

If Earth falls...

could interstellar travel
be our salvation?

Teviet Creighton
South Texas Space Science Institute
University of Texas Rio Grande Valley



Edition: **United States** ▾

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If Earth falls, will interstellar space travel be our salvation?

January 22, 2015 5:41am EST



Is this how space travel will look some day? 'Sulu, punch it!' Shutterstock

Authors



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Texas at Brownsville



Lighter hearts

Beyond Main Street and Wall Street, our scholars also offered some more lighthearted fare, from research [debunking](#) the “opposites attract” cliché to the [economics of literature](#) and the detective story. Our columnist Jay Zagorsky also [looked](#) into Star Wars and the force of inflation.

Looking at just the numbers, here are the top 10 economics and business articles of 2015, based on number of reads:

1. [If Earth falls, will interstellar space travel be our salvation?](#)
2. [Lessons from Greece as controversial finance minister exits stage left](#)
3. [The rise and fall of US labor unions, and why they still matter](#)
4. [Homeownership losing role as lynchpin of the American dream](#)
5. [Elon Musk's Brave New World: it worked for Henry Ford; why not Tesla?](#)
6. [So when should you book that flight? The truth on airline prices](#)
7. [Right-to-work's rapid spread is creating more union free riders](#)

How it's portrayed...



How it's portrayed...



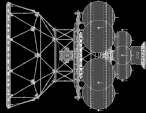
How it's portrayed...



But is it possible?

Newton's Law:

"The only way of getting somewhere is to leave something behind."



Newton's Law:

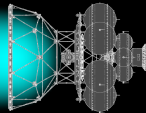
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Newton's Law:

“The only way of getting somewhere is to leave something behind.”

$$m_{\text{fuel}} v_e \leftarrow$$



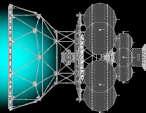
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Final speed Δv depends on *mass* you eject (relative to ship mass), and *speed* you eject it v_e (typically $< 4 \text{ km/s}$ for current rockets).

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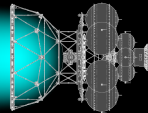
Tsiolkovsky equation

$$m_{\text{initial}} = m_{\text{final}} e^{\Delta v / v_e}$$

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Payload Final speed



$$\Delta v = v_e$$

($\sim 4 \text{ km/s}$)

Fuel:



Tsiolkovsky equation

Newton's Law:

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Payload	Final speed
	$\Delta v = 2v_e$ ($\sim 8 \text{ km/s}$)

Fuel:

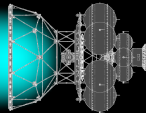


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Payload	Final speed
	$\Delta v = 3v_e$ ($\sim 12 \text{ km/s}$)

Fuel:

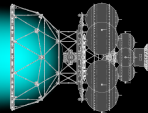


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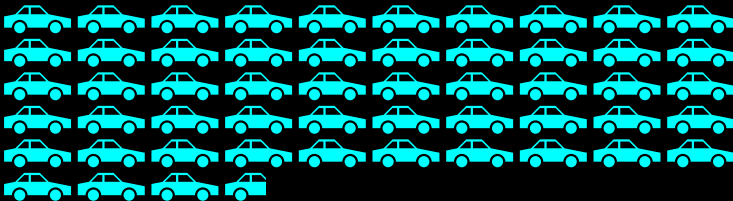
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Payload	Final speed
	$\Delta v = 4v_e$ ($\sim 16 \text{ km/s}$)

Tsiolkovsky equation

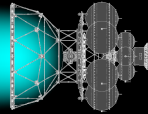
Fuel:



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Payload	Final speed
	$\Delta v = 5v_e$ ($\sim 20 \text{ km/s}$)

Tsiolkovsky equation

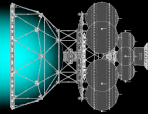
Fuel:



