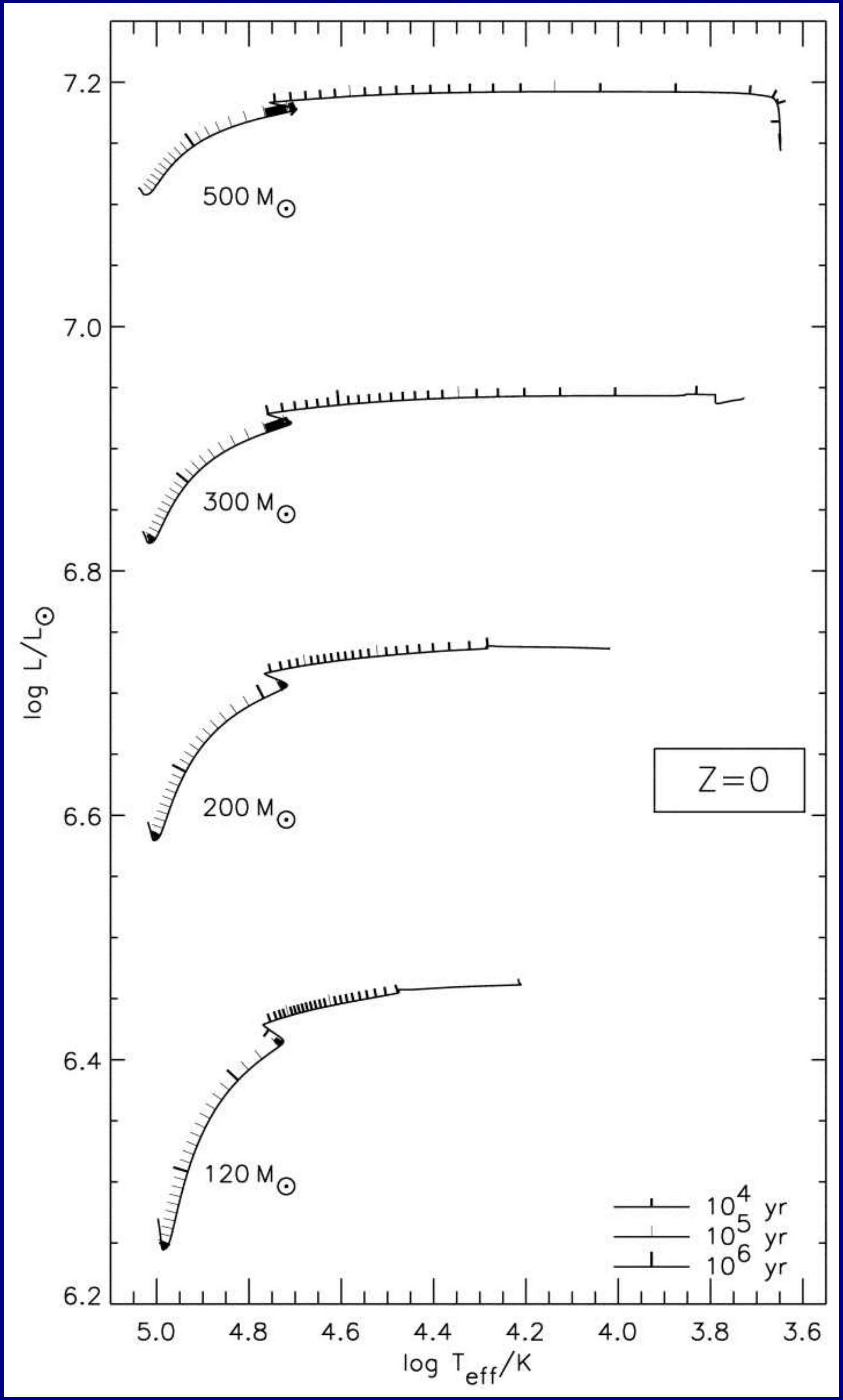
$M/M_\odot$	t_{zams} yr	$R/R_\odot$
5	4.24×10^6	1.33
10	1.68×10^6	1.54
20	3.81×10^5	1.76
30	2.50×10^5	2.11
100	1.46×10^5	3.38
200	1.71×10^5	4.33

Ezer & Cameron

At around 10^8K, *triple-alpha* starts on main sequence to generate trace amounts of ^{12}C

CNO cycle begins!

Contraction halts, and the star burns H->He through this cycle with $T_c \sim 10^8$, $T_e \sim 10^5$

