Seeking God in Einstein's Universe
The Substance of the World
Aileen A. O'Donoghue
Evening Came ...

“As the universe expanded and cooled, darkness descended,”
...And Morning Followed

“Then light dawned anew with the formation of the first stars. Each star is a nuclear furnace where matter is coaxed into releasing a little of the energy it inherited from the primordial fireball.”

Timothy Ferris
The Creation of the Universe
Starbirth

Interstellar clouds collapse under gravity and fragment into a cluster of denser clouds that continue collapsing.
Interstellar cloud fragments collapse under gravity to form stars.
Star Birth Region

Great Nebula in Orion

Giant, hot, young stars illuminate nebula

Thick, dusty disks protect forming stars & planetary systems
Forming Solar Systems

Disks of gas and dust surrounding forming stars form planets, moons, etc.

Protoplanetary Disks Orion Nebula

HST · WFPC2

PRC95-45b · ST ScI OPO · November 20, 1995
M. J. McCaughrean (MPIA), C. R. O'Dell (Rice University), NASA
Disks of gas and dust surrounding forming stars seen edge-on in Orion Nebula.

Edge-On Protoplanetary Disk
Orion Nebula

HST • WFPC2

PRC95-45c • ST ScI OPO • November 20, 1995

M. J. McCaughrean (MPIA), C. R. O'Dell (Rice University), NASA
Starbirth In The Eagle Nebula

Canton’s southern sky at 9 pm, September 15 or 7 pm, October 15
Starbirth In The Eagle

Gaseous Pillars - M16

PRC95-44a - ST ScI OPO - November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA
Light and stellar winds from above evaporate gas leaving dense, star-forming regions ... Evaporating Gaseous Globules.

EGGs

Star-Birth Clouds • M16

PRC95-44b • ST ScI OPO • November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA
The surface of a molecular cloud is illuminated by intense ultraviolet radiation from nearby hot stars. The radiation evaporates material off of the surface of the cloud.

**EGG = Evaporating Gaseous Globule**

As the cloud is slowly eaten away by the ultraviolet radiation, a denser than average globule of gas begins to be uncovered. Eventually the EGG may become totally separated from the molecular cloud in which it formed. As the EGG itself slowly evaporates, the star within is uncovered and may appear sitting on the front surface of the EGG.

**Ultraviolet light and stellar wind (charged particles) from “sibling” star beyond image.**
Solar System Formation
Planets form from debris around star.
What Makes A Star?

Nuclear Fusion

- Light elements combine to make heavier elements.

Hydrogen fuses to Helium
What Makes A Star?

Nuclear Fusion

Light elements combine to make heavier elements.

Helium fuses to Carbon, Oxygen, Nitrogen ...
Fusion Releases Energy

Mass of 4 H atoms
4 x (1.007940 amu) = 4.031760 amu

Mass of 1 He atom - 4.002602 amu

Difference (loss) = 0.029158 amu

= 0.7 % of H

Where does it go?

$E = mc^2$ → Energy!
Energy Of Fusion: Solar Power

Convert 1 kg of H to He:

0.7% (= 7 grams) becomes energy

by \( E = mc^2 \),

\[
(0.007 \text{ kg}) \times (3.0 \times 10^8 \text{ m/s})^2 = 630 \text{ trillion joules}
\]

= 175 million kWhr

= 175 GWhr

US Annual Electrical Use = 3700 GWhr

Converting 22 kg of H to He would power the entire US for one year!
Products Of Stellar Fusion

Early universe was 75% H, 25% He

All other elements are the products of stars!
Substance Of Life

Life requires H, C, O, & N

☒ All elements of life came from stars that lived AND DIED before the sun formed.

☒ Sun is a 2\textsuperscript{nd} or 3\textsuperscript{rd} generation star

☒ 1\textsuperscript{st} stars were pure hydrogen and helium)

“We are the matter of the cosmos contemplating itself.”