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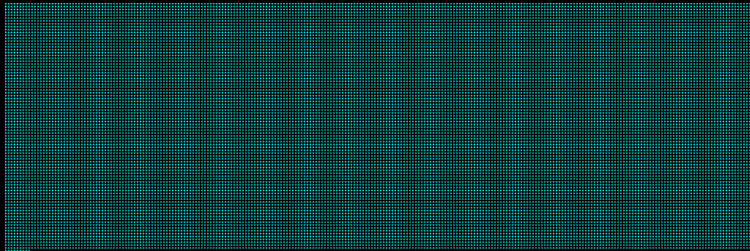
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Payload	Final speed
	$\Delta v = 10v_e$ [$\sim 40 \text{ km/s}$]

Fuel:

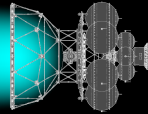
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Payload Final speed Fuel:



$$\Delta v = 20v_e$$

($\sim 80 \text{ km/s}$)

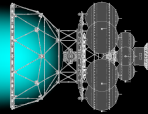
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Payload Final speed Fuel:



$$\Delta v = 50v_e$$

($\sim 200 \text{ km/s}$)

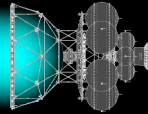
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Payload Final speed Fuel:



$$\Delta v = 100 v_e$$

($\sim 400 \text{ km/s}$)

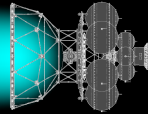


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Payload Final speed Fuel:



$$\Delta v = 120 v_e$$

($\sim 480 \text{ km/s}$)

Tsiolkovsky equation



Rockets, by the numbers:

To deliver a 1 kg payload to nearest star (4.24 lightyears away) within a *century*, we need $\Delta v = 0.085c$.

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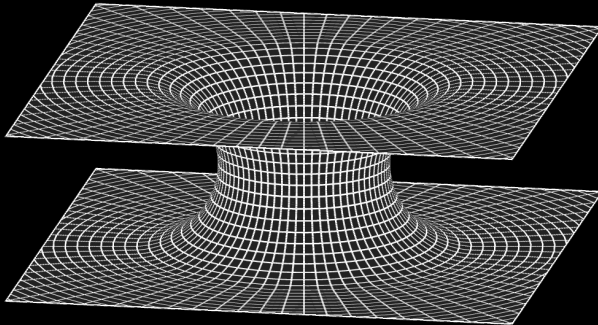
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To arrive within a *decade* (shipboard time), even an optimal thermonuclear rocket would need $9 \times 10^3 \text{ kg}$ of fuel per kg of payload.

⇒ Expect to spend lifetime on board.

What about FTL?

Yes: faster-than-light travel is *theoretically* allowed.

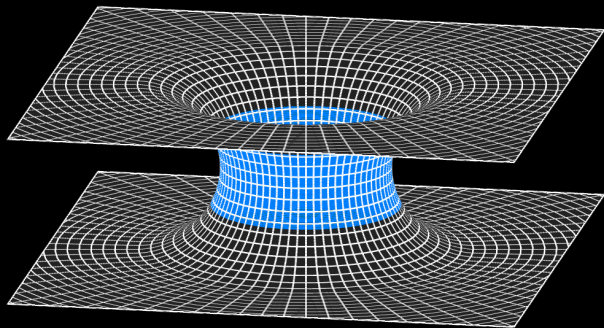


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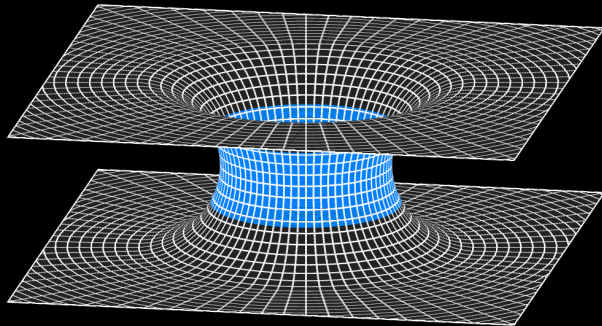
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(requires *contramatter* with negative energy density)



