

Explain how dynamical friction of planet and dust disk works to make planet spiral inward, leading to “hot Jupiters.”

Chapter 14: Implications of Contact

More a summary and conclusion chapter.

You've come a long way. You've covered the book!

Started course by asking if there is life elsewhere in the universe

By now should be familiar with the issues and methods, and what results we have.

General outline:

Examined the one example we have.

Studied life on Earth, try to find underlying principles, basic requirements to guide in our search for life elsewhere

three key ideas to pull from this course of why life is likely

1) Material for making life: elements and molecules we know imp. to life common throughout universe (hydrogen (most abundant), oxygen (3rd), carbon (4th), nitrogen (6th))

THESE THINGS FORM ABUNDANTLY IN SPACE

observed elements in interstellar material

hydrogen, then stellar nuclear fusion (and low mass dwarfs create molecules!!), then supernovae, then incorporated into next-gen stars and planets

observed amino acids in comets/meteorites

more complex hydrocarbons abundant in clouds (Brandon's thesis on PAHs), organic molecules in space

2) Environment for life to thrive: wider range of environmental conditions than we once considered

forming: stable orbits, habitable zones of different stars

developing: Earth more robust than we thought; good CO₂ cycle, greenhouse effect, stabilizing Moon

surviving: life in more extreme environments than we thought (extremophiles), requirements simpler than we thought

need liquid medium for transport

need energy source for metabolism

3) Getting started: life seemed to take hold quickly once the conditions were right

earliest fossil records indicate start after heavy bombardment even with uncertainties in exact date, we know rough

time scale must be very small

(either to arise or to be transferred from another planet)

Work under the principles that physical processes at work on Earth apply to the rest of the universe

Use what tools we have to examine and even explore outside of our planet

Start local: life in our solar system

Mars likely to have had life in the past, maybe life now
evidence for liquid water present, atmosphere has carbon, hydrogen, oxygen, nitrogen
possible to have chemical rxns between water and rock to fuel early life (like stromatolites)

Europa likely to have life currently
evidence for lots of liquid water (100 km thick ocean under ice)
rocky interior
suggests microbial life possible

Ganymede and Callisto also show evidence of having liquid oceans under surface (deeper)

Titan may have pools of other liquids, has organic molecules on sfc

Looking further: life in other star systems

you just did this in the homework!

seems planet formation is natural consequence of star formation

study of exoplanets, observed gas giants

different from our solar system, but mainly selection effect of detection limits

learn from what we see: now consider a dynamic star system, with planets which can migrate

similar to when Hubble first looked at redshifts of distant galaxies and realized they were moving away from us, and moving faster from us the further away they are. This led to idea of expanding universe, very much at odds with the popular idea of the time of a static, unchanging universe. The debates were fierce!

You're seeing the growth of a young new field of astronomy. May seem confusing, that no one has answers or have data that conflict. In time as we learn more these ideas will smooth out as observations start to fit a pattern.

I was told when I asked about picking a PhD thesis topic: we investigate things which are unproven and controversial because otherwise that research wouldn't be worth doing. If it were straightforward and easy to prove, we would have done so by now. Exoplanets push the limit of our tools and techniques! Very cutting edge, making the best of what we have!

Also looking for civilizations by looking for signals (SETI)

Extraterrestrial life and the human condition

have considered the science of life elsewhere in universe
must also consider the psychological/philosophical/societal side

What is it about searching for life elsewhere that is so interesting to almost everyone?

Touches on some human issues

Changing worldviews

moved from one valley being the world, civilizations which got larger, countries, a planet, a planet in a solar system, one solar system in a whole galaxy, one galaxy in a field of galaxies

concept of what's out there expanding
changes also make us rethink our relationship with that which surrounds us

Copernican Revolution shattered the idea of the Earth as the center of the universe

powerful psychological statement!!

didn't matter in day-to-day activities, but it makes you think
such a change met resistance in Western society for a few hundred years

Evolution shattered the idea of humans as the center of the biological universe

explaining how species change by modification for survival
and inheritance of those changes

species changing all the time without even needing our
interference, also changing without interference

recognize relations among species

again, change met resistance, and most US-wide surveys
indicate that half the population favors a creationist view on
the origin of life

Exoplanets and discovering that what happened here, in our solar system, can happen elsewhere, shatters the idea that the conditions that led to life as we know could happen elsewhere

Given all these changes, what impact would actually finding life have? No data, just doing some talking, here.

