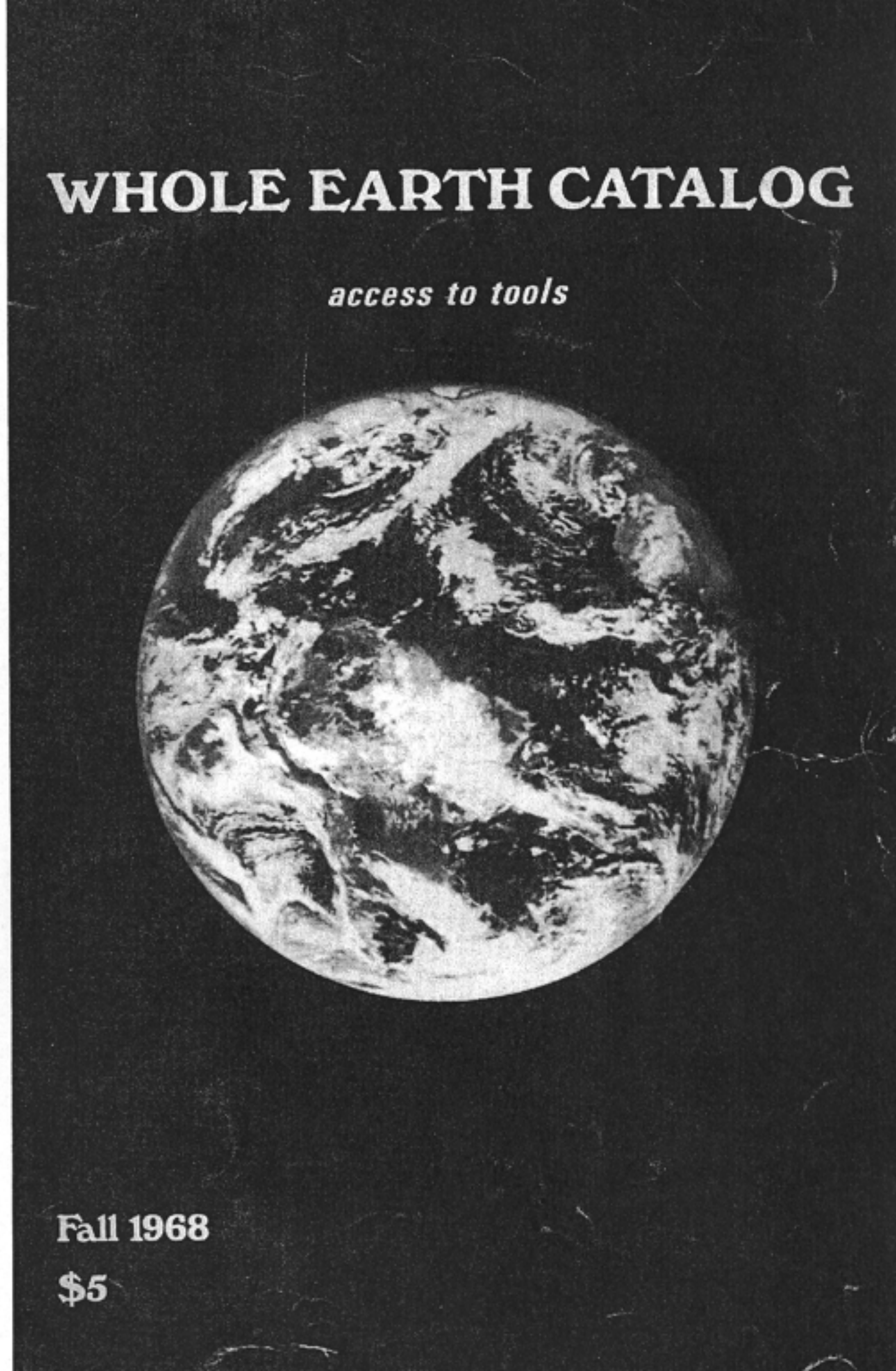
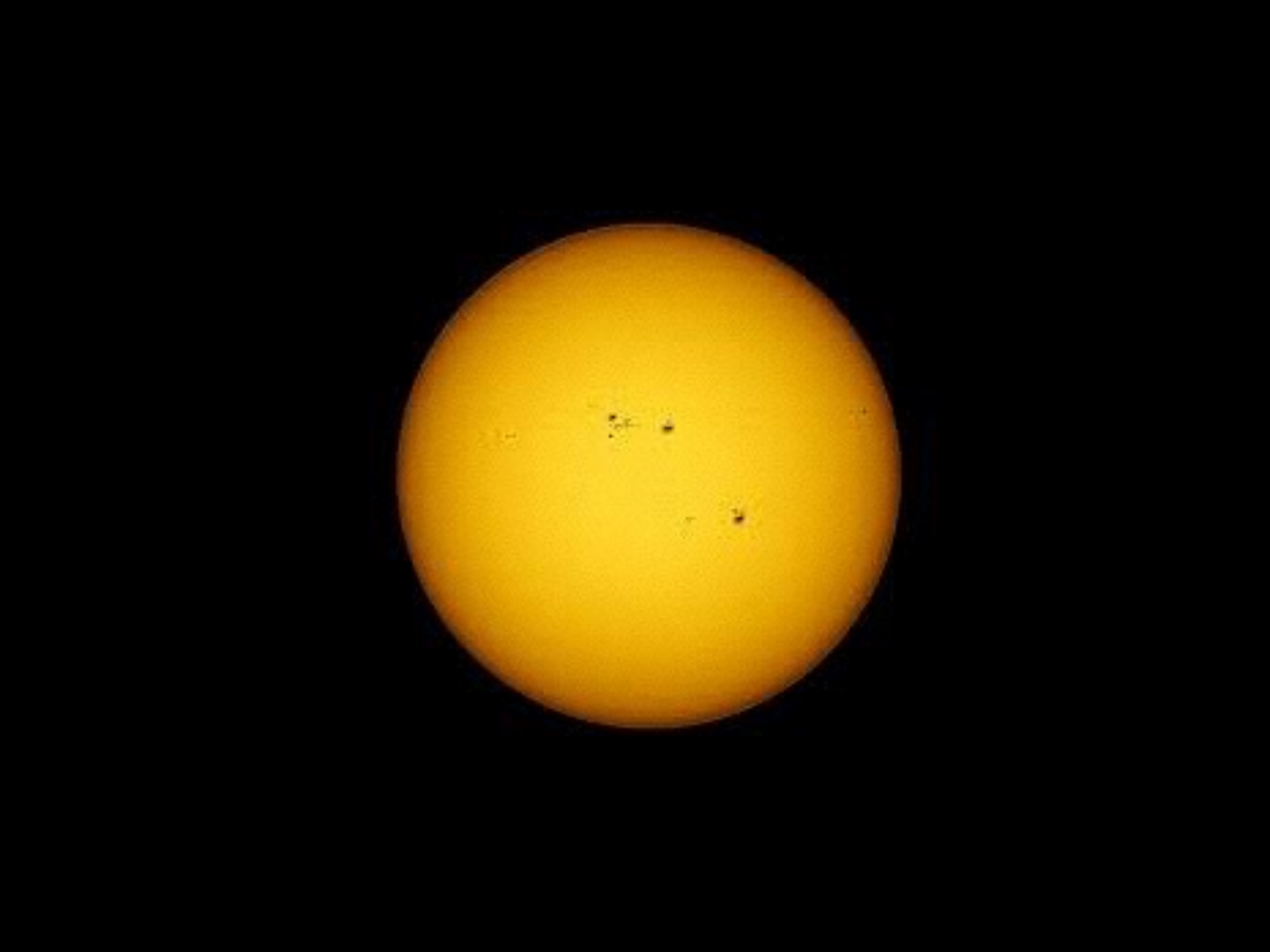
