

BioCosmology: the birth of a new Science!



Marina Cortês



with

Lee Smolin (Perimeter Institute)

Andrew R. Liddle (University Lisbon)

Stuart Kauffman (Systems Biology Institute)



*Cosmology from Home 2022 - **San Francisco!***

**For the first time we've created
a common language between
cosmology and biology and
given a quantitative value for
how much life is worth, based
on the foundational laws of the
universe.**

That is, the currency of the

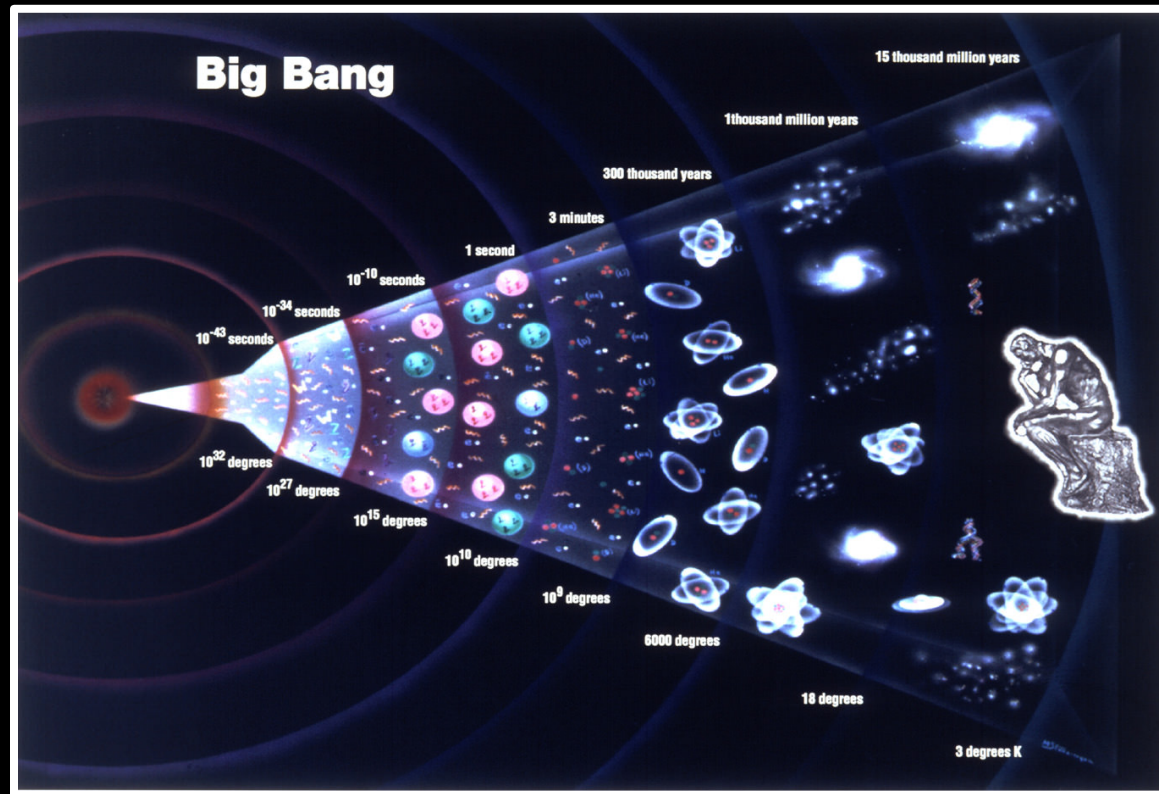
COSMOS.



- **Biology from a physics POV**
- **Done usually through approximations**
- **Take a fundamental physics approach**