Okay, start simple: microbial life on Mars

check whether related to terrestrial life

structure the same (DNA? RNA?)? use same amino acids?

carry out same reactions? chirality the same?

microbes are not glamorous, so maybe most people wouldn't care

and only scientists would get excited about bugs on Mars

actually pretty significant!

would be another major change: the idea that origin of life not unique, that can happen elsewhere

also, learn more information on what conditions necessary for life to arise (we like to make our data sets bigger!)

That's just bugs, who cares? What about intelligent life?

People always thinking: look at science fiction

benevolent aliens could help us with our problems (*Contact*, *2001*, *ET*)

suggesting that we cannot solve our own problems

suggesting that aliens would want to help us

malevolent aliens would come and destroy us, either intentionally or inadvertently (*Independence Day*, *Earth: Final Conflict*)

analogy to our own history, when cultures meet for the first time, usually the least technologically apt being subsumed by the other

Why do we look?

Science

learning more about another type of life would help understand more about what makes Earth life unique and what life requires in general

might be able to share research, technology and learn more

psychology

exploration of world around us (curiosity!) and how we came to be not driven by need to find specific answer to specific question ---

always asking more
sometimes get practical applications, sometimes just learn more
about how the universe works, which is a kind of heritage of our
culture and is passed to future generations
the more we learn about where we live, the more we learn about
what it means to be human

It's like walking into someone's house and learning more and
more about them by looking at what pictures they hang,
books they read, movies they watch, how they position
furniture, what clothes they wear, etc.

exploring extraterrestrial life would be a way to explore what it
means to be human

learn about our own "face" by looking at something different

Attempt to determine the nature of humanity and understand where we fit in the universe

we explore human consciousness in the arts (music, art, dance,
literature), helps us learn what it means to be alive and human
issues of life in the universe cross many scientific discipline boundaries
as well as crossing into the humanities
big issue, ties a lot together

As always with change, there will be difficulty in accepting it extraterrestrial life and effects on religion

could see it as 'if found life elsewhere, what makes humans special?'

could see it as no big problem

depends on the religion

religions have adapted to scientific revelations before (Copernican
revolution)

current trouble accepting evolution: Roman catholic Pope John
Paul II argued that there is overwhelming evidence for Darwinian
evolution, and that God infused humanity with a soul which
separates us from other animals

Extra material, not in the book and most certainly won't be on the final ... consider it just food for thought

Trouble comes about from not thinking mythically?

belief not based on evidence

science could be considered belief based on evidence

what about faith?

faith and belief different

development since Enlightenment that in order to be religious, people must accept certain credos, dogma = faith
previously faith was commitment = belief

Martin Luther, founder of Lutherism, had little time for dogma of Roman Catholic church of the time: faith is heroic cultivation of trust in the idea that, in spite of all evidence to the contrary, life has some ultimate, though possibly ungraspable, meaning and value.

In **Koran**, verse and story are called parables, because is only possible to talk about God in terms of symbols and signs, thus accepting evolution wasn't much trouble for Muslim world.

Until modern world, no one considered 6-day creation story as literal truth

Plato suggested two ways of understanding world: mythos and logos. **Logos** covered the practical, the logical, as reason and science. **Mythos** covered the more elusive, puzzling aspects of being human, a kind of psychology.

Success of logos in modern society led to decline in mythos, but each has sphere of competence and does not work well outside of that.

(Punchline of article: ID not only bad science but bad religion)

Want to read more? Check up on the article I used as a reference for this last part! It was a book review of Michael Ruse's **The Evolution-Creation Struggle** (Harvard University Press, 2005). The review was written by Karen Armstrong and appeared in *New Scientist*, p. 42, July 2005.