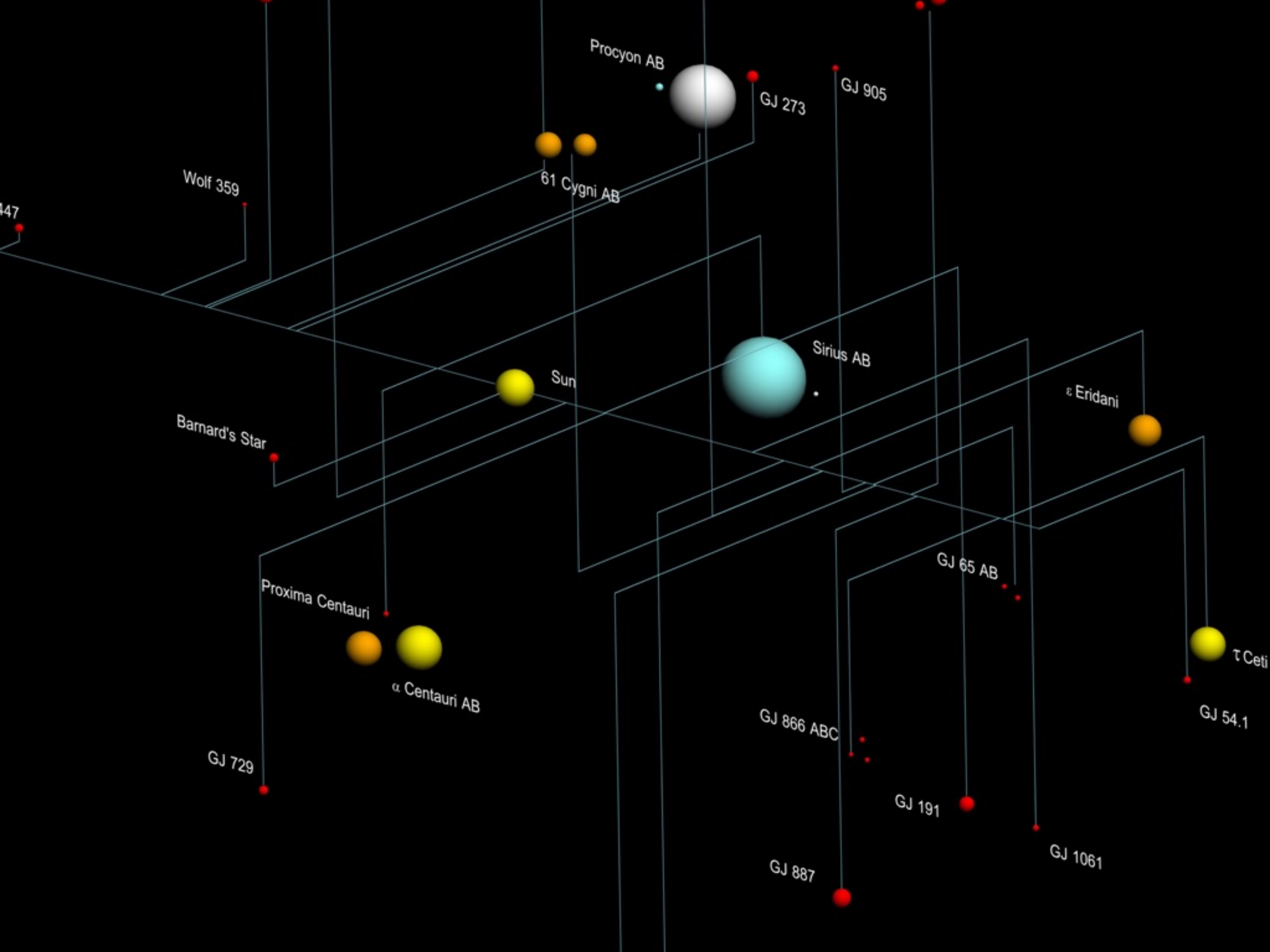
Is there an origin of the universe?