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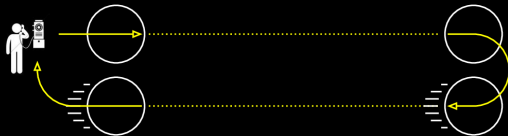
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 - If possible, it may prove to be impractical
(e.g. engines the size of galaxies)



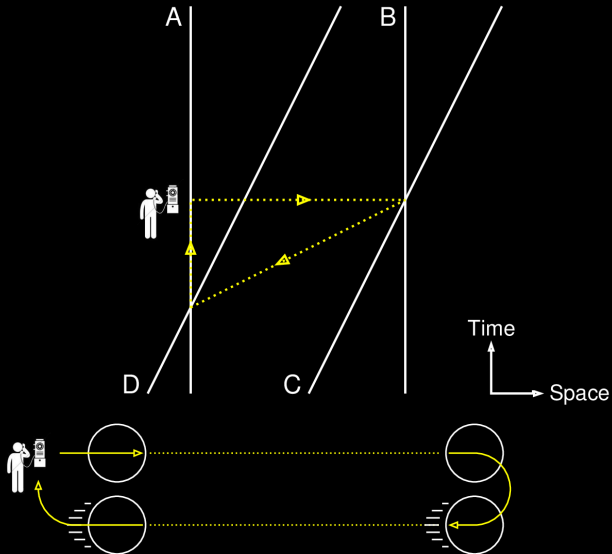
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- But:*
- It may yet prove to be impossible
(requires *contramatter* with negative energy density)
 - If possible, it may prove to be impractical
(e.g. engines the size of galaxies)
 - If practical, it will likely not be used for interstellar travel
(most obvious application is a time machine)



What about FTL?



What's out there?

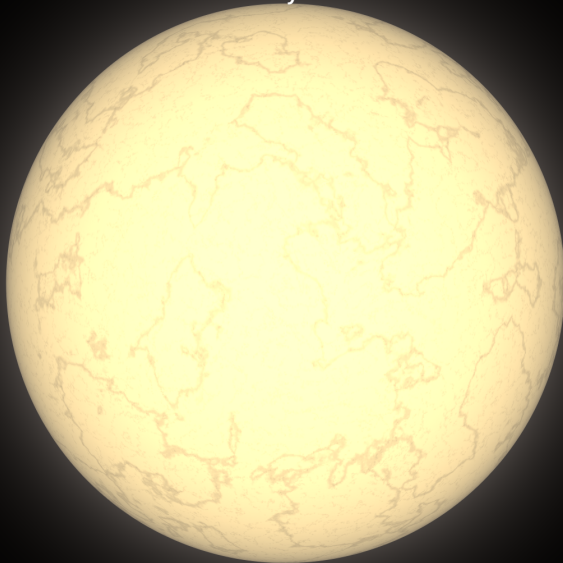


Many stars like our Sun...



