COURSE SUMMARY: ASTRONOMY, PHYSICS, COSMOLOGY -- THE PROFOUND QUESTIONS.

Each session includes a video or powerpoint or Stellarium astronomy software presentation, with your discussions. No background in science or mathematics is needed. Observation evenings (clear skies permitting -- *O clouds unfold*) are difficult to schedule in Melbourne; our 21 cm (8 inch) aperture Schmidt-Cassegrain tracking telescope can be available, e.g. at our scenic dark-sky hill-top venue, on request. Topics for the 25 x 1.5 hours meetings are structured as follows; however, any "questions arising" are welcome at any time during the course. Suggested readings from the Course Notes (available on request) for prior or follow-up discussions of each topic, are given in parentheses.

1. REALM OF THE GREAT GALAXIES. What is the large-scale structure of deep space and deep time? What controls cosmic expansion? Why so vast, so ancient? What evidence supports the "Big Bang" theory and the cosmic time-line? What might have existed "before" the Big Bang? ***(pp 5-8, 11, 23-29, 31-32, 33, 36, 37).***

2. EINSTEIN'S UNIVERSE. What is the evidence for time dilation? Curved spacetime? Black holes? Singularities in space-time? What causes gravity? What are Nature's four fundamental forces? ***(pp 8-9, 11, 47).***

3. QUANTUM COSMOLOGY. In the beginning.....what happened? Did the "Big Bang" have a cause? Could parallel universes exist? What is the deep structure of matter? The Large Hadron Collider? Who or what "breathed the fire into the equations, and gave them a universe to work on"? A string or brane "theory of everything"? ***(pp 10-11, 35, 48, 49).***

4. STARBIRTH, STARDEATH: How did the galaxies and stars form, and evolve? Are such processes still in action? How may it all evolve: our near and far destinies? "Big Crunch"? "Big Bounce"? "Big Chill? ***(pp 12-15, 25-28, 34, 39).***

5. THE RISE OF LIFE. How do planets form? Other solar systems? How did life on Earth originate and evolve? Are we alone: possible exobiologies; shadow life here on Earth? How goes the search, SETI? ***(pp 12-19, 33-35,48).***

6. COSMOS, CHAOS, COMPLEXITY. Are we in a fractal universe? Is there a self-organising principle driving matter towards ever-increasing complexity? Has the universe always been "pregnant with mind"? ***(pp 34-35, 47).***

7. CONSCIOUS MIND, COSMIC SIGNIFICANCE. A self-aware universe? Mind-brain duality? How does mind emerge from brain function? Whence came the "Big Brain"? What is the mind? ***(pp 15-19, 25-36, 47, 62).***

8, SCIENCE, RELIGIONS. AND HISTORY. What is it all for? Can scientific cosmology complement philosophy, theology, and traditional cosmologies, in our search for meaning, for "de-tribalisation", for political, social and environmental maturity? Can the histories and evolution of modern societies be seen in a cosmic and biological context? Could this "big history" perspective assist in solving environmental problems and inter-cultural conflicts? ***(pp 1-5, 12-19, 19-21, 23-31, 50-53).***

To view more detailed summaries of the topics discussed during the above Cosmology seminars, please consult your up-dated fully referenced Course Notes (available on enrolment, or by prior arrangement with your course co-ordinator). Also, please note that every statement and opinion contained in the Course Notes is open for debate and discussion by you, the course participants. In particular, this applies to the attempt to view contentious current and historical geopolitical topics from a cosmological and biological perspective. We anticipate you will find the course stimulating and enjoyable....even fascinating ! Your suggestions for inclusion or extension of topics are welcome.