An empiricist's approach

PJEP 7 Pines May 2016







Procyon AB
GJ 273
GJ 905
Wolf 359
447
61 Cygni AB
Sirius AB
Sun
ε Eridani
Barnard's Star
GJ 65 AB
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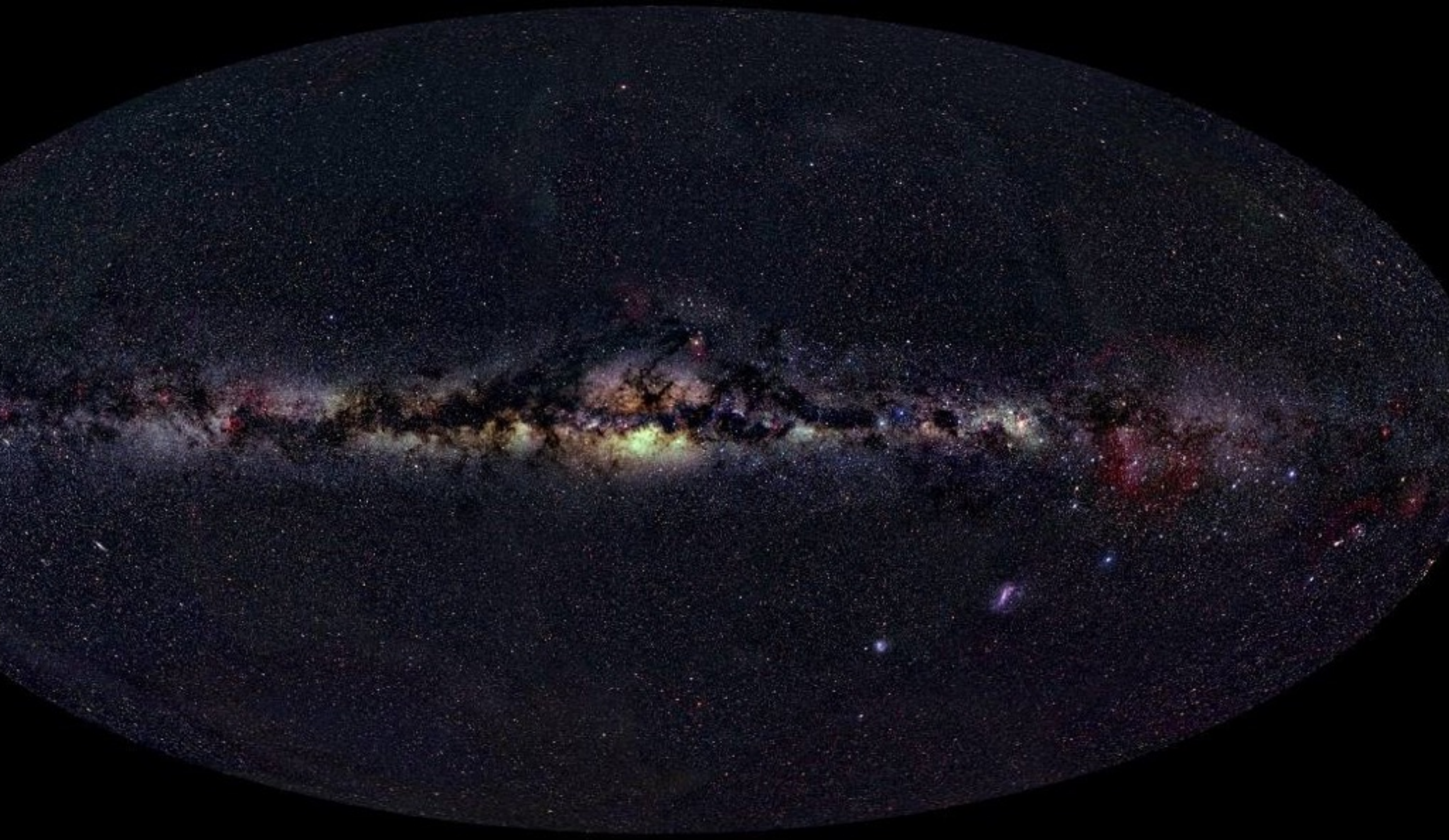
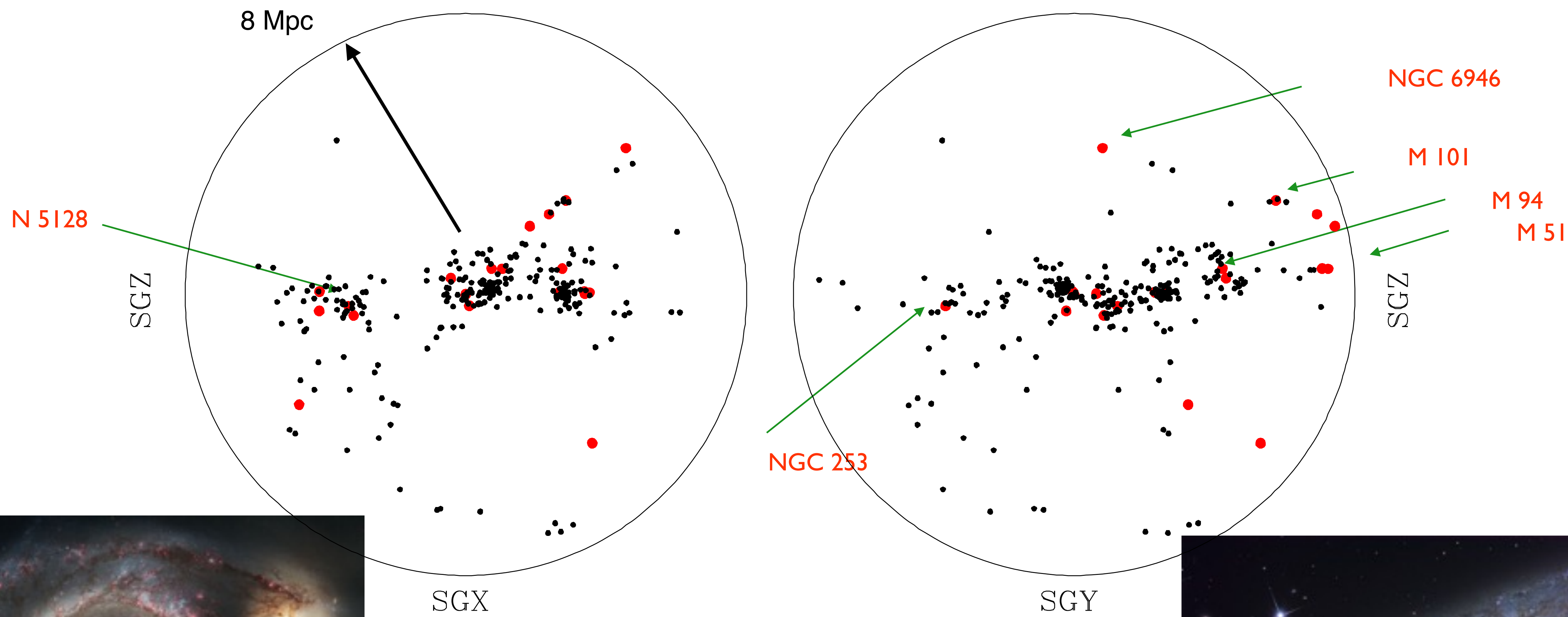
τ Ceti
α Centauri AB
GJ 54.1
GJ 866 ABC
GJ 729
GJ 191
GJ 1061
GJ 887