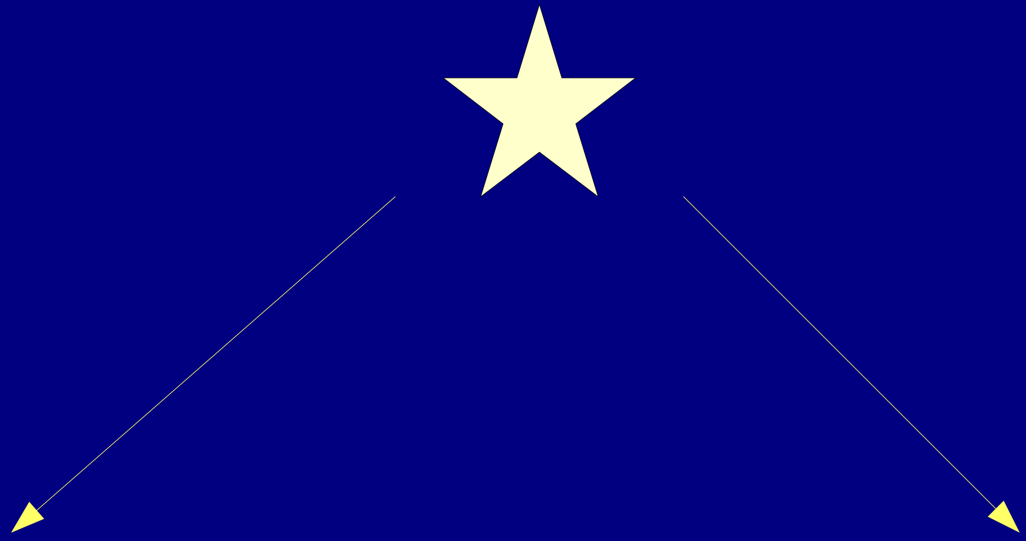


HOT, LUMINOUS

POP II counterparts would lie to the right on this diagram

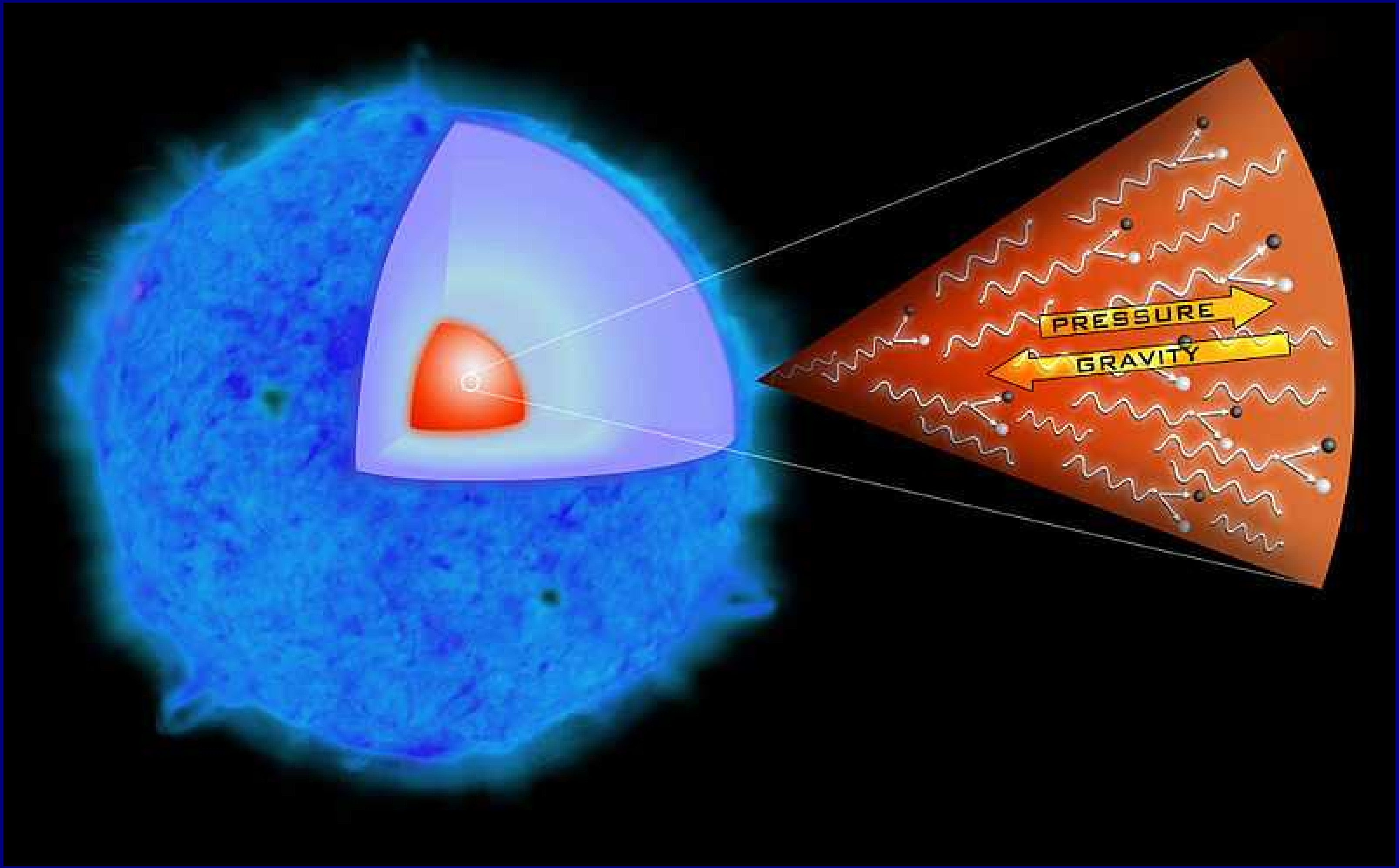
Baraffe, 2001

The fate of supermassive POP III stars



BLACKHOLE
(<140, >260
sol M)

PAIR
INSTABILITY
SUPERNOVA
(140-260 sol M)



“This illustration explains the process that astronomers think triggered the explosion in SN 2006gy. When a star is very massive, its core can produce so much gamma-ray light that some of the energy from the radiation is converted into particle and anti-particle pairs. The resulting drop in energy causes the star to collapse under its own huge gravity. After this violent collapse, runaway thermonuclear reactions (not shown here) ensue and the star explodes, spewing the remains into space.”

http://chandra.harvard.edu/photo/2007/sn2006gy/more.html


NO DIRECT EVIDENCE OF METAL-FREE STARS
HAVE YET BEEN FOUND

However, there are lots of reasons we may not see them today:

1. Massive, died along time ago
2. Telescopes (they are far away man!)
3. Lack of supernovae remnants
4. Nucleosynthesis may obscure them
5. Travel through ISM, dirty them
6. others?

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