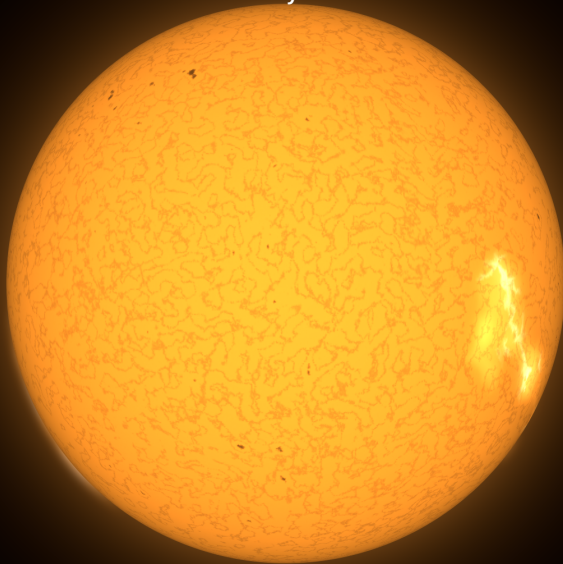
G2V Star

Many stars like our Sun... but many more that are not



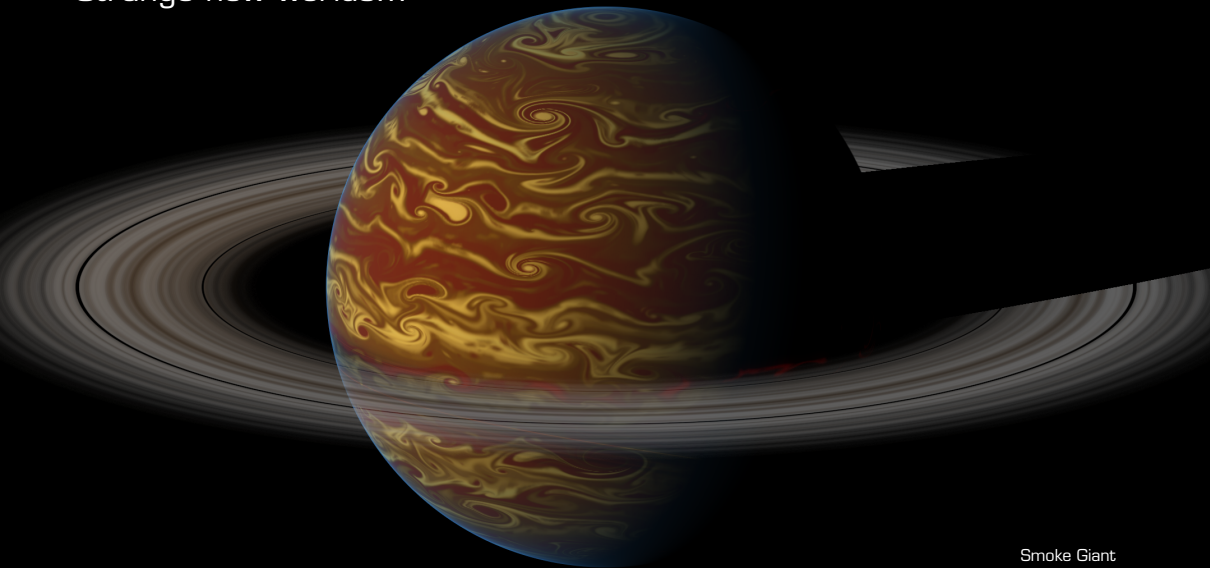
D9 Remnant