8 Mpc
N 5128
SGZ
SGX
NGC 6946
M 101
M 94
M 51
NGC 253
SGZ
SGY


M 51


NGC 293


NGC 6946

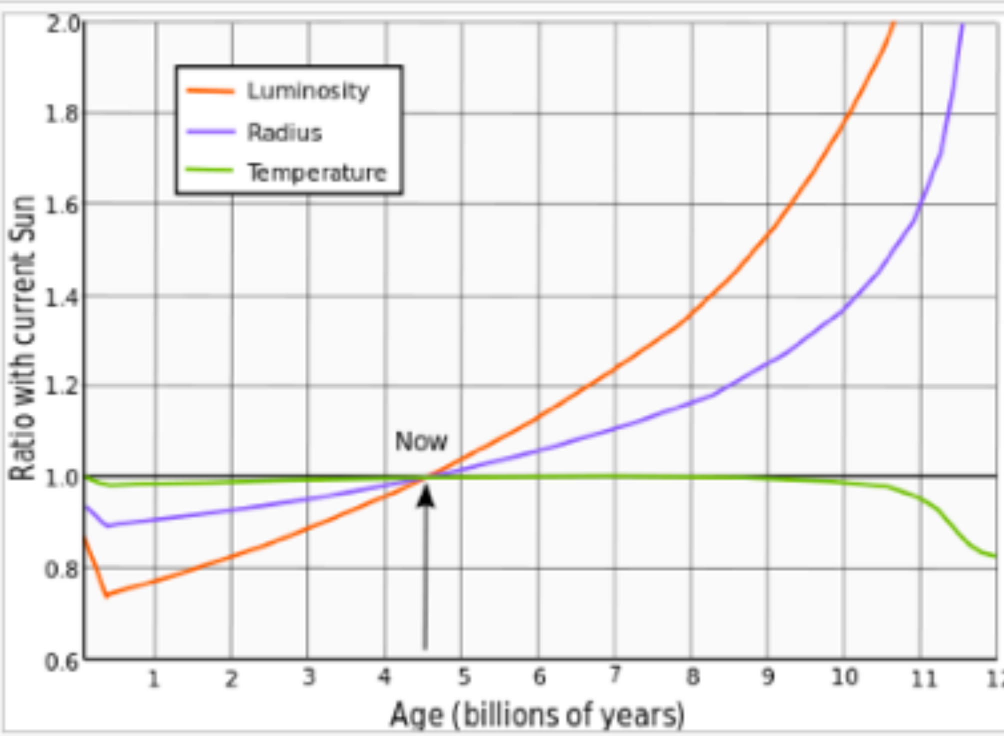

NGC 5128


M 101


M 94

Here is how will the world will end.

Solar structure theory is well checked by helioseismology and solar neutrino detections. It predicts the Sun was seriously less luminous 3.5 Gyr ago. But the greenhouse effect of water vapor kept Earth warm enough for bacteria, and it still keeps us from freezing.

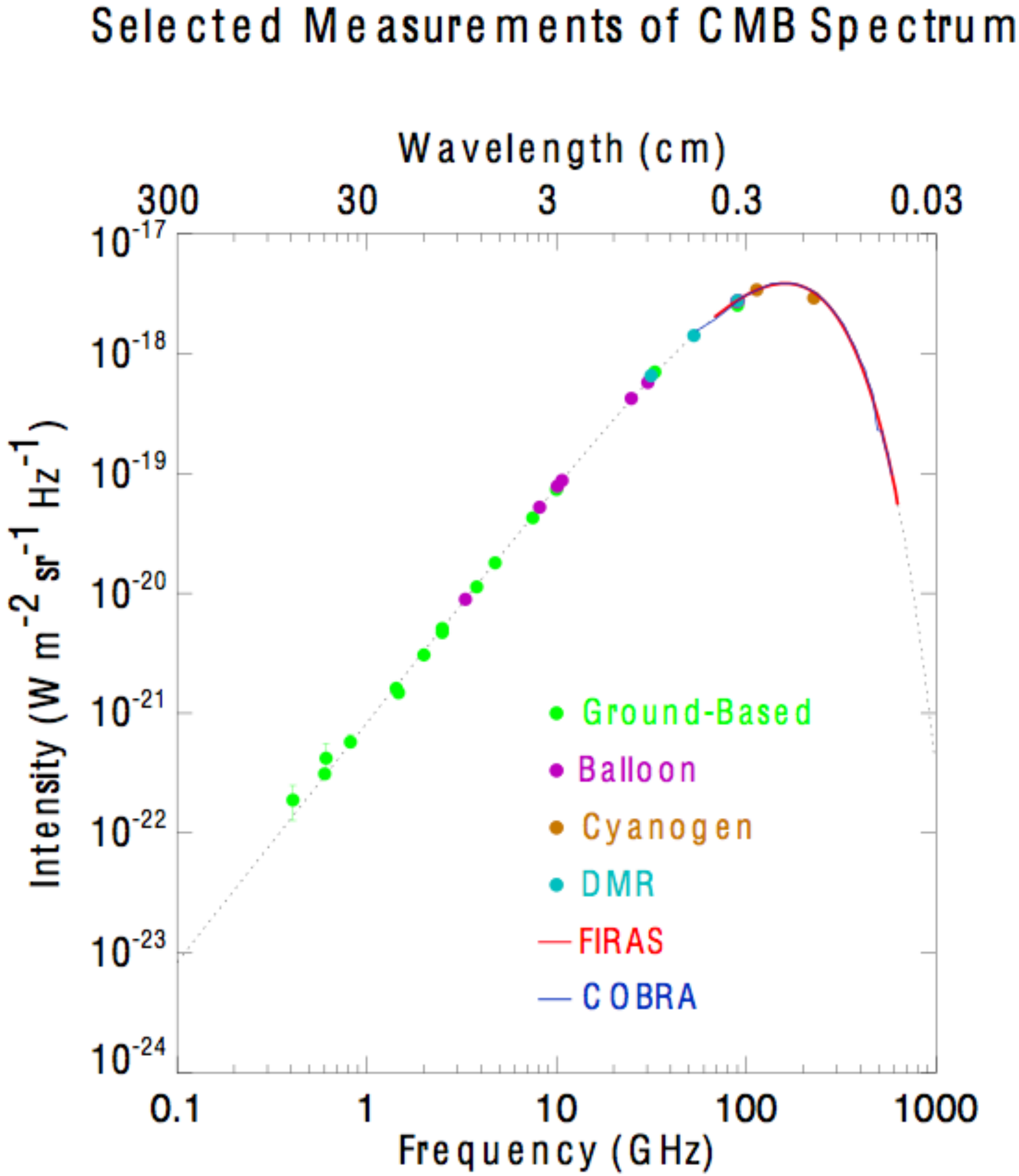


Evolution of the solar luminosity, radius and effective temperature compared to the present-day Sun. After Ribas (2010)[1]

In a few more billion years the solar luminosity will grow large enough to evaporate Earth’s atmosphere and oceans, annihilating life as we know it.