Course co-ordinators and tutors: John O'Connor, Tony Heyes Feb. 2020
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A thought, from cosmologist Abraham Loeb (Scientific American, Nov. 2006): *"When I look up into the night sky, I often wonder whether we* ***humans are too preoccupied with ourselves.....the universe puts things in perspective****.....my own life, for example....it gives me a sense of longevity.....because of the big picture. Perhaps the greatest triumph of the past century has been a model of the universe that is supported by a large body of data.* ***The value of such a model to society is sometimes underappreciated.*** *When I open the daily newspaper.....I often see lengthy descriptions of conflicts between people about borders, possessions or liberties. Today's news is often forgotten a few days later. But when one opens ancient texts that have appealed to a broader audience over a longer time, such as the Bible, what does one find in the opening chapter? A discussion of how the constituents of the universe -- light, stars, life -- were created. Although we humans are often caught up with mundane problems, we are curious.....****as citizens of the universe, we cannot help but wonder*** *how the first sources of light formed, how life came into existence and whether we are alone as intelligent beings in this vast space. Astronomers in the 21st century are uniquely positioned to answer these big questions."*

COURSE SUMMARY (continued) : OUR GALACTIC SIGNIFICANCE.

FRANK DRAKE'S EQUATION: Number of ETC's (at least one) in the Galaxy, N = S x P x T x B x I x C x L.
(Alternative symbols : $N = R_* f_p n_e f_l f_i f_c L$).

To help us to organise and simplify our thinking – our attempt to make sense of a cosmic "Big History" influenced by countless variable factors -- we can use American radio-astronomer Frank Drake's "equation" to estimate the probability of any other ***"ETC"*** (***Electromagnetically Telecommunicating Civilization***) co-existing with us, elsewhere in "our" Galaxy. Drake proposed seven *sequential* factors – three astronomical, two biological, and two sociological (these last two cause most of the arguments!). For each factor, we can estimate a non-zero probability (low to high), or a value (for S, T and L). The chance of finding another ETC in the Milky Way Galaxy is then estimated by multiplying together the values assigned to each factor. So: here goes.

S is the rate of formation of ***stars, per year***. The number of stars in the Galaxy is 200 to 400 billion, formed during some 12 billion years. Drake estimates that about 20 new single long-life (Sun-like) stars form every year within the Galaxy's habitable zone ("ecosphere"), as detected by infra-red observations within its "giant molecular clouds" (dark nebulae).

P is the fraction of these new stars with ***planetary systems***. Angular momentum conservation during planetary accretion (cosmic dust/ "sticky fluff"/ "putty balls"/ planetesimals/ planets); observations of proto-planetary gas/dust discs around young stars; "wobble-watching" studies of nearby stars: these indicate a high probability for P: 0.9 (90%) or greater.

T is the *average number of* ***terrestrial-type planets*** *per planetary system*, able to support life. Our own Solar System, and detection of 500+ extrasolar planets, imply the existence of bio-friendly terrestrial-type planets. "Inner solar systems" seem necessary, protected from infalling comets and asteroids by outer Jupiter-type "punching-bag" gas giants, with at least one rocky silicate/carbon inner water world orbiting within the "ecosphere" of a long-life parent star: a "Goldilocks" world, enough gravity to retain an atmosphere, warm enough for liquid water. But: excess carbon over oxygen forms bio-unfriendly worlds - graphite crust, diamond interior, tar oceans. T *could* be 0.1 (ie.1 terrestrial planet/10 systems).

B is the fraction of these "bio-friendly water-worlds" on which a *self-sustainable living* ***biosphere*** originates and develops. Based on the ubiquitous presence of small organic molecules in dark nebulae, chondrite meteorites and cosmic dust grains, and the apparent ease of synthesis of "protobiont" organic molecules in experiments with primitive reducing atmospheres and oceans, it seems that B could be high: 0.5 or greater. However, it seems likely that any life on Mars was short-lived. Are other "exobiologies" possible, not based on water and carbon? We know only one life-bearing planet: Earth (the *"n=1 problem"*).

I is the fraction of these primitive (procaryote, bacterial?) biospheres which evolve to include complex *conscious self-aware* ***"intelligent"*** *life-forms*. Some 9 billion years for supernovae to generate enough "metals", plus 4 billion years evolution on Earth, have been needed. I could be very small. Are we among the first to attain intelligence? Hence, SETI's "great silence"?