How did the Universe begin? Initial conditions



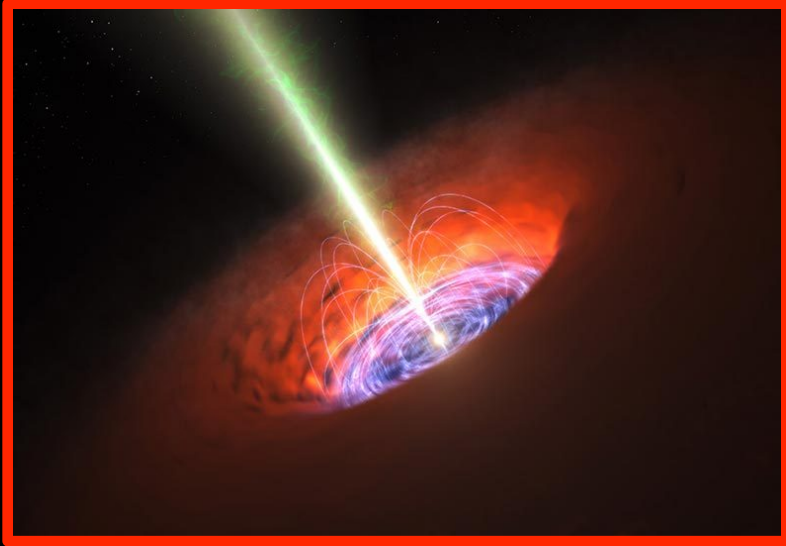
Why are there so many things (microstates) in the Universe today,

(stars, planets, galaxies, supernovas, black holes, dark energy)

Instead of a huge blob of gas in equilibrium?

(2nd law of thermodynamics)

To begin to answer this we count the number of different things
(microstates) in the universe today

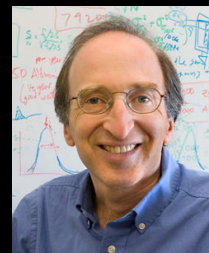


Black Holes $e^{10^{101}}$ microstates

(likelihood of existing)



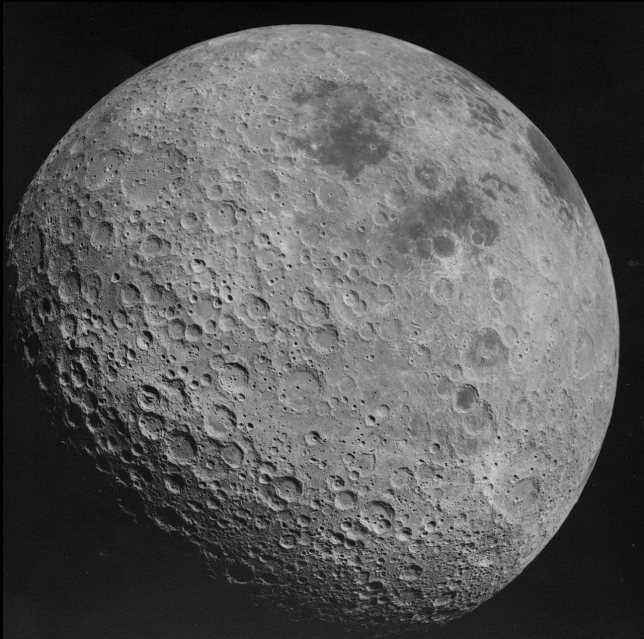
Dark Energy $e^{10^{124}}$ microstates



Nobel Prize Saul Perlmutter

Our counting of the
Universe in Physics
looks like this.

NOT like this.



We have NOT counted life

How many (classical) microstates are there in life?
Does it count compared to the rest of the Universe?

NO. Our planet is tiny. It cannot hold many different things compared to Dark Energy. OBVIOUSLY it does not count.

We don't KNOW how to count life. It is too complex to describe in a physics sense.

Physics and Biology DO NOT share a common language and translator. So we cannot measure life.

(Plus assume it's negligible anyway)

Plus... There are no laws.