Many stars like our Sun... but many more that are not



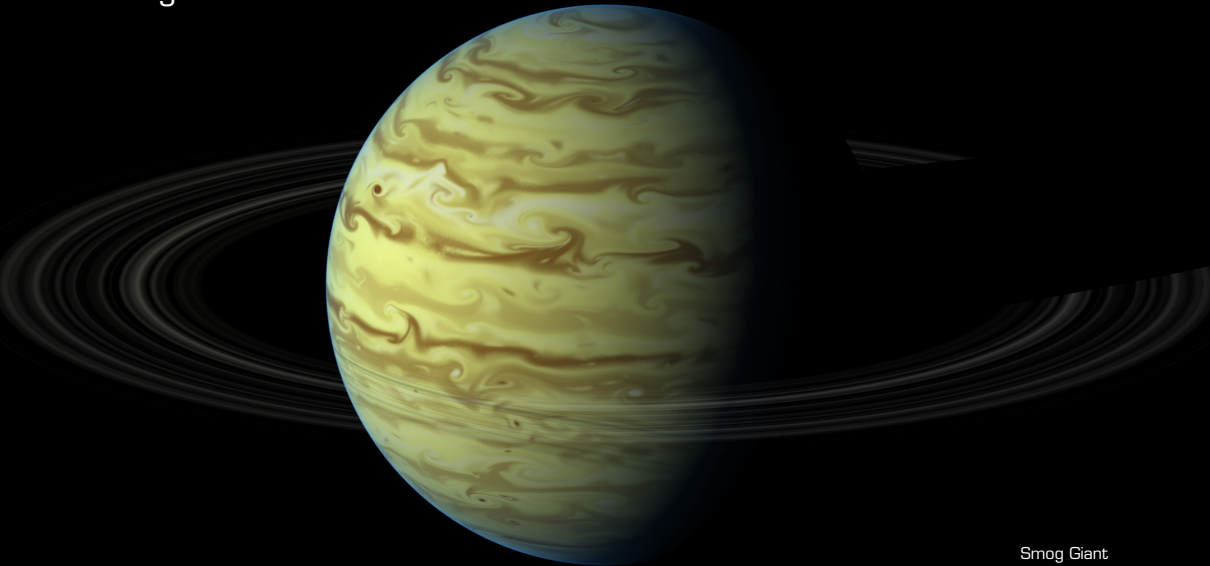
M7Ve Star

Strange new worlds...



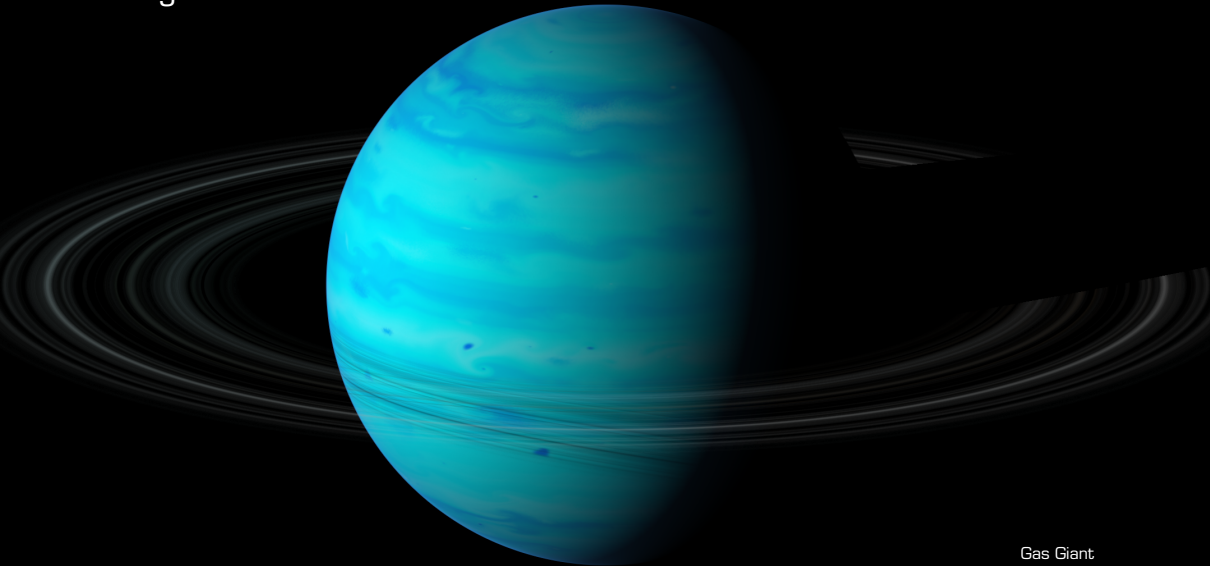
Smoke Giant

Strange new worlds...