- Carl Sagan
Interstellar Medium

Ancient stars enriched the ISM with the products of their fusion by:

- **Stellar Winds**
  - Stars constantly blow particles into space
  - Solar wind & storms cause aurorae
- **Deaths as Planetary Nebulae**
Planetary Nebulae
The source of common heavy elements (lighter than iron) ... C, O, N, Ca, K, P, etc.
Planetary Nebulae

Planetary Nebula Mz 3
The Hourglass Nebula

Hourglass Nebula • MyCn18
HST • WFPC2

PRC96-07 • ST ScI OPO • January 16, 1996
R. Sahai and J. Trauger (JPL), the WFPC2 Science Team and NASA
The sun and all the planets formed from the same cloud of "used" star stuff enriched with heavy elements by previous generations of stars.
There is a Time For Every Purpose Under Heaven..

“Lift up your eyes to the heavens, and look at the Earth down below for the heavens will vanish like smoke, and the earth will wear out like a garment.”

Isaiah 51:6
There is a Time For Every Purpose Under Heaven..

Stars use up their nuclear fuel and die.

Death of a sun-sized star:
Core fusion stops.
Star swells to Red Giant (Betelgeuse, Antares)
Becomes a Planetary Nebula
Ends as a White Dwarf.
Star Death

The sun will become a Red Giant in about 5 By, a White Dwarf in about 7 By
Europa 6 Billion AD

The ice of Europa will melt when the sun becomes a red giant and swells beyond the size of Earth’s orbit.

And all the elements we are made of will return to the stars ...
Planetary Nebulae

The elements we're made of were once part of a planetary nebula ...
Planetary Nebulae

The elements we're made of will again be part of a planetary nebula.
Only elements lighter than iron can be made in living stars.

Light elements from living stars

Heavy elements from ...
Giant Stars

Have layers fusing different elements

- Nonburning hydrogen
- Hydrogen fusion
- Helium fusion
- Carbon fusion
- Oxygen fusion
- Neon fusion
- Magnesium fusion
- Silicon fusion
- Iron ash
Iron

Iron is the most stable element
- ABSORBS energy in fusion
- ABSORBS energy in fission

When iron core begins to fuse
- energy is absorbed by reaction
- core cools ... contracts
- outer layers begin to fall in
- star implodes ...
- outer layers bounce off dense inner core
- star explodes ...
Supernova
Crab Nebula
Supernova Observed in 1054 by Chinese & Anazazi

M1

Sirius in Canis Major

Rigel in Orion

Pollux in Gemini

Castor in Gemini

Capella in Auriga

Aldebaran in Taurus

Procyon in Canis Minor
Supernova Remnant

Crab Nebula

"Guest Star" in Taurus noted in Chinese records in 1054 and on rock overhang in Chaco Cañon, NM.

Is still expanding ... still exploding!
Crab Pulsar
Neutron star pulses!
Called “LGM” at first for “little green men.”
Crab Nebula

Core of exploded star is a neutron star
Neutron Stars

Dense
- all space squeezed out from within atoms

Enlarge an atom to size of St. Peter’s Basilica
The nucleus is the size of a grain of salt

Rotate Very Quickly
- spun up as core collapsed

Strong Magnetic Fields
- increased as core collapsed
- Radiation strongly beamed along axis
Pulsars
Rapidly Rotating Neutron Stars
- Emission “beamed” by magnetic fields
- Bright when beam points at Earth
- Stars “spin-up” during collapse like spinning skater
Crab Nebula

Neutron star heats nebula to glow in X-rays
Supernovae
Can outshine entire galaxies ...
Super-nova 1987 A
First SN observable with unaided eye in 400 yr!

Before
Sanduleak -69 202a indicated by arrow (before 1987!)

After
SN 1987a

© Anglo-Australian Observatory
Southern Sky from CTIO
Cerro Tololo Interamerican Observatory
La Serena, Chile
4 m telescope
1.5 m telescope
LMCLMC
SMCMC

Southern Cross (Crux)
α Cen
β Cen
β Cen
γ Cen
δ Cen

Tarantula Nebula
Before SN 1987 A

© Anglo-Australian Observatory/ Royal Observatory, Edinburgh
Eta Carinae

A star 100 times the mass of Sol ... in death throes

Eta Carinae

HST - WFPC2

PRC96-23a · ST ScI OPO · June 10, 1996
J. Morse (U. CO), K. Davidson, (U. MN), NASA
η Car

A star surrounded by a torus of x-ray emitting gas

2 light years
3000 x Pluto’s orbit
“... Bathe yourself in the ocean of matter; plunge into it where it is deepest and most violent; struggle in its currents and drink of its waters.