C is the fraction of intelligent life-forms which discover the necessary ***communications technology***, and are willing and able to send/search for radio and other electromagnetic signals from other ETC's. On Earth, among many cultures living in settled communities, those using Western science-based technology have recently entered this stage of development. C seems to depend on the development of non-nomadic societies (eg. agriculture-based city-states with stable institutions - universities or similar), able to undertake evidence-based research into nature's workings, unobstructed by totalitarian or other orthodoxies. Can we assume that, given time (some 100,000 years, if Earth is any guide), C is greater than 0.5? Again, the "n=1 problem": might any other ETC's conduct their affairs more rationally and responsibly, avoiding waste and tribal warfare?

L is the estimated ***life-span of an ETC***, from its emergence to its extinction. The "n=1 problem" again looms large. Our civilization has existed for some 100 years since radio-communication came into wide use, and the first radio-astronomers detected extra-terrestrial signals (Jansky, 1930's, found radio noise originating from Jupiter's turbulent atmosphere and the Galactic plane). Provided that our technological civilization is able to sustain itself, avoiding collapse due to planetary climatic impacts, over-use of limited resources, or catastrophic inter-tribal conflict, it could conceivably last for another billion years or so before Earth becomes uninhabitable due to gradual solar warming (about 10% per billion years). Or it could collapse to a primitive state, with loss of radioastronomy and other advanced technologies, within (say) 100 years? Would a life-span somewhere within this huge range be typical of other ETC's? Would "they" be interested in searching for signals from other ETC's ? Multiplying all the estimated values, we arrive at an estimate that ***ETC's are probably exceedingly rare, at best none within thousands of light-years of Earth, far beyond the nearest stars.*** Indeed, we could be the only one within the Milky Way Galaxy's 200,000 million stars. Other galaxies are too remote for radio contact to be possible. In which case, the means by which we manage our small world and conduct our affairs could be of galactic, even cosmic significance? **Conscious mind**, capable of "bringing self-awareness to the Universe", could be an **exceedingly rare** phenomenon. We may usefully recall Monty Python's pithy injunction (taken from A Cheerful Appendix, p.38 in our course notes): ***"So pray that there's intelligent life somewhere out in space, 'cause there's b#!@%! all down here on Earth."***

COSMOLOGY "BIG HISTORY" COURSE NOTES : LIST OF CONTENTS.

1	Our cosmic instant, and its anxieties.
2	Environmental and social problems: a synopsis.
5	Our recent perspective: the pale blue dot.
6	Realm of the great galaxies: a science-based world view.
8	Einstein's universe: the Special and General Theories of Relativity.
9	Quantum cosmology: in the beginning....no cause? A multi-versal wave equation?
11	Black holes and other stellar corpses: our distant future? Hawking's information paradox.
12	Animated stardust: the rise of life.
15	Where we fit in: a blip in a vast, ancient, indifferent universe? Or a rare, complex, cosmically significant form of matter?
17	Human consciousness: the self-aware cosmos? Mind as an emergent property of matter?
19	The evils of evolution: the influence of our cosmic and biological heritage on human affairs. A "demon-haunted world"?
21	Geopolitical questions arising: is democracy again subject to existential threats, e. g. nuclear jihad? Could the "Big History perspective" offer a solution?
22	"Big History" and us: social and cultural Darwinian selection?
25	Cosmology and theology: a possible purpose? (Cosmic *belles lettres* quotes from many sources).
29	An afterlife for the individual mind? Mind-brain dualism?
30	The uncertainty principle: what is truth?
32	So: what can we believe in? Does faith make sense? Or science?
33	Are we alone in the Universe? The "Great Silence" of SETI.
34	Chaos and Order: Intelligent Design? How can complex entities exist?
35	Are we inextricably connected with the entire Universe?
36	A suggestion.
36	.....and finally: the Three Big Questions.

APPENDICES.