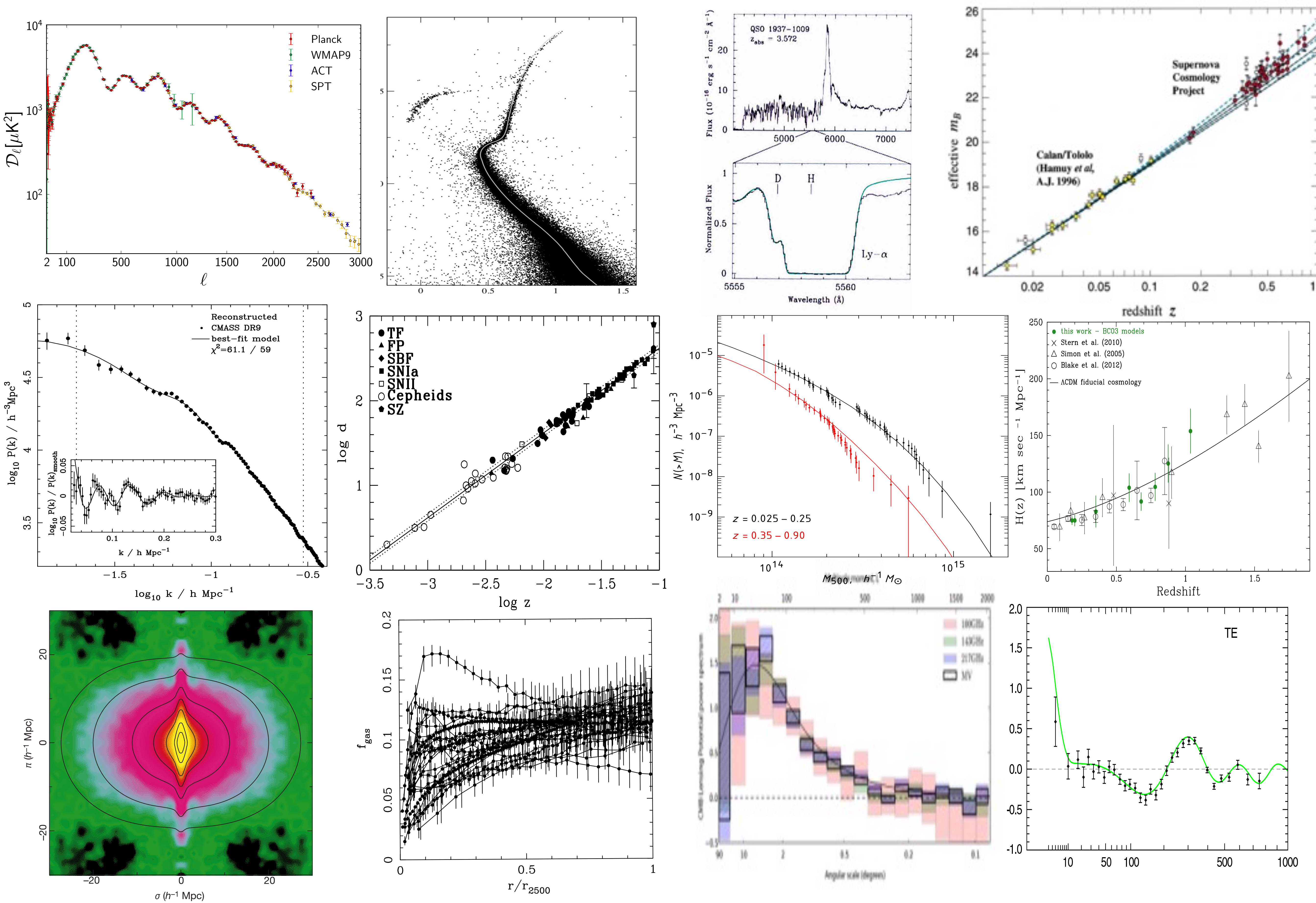
In the standard relativistic ΛCDM cosmology the universe expanded from a very close to homogeneous, hot, dense, condition.

The simplest piece of evidence is the very close to isotropic thermal sea of radiation.



Al Kogut, 2012

The relativistic ΛCDM theory of expansion from a hot near homogeneous initial state passes an abundance of tests.



The 6-parameter cosmologically flat ΛCDM theory assumes general relativity with texbook physics, and it postulates

non-baryonic dark matter,

Einstein cosmological constant, Λ,

flat space sections,

initially small adiabatic near scale-invariant growing departures from the spatially flat Friedman-Lemaître solution.

This allows six free parameters, which fits many more measurements.