Physics

Biology

$$\begin{aligned}
 \mathcal{L}_{SM} = & -\frac{1}{2}\partial_\nu g_\mu^\alpha \partial_\nu g_\mu^\alpha - g_s f^{abc} \partial_\mu g_\nu^a g_\mu^b g_\nu^c - \frac{1}{4}g_s^2 f^{abcd} g_\mu^a g_\nu^b g_\mu^c g_\nu^d - \partial_\nu W_\mu^+ \partial_\nu W_\mu^- \\
 & M^2 W_\mu^+ W_\mu^- - \frac{1}{2}\partial_\nu Z_\mu^0 \partial_\nu Z_\mu^0 - \frac{1}{2c_w^2} M^2 Z_\mu^0 Z_\mu^0 - \frac{1}{2}\partial_\nu A_\nu \partial_\nu A_\nu - igc_w (\partial_\nu Z_\mu^0 (W_\mu^+ W_\nu^- \\
 & W_\nu^+ W_\mu^-) - Z_\nu^0 (W_\mu^+ \partial_\nu W_\mu^- - W_\nu^- \partial_\mu W_\mu^+) + Z_\mu^0 (W_\nu^+ \partial_\nu W_\mu^- - W_\nu^- \partial_\nu W_\mu^+)) - \\
 & ig s_w (\partial_\nu A_\mu (W_\nu^+ W_\mu^- - W_\nu^- W_\mu^+) - A_\nu (W_\mu^+ \partial_\nu W_\mu^- - W_\nu^- \partial_\mu W_\mu^+) + A_\mu (W_\nu^+ \partial_\nu W_\mu^- \\
 & W_\nu^- \partial_\nu W_\mu^+)) - \frac{1}{2}g^2 W_\mu^+ W_\mu^- W_\nu^+ W_\nu^- + \frac{1}{2}g^2 W_\mu^+ W_\nu^- W_\mu^- W_\nu^+ + g^2 c_w^2 (Z_\mu^0 W_\nu^+ Z_\nu^0 W_\mu^- \\
 & Z_\mu^0 Z_\nu^0 W_\nu^+ W_\mu^-) + g^2 s_w^2 (A_\mu W_\nu^+ A_\nu W_\mu^- - A_\mu A_\nu W_\nu^+ W_\mu^-) + g^2 s_w c_w (A_\mu Z_\nu^0 (W_\mu^+ W_\nu^- \\
 & W_\nu^+ W_\mu^-) - 2A_\nu Z_\mu^0 W_\nu^+ W_\mu^-) - \frac{1}{2}\partial_\nu H \partial_\nu H - 2M^2 \alpha_h H^2 - \partial_\mu \phi^+ \partial_\mu \phi^- - \frac{1}{2}\partial_\mu \phi^0 \partial_\mu \phi^0 - \\
 & \beta_h \left(\frac{2M^2}{g^2} + \frac{2M}{g} H + \frac{1}{2}(H^2 + \phi^0 \phi^0 + 2\phi^+ \phi^-) \right) + \frac{2M^4}{g^4} \alpha_h - \\
 & g\alpha_h M (H^3 + H\phi^0 \phi^0 + 2H\phi^+ \phi^-) - \\
 & \frac{1}{8}g^2 \alpha_h (H^4 + (\phi^0)^4 + 4(\phi^+ \phi^-)^2 + 4(\phi^0)^2 \phi^+ \phi^- + 4H^2 \phi^+ \phi^- + 2(\phi^0)^2 H^2) - \\
 & gM W_\mu^+ W_\mu^- H - \frac{1}{2}g \frac{M}{c_w^2} Z_\mu^0 Z_\mu^0 H - \\
 & \frac{1}{2}ig (W_\mu^+ (\phi^0 \partial_\nu \phi^- - \phi^- \partial_\nu \phi^0) - W_\mu^- (\phi^0 \partial_\nu \phi^+ - \phi^+ \partial_\nu \phi^0)) + \\
 & \frac{1}{2}g (W_\mu^+ (H \partial_\nu \phi^- - \phi^- \partial_\nu H) + W_\mu^- (H \partial_\nu \phi^+ - \phi^+ \partial_\nu H)) + \frac{1}{2}g \frac{1}{c_w} (Z_\mu^0 (H \partial_\nu \phi^0 - \phi^0 \partial_\nu H) + \\