38	A cheerful appendix: Monty Python's cosmic thoughts.
39	A serious appendix: cosmic and geological summary of "Big History" from origin to present time.
43	A future appendix: reasons for optimism. (Short-term geopolitical and environmental prospects;
47	probable scientific advances; longer term possibilities).
49	A quantum appendix: could the universe be the ultimate computer?
50	A metaphysical appendix: Heavens Above.
51	A cosmology / theology appendix: The Two Books – Scripture and Nature; the evolving concept of a Creator, comparing scientific, philosophical and religious perspectives.
54	A human mind appendix: How did it arise? What distinguishes it from other animal minds?
55	A love appendix: What is this thing called love? A consequence of big brain and bipedalism?
55	References.
62	Cosmology video/DVD documentary programmes.
63	Cosmology websites.
64, 65	Course Summary: Topic outlines; Frank Drake's equation to help organise our cosmic thinking.
66	An alien appendix: From the outer reaches, a view of a troubled planet. ("When will we visit them?" "When they grow up.")

Illustrations and diagrams, on pages identified alphabetically (a, b, c....etc.), are interleaved between their appropriate pages of text (listed above).

Omar Khayyam, The Rubaiyat:
"Myself, when young, did eagerly frequent doctor and sage, and heard great argument about it, and about, and evermore came out the same door as in I went."

The Duke of Gloucester, presented with "Decline and Fall":
"Ah, Mr. Gibbon, another damned fat square book. Always scribble scribble scribble, eh?"

COSMIC TIMELINE

Fomalhaut b, first direct imaged planet, forms.	13.82 Ga	BIG BRAIN (1500 ml): early Homo sapiens. Many ancestral Hominin spp.
Sirius forms; followed by red supergiant stars Antares, then Betelgeuse.		**Dinosaurs dominant; K/T mass extinction, mammalian radiation.**
		Early terrestrial life: vascular plants, Arthropods (insects, spiders), etc.
Whirlpool Galaxy; Antenna Galaxies collide; first exoplanet's climate.		Cambrian life Explosion: Arthropods,Molluscs, Chordate pre-Vertebrates
Hyades star cluster. Copernicus bright ray lunar crater.	13 Ga	Ediacaran Period: multicellular marine life.
Andromeda Galaxy and satellite, M31/M110 double.		Cryogenian Period: Earth totally ice ensheathed.
Mercury: Kuiperian Era begins.		
Milky Way captures Sagittarius dwarf elliptical galaxy.	12 Ga	Endosymbiosis: Eucaryote cells- nuclei, organelles
Mars: Valles Marinaris rift valley forms.		Proterozoic Era begins.
		Aerobic respiration evolves: Eubacteria
	11 Ga	First atmospheric oxygen.
Mercury: Beethoven Basin forms.		Earliest fossil life: cyanobacteria, stromatalites, Procaryote cells, Archaea.
Mars: Amazonian Basin forms; atmosphere thins, less CO_2.		
Moon: Eratosthenian Period, impact cratering.	10Ga	Archaean Era: first oceans. Life's viral & unicellular origins, RNA World,
		DNA, sexual reproduction, photosynthesis, oxygenation of oceans.
Close encounter, Andromeda & Triangulum Galaxies.		Earth collides with Theia planetoid: Earth/Moon system forms.
Jupiter/Saturn resonance moves Neptune outwards; comets, Oort Cloud,		
Kuiper Belt, asteroids, Late Heavy Bombardment of Earth/Moon.	9 Ga	**Solar System forms:** primal supernova,Sun,planets,Hadean"Black Earth"
Mars: pre-Noachian Era, then early oceans.		M67 open star cluster, Proxima Centauri form.
Lunar Late Imbrium Period, Orientale Basin asteroid impact.		Christmas Burst GRB (Gamma Ray Burster): lasts 28 minutes!
		Tau Ceti star: 5 planets, one habitable?
COSMIC ACCELERATION begins: Dark Energy Overcomes gravity's attraction.	8 Ga	Capella star system; Alpha Centauri a,b binary forms, closest stars to Sun.
		Mira binary system; Kepler 452b "Earth Twin"planet forms.
		Mu Arae star: 4 exoplanets, the first observed from Earth.
	7 Ga	Polaris & Arcturus stars form.
		Furthest naked-eye GRB (gamma ray burster)
Larger structures form: galaxy sheets, walls, clusters, superclusters, voids.	6 Ga	Rigel star forms.
		51 Pegasi b (Bellerophon) & its exoplanet form.
		55 Cancri b "hot Jupiter", & Kepler11 c "giant ocean"planet, form.
Galaxies collide: Milky Way's spiral arms form: major starburst formation.		
Earliest sun-like "metal rich"stars form.	5 Ga	First rocky terrestrial planets, moons, asteroids, icy comets.
Andromeda Galaxy – rapid star formation, an InfraRed galaxy.		Andromeda Galaxy now set for eventual collision with Milky Way.
Beethoven Burst GRB. Andromeda Galaxy forms, by galactic merger.	4 Ga	NGC 2808 globular star cluster forms.
		Supernova SN UDS10W11 explodes.
BX442, oldest "grand design" spiral galaxy forms.		
	3 Ga	Gliese 581 star and planetary system – first ocean planet.
		Omega Centauri globular star cluster forms.
Globular cluster M15 – has an intermediate black hole.	2 Ga	Oldest observed supernova and pulsar neutron star.
M80 globular cluster: also has many recent "blue straggler" stars.		M55 globular cluster forms.
Early globular star clusters form, e.g. M4 (near Antares.)	1.4 Ga	"Diamond Planet" forms around a pulsar.
GALAXY EPOCH: most distant normal galaxy, HDM-6A; many galactic	1 Ga	Hubble Ultra Deep Field limit.
mergers – blazars, Seyferts, elliptical galaxies.		47 Tucanae globular cluster forms.
RENAISSANCE - end of Dark Ages. Early Milky Way forms.	0.6 Ga	Hubble Extreme Deep Field limit. Genesis planet.
LARGE-SCALE STRUCTURES: gravitational collapse, proto-galaxy clusters.	0.4 Ga	Oldest known quasar, black hole.
STELLIFEROUS ERA: First stars, first light; oldest known star "Methuselah."	0.2 Ga	**Re-ionisation of H and He** by UV from early giant stars and quasars.