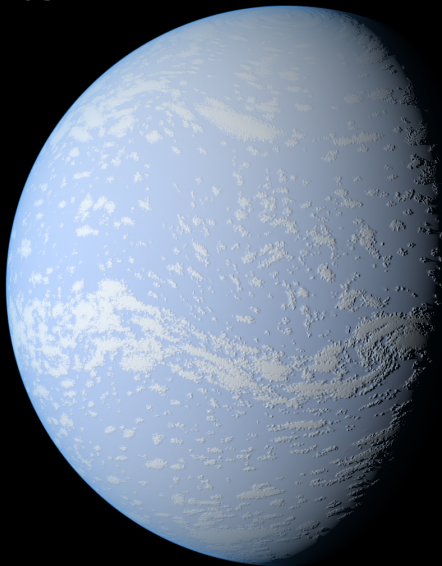
Smog Giant

Strange new worlds...



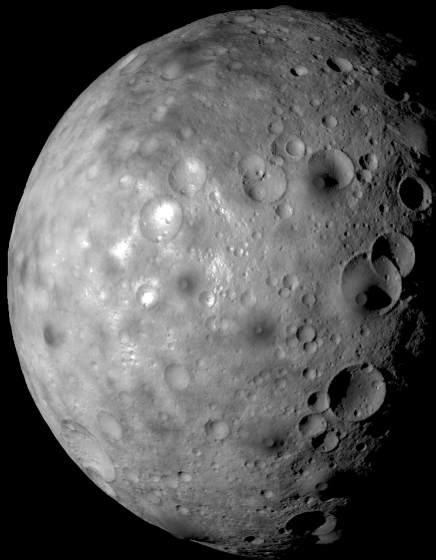
Gas Giant

Strange new worlds...



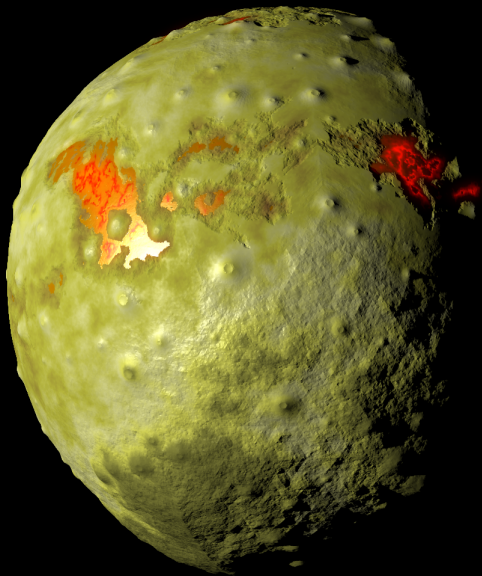
Steam Subgiant

Strange new worlds...