 & M (\frac{1}{c_w} Z_\mu^0 \partial_\nu \phi^0 + W_\mu^+ \partial_\nu \phi^- + W_\mu^- \partial_\nu \phi^+) - ig \frac{g_s}{c_w} M Z_\mu^0 (W_\mu^+ \phi^- - W_\mu^- \phi^+) + ig s_w M A_\mu (W_\mu^+ \phi^- \\
 & W_\mu^- \phi^+) - ig \frac{1-2c_w^2}{2c_w} Z_\mu^0 (\phi^+ \partial_\nu \phi^- - \phi^- \partial_\nu \phi^+) + ig s_w A_\mu (\phi^+ \partial_\nu \phi^- - \phi^- \partial_\nu \phi^+) - \\
 & \frac{1}{4}g^2 W_\mu^+ W_\mu^- (H^2 + (\phi^0)^2 + 2\phi^+ \phi^-) - \frac{1}{2}g^2 \frac{1}{c_w} Z_\mu^0 Z_\mu^0 (H^2 + (\phi^0)^2 + 2(2s_w^2 - 1)\phi^+ \phi^-) - \\
 & \frac{1}{2}g^2 \frac{g_s^2}{c_w} Z_\mu^0 \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^+) - \frac{1}{2}ig^2 \frac{g_s^2}{c_w} Z_\mu^0 H (W_\mu^+ \phi^- - W_\mu^- \phi^+) + \frac{1}{2}g^2 s_w A_\mu \phi^0 (W_\mu^+ \phi^- + \\
 & W_\mu^- \phi^+) + \frac{1}{2}ig^2 s_w A_\mu H (W_\mu^+ \phi^- - W_\mu^- \phi^+) - g^2 \frac{2m_c}{c_w} (2c_w^2 - 1) Z_\mu^0 A_\mu \phi^+ \phi^- - \\
 & g^2 s_w^2 A_\mu A_\nu \phi^+ \phi^- + \frac{1}{2}ig_s \lambda_{ij}^2 (\bar{q}_i^c \gamma^\mu q_j^c) g_\mu^a - \bar{e}^\lambda (\gamma^\mu + m_e^\lambda) e^\lambda - \bar{\nu}^\lambda (\gamma^\mu + m_\nu^\lambda) \nu^\lambda - \bar{u}_j^c (\gamma^\mu + \\
 & m_u^c) u_j^c - \bar{d}_j^c (\gamma^\mu + m_d^c) d_j^c + ig s_w A_\mu (-(\bar{e}^\lambda \gamma^\mu e^\lambda) + \frac{2}{3}(\bar{u}_j^c \gamma^\mu u_j^c) - \frac{1}{3}(\bar{d}_j^c \gamma^\mu d_j^c)) + \\
 & \frac{ig}{4c_w} Z_\mu^0 \{ (\bar{\nu}^\lambda \gamma^\mu (1 + \gamma^5) \nu^\lambda) + (\bar{e}^\lambda \gamma^\mu (4s_w^2 - 1 - \gamma^5) e^\lambda) + (\bar{d}_j^c \gamma^\mu (\frac{4}{3}s_w^2 - 1 - \gamma^5) d_j^c) + \\
 & (\bar{u}_j^c \gamma^\mu (1 - \frac{8}{3}s_w^2 + \gamma^5) u_j^c) \} + \frac{ig}{2\sqrt{2}} W_\mu^+ ((\bar{\nu}^\lambda \gamma^\mu (1 + \gamma^5) U^{lep}{}_{\lambda e} e^\lambda) + (\bar{u}_j^c \gamma^\mu (1 + \gamma^5) C_{\lambda e} d_j^c) + \\
 & \frac{ig}{2\sqrt{2}} W_\mu^- ((\bar{e}^\lambda U^{lep}{}_{\lambda \kappa} \kappa^\lambda \gamma^\mu (1 + \gamma^5) \nu^\lambda) + (\bar{d}_j^c C_{\lambda \kappa}^1 \gamma^\mu (1 + \gamma^5) u_j^c) + \\
 & \frac{ig}{2M\sqrt{2}} \phi^+ (-m_e^c (\bar{\nu}^\lambda U^{lep}{}_{\lambda \kappa} (1 - \gamma^5) e^\kappa) + m_\nu^c (\bar{\nu}^\lambda U^{lep}{}_{\lambda \kappa} (1 + \gamma^5) e^\kappa) + \\