“For it cradled you long ago in your preconscious existence; and it is that ocean that will raise you up to God.”

Teilhard de Chardin
Supernovae

ONLY way to fuse heavy elements ...

Source of all the

- iron, zinc, copper, iodine, etc.
- in our bloodstreams,
- gold, silver, bronze, tin, etc.
- in our jewelry (and teeth!),
- mercury, lead, molybdenum, etc.
- in our machines.
God’s Blessings

“For the LORD your God is bringing you into a good land, a land with flowing streams... a land whose stones are iron and from whose hills you may mine copper. You shall eat your fill and bless the LORD your God for the good land that he has given you.”

Deuteronomy 8:7,9,10
Machines

- Made of elements from supernovae
  - ashes of giant stars that died before the sun was born
  - one may have initiated the sun’s formation with shock waves
- Created by human minds,
- Created by human vision
- Created by human toil ...

Machines are not foreign to the universe!
VLA Radio Telescope

Where “Ellie” heard the signal of another civilization …

Contact, The Movie
"Our scientific knowledge of the physical evolution of the universe, and our very limited knowledge of the origin of humans within it, might provide an opportunity to enrich our relationship to God as creator, if only we get loose of our idolatries."

Dr. George Coyne, S. J., Director
Machines

Bless our lives

- science
- healthcare
- I am alive because of machines testing and refrigerating blood
- transportation
- sanitation
- communication

But the blessings of machines can be hidden
Pollution Hides Blessings

Rochester

Thousand Islands
Dumps Hide Blessings

Denver, Colorado

Mt. Evans
Mining Hide Blessings

Arizona

Bolivia

© Stephen Ferry/Lookat, Suisse
But Blessings Lurk

Behind the junk ...

Within the junk ...
Machines

Seen as evil ...

“Our intellectual journals are full of gloomy tracts that depict a society debased by technology. Our health is being ruined, ..., our landscape despoiled, and our social institutions laid waste”

Samuel Florman
Blaming Technology
Machines

Seen to reduce us ...

“Atomism, or the machine model, reduces all living things to their most basic chemical compounds, so that we and all other organisms are “nothing but” the chemicals in our bodies.”

Sallie McFague
The Body of God
... “Imagine God as the living awareness in the space between the atoms ... Is God immanent or transcendent, internal or external, composed or compassionate? Like the question of whether the atom is a wave or a particle, the answer is: yes.”

Tom Mahon
The Spirit in Technology
Seeing Machines Anew

Teilhard’s Christ ...

“Glorious Lord Christ: The divine influence secretly diffused and active in the depths of matter…”

Is also diffused and active in machines!
Hymn To Matter

“Blessed be you, mighty matter, irresistible march of evolution, reality ever newborn; you who, by constantly shattering our mental categories, force us to go ever further and further in our pursuit of truth.”
Blessed be you, universal matter, immeasurable time, boundless ether, triple abyss of stars and atoms and generations: you who by overflowing and dissolving our narrow standards of measurement reveal to us the dimensions of God.
Hymn To Matter

“Blessed be you, impenetrable matter: you who, interposed between our minds and the world of essences, cause us to languish with the desire to pierce through the seamless veil of phenomena.”

Teilhard de Chardin
The World is charged with the grandeur of God.
It will flame out, like shining from shook foil;
It gathers to a greatness, like the ooze of oil
Crushed. Why do men then now not reck his rod?
Generations have trod, have trod, have trod;
And all is seared with trade; bleared, smeared
with toil;
And wears man's smudge and shares man's smell:
the soil
Is bare now, nor can foot feel, being shod.
And for all this, nature is never spent;  
There lives the dearest freshness deep down  
things;
And though the last lights off the black West went  
Oh, morning, at the brown brink eastward,  
spings—
Because the Holy Ghost over the bent  
World broods with warm breast and with ah!  
bright wings.

Gerard Manley Hopkins