Parameter	TT
$\Omega_b h^2$	0.02222±0.00023
$\Omega_c h^2$	0.1199±0.0022
$100\theta_*$	1.04086±0.00048
τ	0.078±0.019
n_s	0.9652±0.0062
H_0	67.3±1.0
Ω_m	0.316±0.014
σ_8	0.830±0.015
z_{re}	9.9±1.9

...but beware there are still low level systema spectra

preliminary

The dark sector certainly may be more interesting than CDM and Λ.

My intuition is that a more radical departure from ΛCDM, while always conceivable, is exceedingly unlikely.

Our physics grew by an elegant hierarchy of successive approximations.

- Maxwell ~ 1865
- Einstein 1905-1915
- ΛCDM

Quantum physics was a big departure from this continuity,

but nonrelativistic quantum theory pretty directly led to QED and from there, with a little help from experiments, to the standard model for particle physics, which passes an even greater abundance of tests than ΛCDM.

Seeking the next level of fundamental physics
What is the next turtle down?

AE in *Albert Einstein Scientist Philosopher:*

“. . . Only “dimension-less” constants could occur in the basic equations of physics. Concerning such I would like to state a theorem which at present can not be based on anything more that upon a faith in the simplicity, i.e., intelligibility, of nature: there are no *arbitrary* constants of this kind; that is to say, Nature is so constituted that it is possible logically to lay down such strongly determined laws that within these laws only rationally completely determined constants occur (not constants, therefore, whose numerical values could be changed without destroying the theory).”

Seeking the next level in cosmology: What happened before ΛCDM could have been been a good approximation?

It makes perfect sense to follow proven directions: explore how to improve and merge the quantum and GR paths.

Maybe this will lead to completion of Einstein's program: a logically coherent and complete final theory of everything, maybe needing no empirical input beyond what we have now, and maybe not even needing anthropic arguments.

It would be marvelous.

But it would present a conundrum: Does the universe really share our notions of intelligibility: logic, coherence, completeness? Or might Nature have more surprises for us?

We may find out by following empiricist paths. We have hints:

Who ordered

- The three generations of quarks and leptons?
- The stark simplicity of the ΛCDM universe at high redshift?
- All those galaxies?
  - One in otherwise empty space seems adequate for us.
  - Does inflation require all those galaxies? Did inflation happen?
- So much entropy?
  - ΛCDM allows a lot more or a lot less less entropy per baryon.
  - Is a zero entropy early universe without inflation a viable alternative history for situations similar to ours in a multiverse?
- Dark matter?
  - Has nonbaryonic DM any socially redeeming value?
  - Could DM really be as simple as ΛCDM?
  - Why is DM so vexatiously difficult to detect, apart from gravity?
- Einstein's Λ?
  - Why the vast disconnect with the naïve quantum vacuum?
- The curiously stable strength of gravity?
  - Why is $Gm_p m_e/e^2 \sim 10^{-40}$ so small yet so close to constant?
- Bulge-free spiral galaxies, baryonic TF, and all that?
  - Puzzling aspects of galaxies may only reflect complex physics, but it's prudent to consider that they may be hints to better physics.

An Alternative Universe

Imagine an early universe with zero entropy, number density n_l in each lepton family, and $n_\nu \gtrsim n_l$ in each neutrino, in the three generations

$$e^-, \quad \mu^-, \quad \tau^-, \quad \nu_1, \quad \nu_2, \quad \nu_3,$$

with baryon number density $n_b = 3n_l$.