 & \frac{ig}{2M\sqrt{2}} \phi^- (m_e^c (\bar{e}^\lambda U^{lep}{}_{\lambda \kappa} (1 + \gamma^5) \nu^\kappa) - m_\nu^c (\bar{e}^\lambda U^{lep}{}_{\lambda \kappa} (1 - \gamma^5) \nu^\kappa) - \frac{g}{2} \frac{m_h}{M} H (\bar{\nu}^\lambda \nu^\lambda) - \\
 & \frac{g}{2} \frac{m_h}{M} H (\bar{e}^\lambda e^\lambda) + \frac{ig}{2} \frac{m_h}{M} \phi^0 (\bar{\nu}^\lambda \gamma^5 \nu^\lambda) - \frac{ig}{2} \frac{m_h}{M} \phi^0 (\bar{e}^\lambda \gamma^5 e^\lambda) - \frac{1}{4} \bar{\nu}_\lambda M_{\lambda \kappa}^R (1 - \gamma_5) \bar{\nu}_\kappa - \\
 & \frac{1}{4} \bar{\nu}_\lambda M_{\lambda \kappa}^R (1 - \gamma_5) \bar{\nu}_\kappa + \frac{ig}{2M\sqrt{2}} \phi^+ (-m_d^c (\bar{u}_j^c C_{\lambda \kappa} (1 - \gamma^5) d_j^c) + m_u^c (\bar{u}_j^c C_{\lambda \kappa} (1 + \gamma^5) d_j^c) + \\
 & \frac{ig}{2M\sqrt{2}} \phi^- (m_d^c (\bar{d}_j^c C_{\lambda \kappa}^1 (1 + \gamma^5) u_j^c) - m_e^c (\bar{d}_j^c C_{\lambda \kappa}^1 (1 - \gamma^5) u_j^c) - \frac{g}{2} \frac{m_h}{M} H (\bar{u}_j^c u_j^c) - \\
 & \frac{g}{2} \frac{m_h}{M} H (\bar{d}_j^c d_j^c) + \frac{ig}{2} \frac{m_h}{M} \phi^0 (\bar{u}_j^c \gamma^5 u_j^c) - \frac{ig}{2} \frac{m_h}{M} \phi^0 (\bar{d}_j^c \gamma^5 d_j^c) + G^a \partial^2 G^a + g_s f^{abc} \partial_\mu G^a G^b G_\mu^c + \\
 & \bar{X}^+ (\partial^2 - M^2) X^+ + \bar{X}^- (\partial^2 - M^2) X^- + \bar{X}^0 (\partial^2 - \frac{M^2}{c_w^2}) X^0 + \bar{Y} \partial^2 Y + igc_w W_\mu^+ (\partial_\mu \bar{X}^0 X^- - \\
 & \partial_\mu \bar{X}^+ X^0) + ig s_w W_\mu^+ (\partial_\mu \bar{Y} X^- - \partial_\mu \bar{X}^+ Y) + igc_w W_\mu^- (\partial_\mu \bar{X}^- X^0 - \\
 & \partial_\mu \bar{X}^0 X^+) + ig s_w W_\mu^- (\partial_\mu \bar{X}^- Y - \partial_\mu \bar{Y} X^+) + igc_w Z_\mu^0 (\partial_\mu \bar{X}^+ X^- - \\
 & \partial_\mu \bar{X}^- X^-) + ig s_w A_\mu (\partial_\mu \bar{X}^+ X^- + \\
 & \partial_\mu \bar{X}^- X^-) - \frac{1}{2}gM (\bar{X}^+ X^+ H + \bar{X}^- X^- H + \frac{1}{c_w} \bar{X}^0 X^0 H) + \frac{1-2c_w^2}{2c_w} igM (\bar{X}^+ X^0 \phi^+ - \bar{X}^- X^0 \phi^-) + \\
 & \frac{1}{2c_w} igM (\bar{X}^0 X^- \phi^+ - \bar{X}^0 X^+ \phi^-) + igM s_w (\bar{X}^0 X^- \phi^+ - \bar{X}^0 X^+ \phi^-) + \\
 & \frac{1}{2}igM (\bar{X}^+ X^+ \phi^0 - \bar{X}^- X^- \phi^0) .
 \end{aligned}$$