COSMIC DARK AGE, 370,000 years: photons decouple, generate **Cosmic Microwave Background (CMB) Radiation**, remnant "fading fireball". **Recombination** of electrons with Hydrogen (75%) & Helium-4 (25%) nuclei; Universe dark, transparent. Gravitational collapse of H/He clouds into dark matter structures.

THE FIRST THREE MINUTES: Matter Era. Photon Epoch: nucleosynthesis of 2H(deuterons), 3He, 4He, & 7Li trace: hot glowing opaque expanding **electron/baryon plasma;** dark matter halos gravitationally attract H and He – the origin of first protostars.

Lepton epoch: hadrons and antihadrons annihilate, leaving leptons and antileptons. Neutrinos decouple from matter, generate cosmic neutrino background.

Hadron epoch: quarks bind to form hadrons, including the **protons and neutrons** constituting today's atomic nuclei.

Quarks epoch: electroweak phase transition : **short range weak force** separates from **long range electromagnetic force;** matter interacts with Higgs field, acquires **mass;** baryogenesis may have given baryon matter the upper hand over antibaryon matter.

Electroweak epoch next: **strong nuclear force** separates, perhaps fuelling **INFLATION;** decay of X,Y, W, Z and Higgs bosons.Inflation ends, with superhot ionised quark/gluon plasma (**the current limit of Large Hadron Collider observations** of extreme states of the early Universe)

GUT (Grand Unification) epoch: gravity separates, leaving electronuclear GUT force; X & Y massive bosons mediate fluctuation between baryon & lepton states.
THE FIRST SECOND: Planck epoch: earliest meaningful time. **BIG BANG:** our space and time originate from a primeval virtual particle or false vacuum state, needing a quantum theory of gravity. All matter and energy of the future Universe is concentrated in an infinitely (?) **hot dense gravitational singularity,** a billionth the size of a nuclear particle, far beyond the limits of observational tests. **WIMPS** (weakly interacting massive particles), **dark matter, dark energy,** if present, maybe helped inflate the singularity. The infant Universe, almost completely uniform, has quantum fluctuations causing slight density variations.

PLANCK TIME, 10^{-43} second: the BIG BANG.