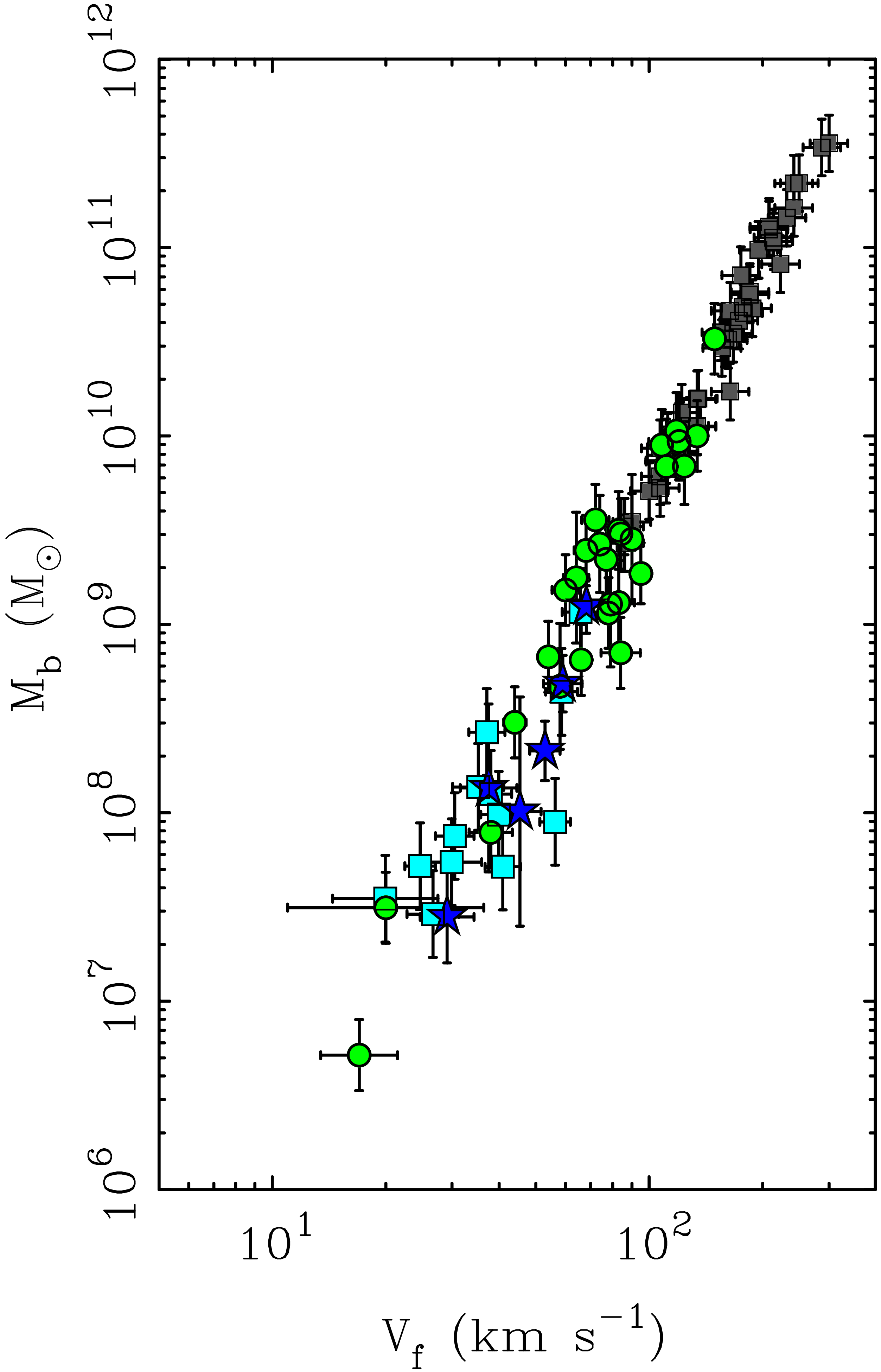
When the nucleon degeneracy kinetic energy is well below the proton rest mass, the reactions

$$p^+ + e^- \leftrightarrow n + \nu_e$$

suppress the abundance of neutrons and unwanted overproduction of helium.

Earlier, I suppose, would be degenerate seas of quarks and leptons.
I haven't thought through possible effects of the entropy produced by irreversible processes as the universe expands.


Sculptor galaxy



Stacy McGaugh 2012

How did the universe begin? What happened before ΛCDM could have been a good approximation?

Primeval Atom
- A prime mover
- Hawking-Hartle no-boundary proposal

Phoenix
- Ashtekar's LQG
- Penrose's conformal cyclic cosmology
- Steinhardt's ekpyrotic universe

Steady state
- Hoyle and Narlikar's quasi-steady state universe
- Eternal inflation

To flesh out any of these scenarios we are going to have to add to the tested and established physics.

How may that go?

The End Game

1. Maybe the next level in the hierarchy of approximations to quantum and gravity physics will reach the final theory, which will
   (a) show us in a fairly direct way how our universe began, or else
   (b) predict a world picture that is difficult or impossible to read off the final theory, though it certainly would be fascinating to try,
2. or maybe it's successive approximations all the way down, and research in early universe physics must advance by
   (a) hints from empirical evidence, as in the issues mentioned above,
   (b) and by pure thought, as in ideas about how it all began that now are far more abundant than our bits of empirical evidence.

Whatever way, we have a foretaste of how natural science must end, in pure thought, leaving those of us of an empirical persuasion to wonder whether that gets it right.

But wait; there's more.

Is there an origin of chemistry?

Dirac 1929:

The underlying physical laws necessary for the mathematical theory of a large part of physics and the whole of chemistry are thus completely known, and the difficulty is only that the exact application of these laws leads to equations much too complicated to be soluble. It therefore becomes desirable that approximate practical methods of applying quantum mechanics should be developed, which can lead to an explanation of the main features of complex atomic systems without too much computation.

Is there an origin of chemistry?

Chemistry is growing its own hierarchy of approximations, driven by wonderfully rich phenomenology, though maybe not quite as Dirac envisioned.

● Fermi Thomas, Hartree Fock.

● DFT (Kohn et al. 1964, 1965), which is inspired by QM, but it is not QM.

Web of Science lists papers with “density functional theory” in title, abstract, or keywords (with a few ringers):

69 papers published in 1970 through 1980
30,000 papers published in the single year 2015.

Chemistry’s hierarchy of theories may converge to established physics. Or maybe that is not an adequate basis for chemistry. And maybe complexity —physical or computational—will prevent our ever knowing.

But wait; there’s more.

Is there an origin of other branches of natural science?

I imagine research in botany, biology, the human brain and all that are each developing their own empirically-guided hierarchies of successive approximations to what's found to be happening,

maybe someday to merge with the hierarchies of particle physics, cosmology, and chemistry, approaching a true theory of everything, and of how it all began,

or maybe not.

Whatever the result, I think we can be sure the pursuit of these issues will involve a lot of fascinating research, theoretical and experimental, which will reveal many wonderful insights into how it all works and how it all began.

Wait; there's more.