- There are no laws.
- Life is anarchy
- The name of the game is

“getting to exist”

Standard Model Lagrangian

Theory of the Adjacent Possible

Combinatorial Innovation

Stuart Kauffman

Reinventing the Sacred (2008)

- At each moment life expands into the adjacent possible. So at each step you must count a million different possibilities.

$$M_{t+1} = M_t + \sum_{i=1}^{M_t} \alpha_i \binom{M_t}{i}$$

Stu Kauffman, Santa Fe Institute



So we went from this

COSMOS

LIFE



$e^{10^{124}}$ microstates

~ 0 microstates

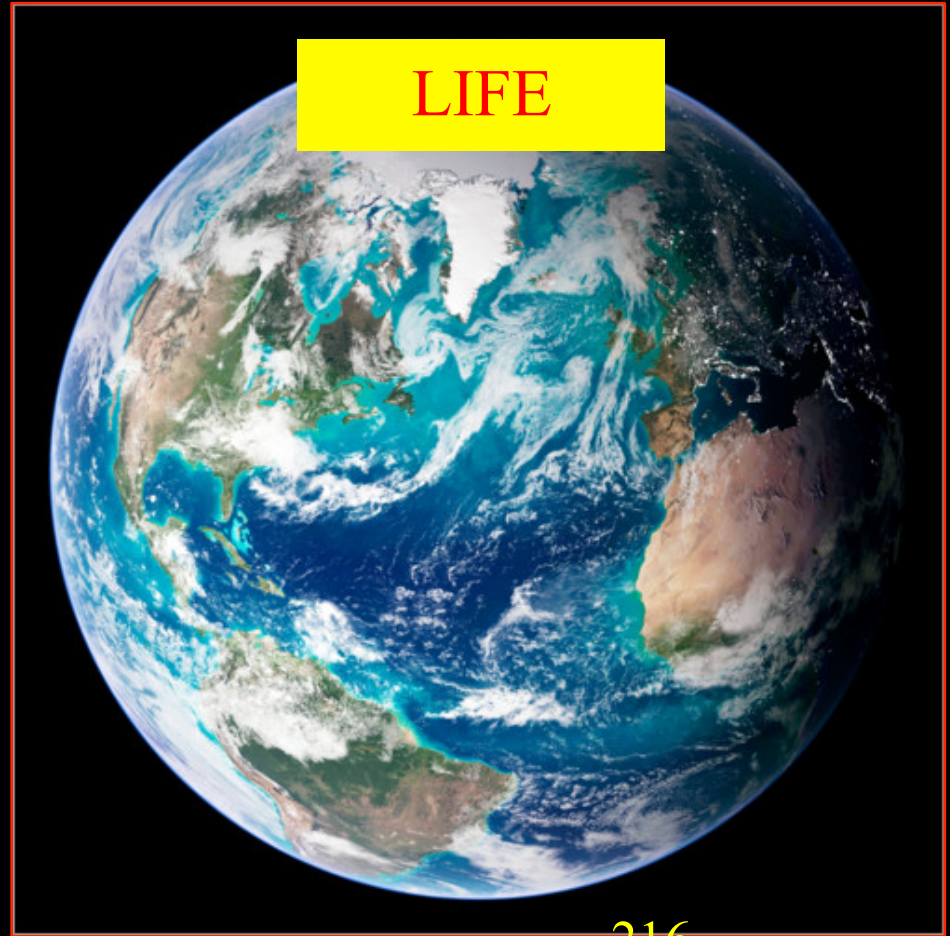
To this

COSMOS




$e \cdot 10^{124}$ microstates

LIFE



10^{216}
 10^{10}
 10^{10}
 10^{10} microstates

up to template synthesis, first RNA molecule




For the first time we've attempted at a common language between physics and biology and given a value for how much life is worth based on the foundations of laws in the universe



22 MAY 2015
INTERNATIONAL DAY
FOR BIOLOGICAL DIVERSITY
BIODIVERSITY FOR SUSTAINABLE
DEVELOPMENT

216
 10^{10}
 10^{10}
 10 microstates

CTE



**Infinitely small, Life in our planet is
biggest puzzle in the universe. If we
thought Dark Energy is a mystery for the
Big Bang, it is nothing comparing to our
life.**

**In our 30 billion light-years long
universe, the biosphere is the largest
diversity central.**



22 MAY 2015
INTERNATIONAL DAY
FOR BIOLOGICAL DIVERSITY
BIODIVERSITY FOR SUSTAINABLE
DEVELOPMENT



Press Release from Everest Base Camp

Theme discussion Andrew R Liddle



Biocosmology.earth