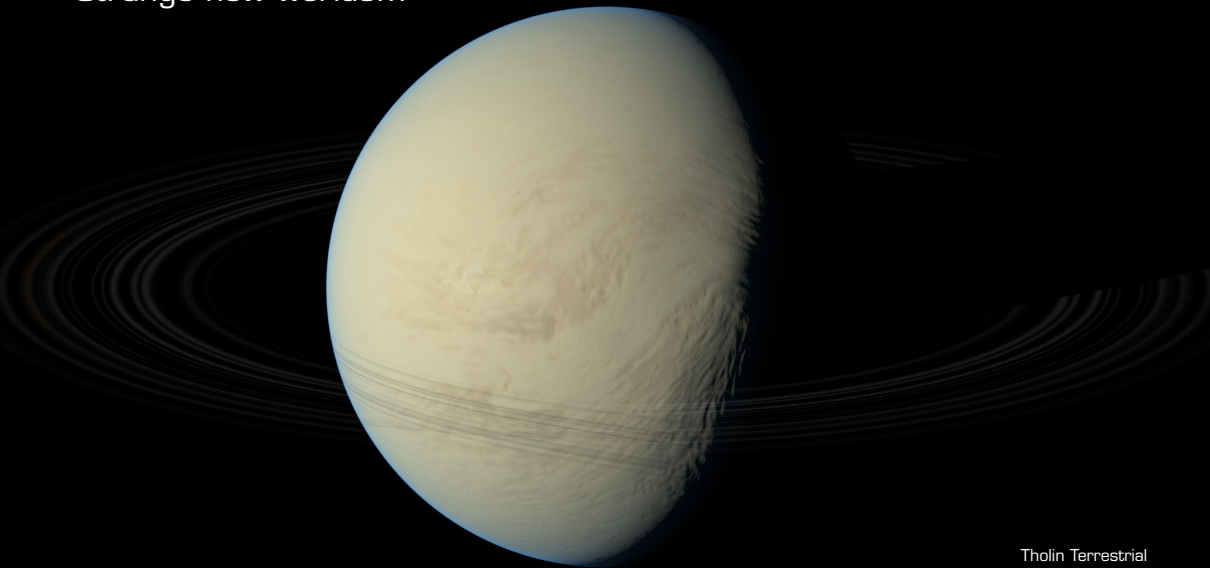
Ice Terrestrial

Strange new worlds...



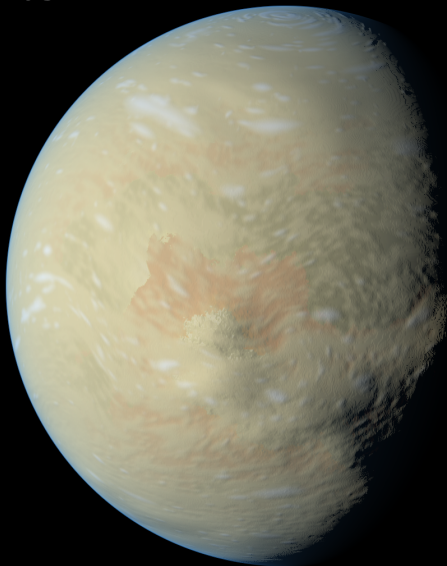
Sulfur Terrestrial

Strange new worlds...



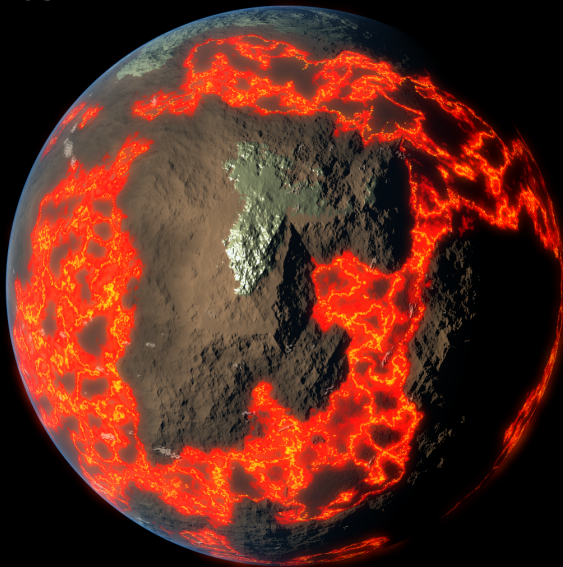
Tholin Terrestrial

Strange new worlds...



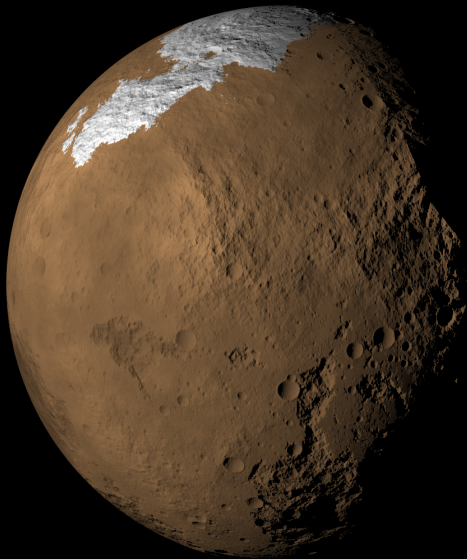
Greenhouse Terrestrial

Strange new worlds...



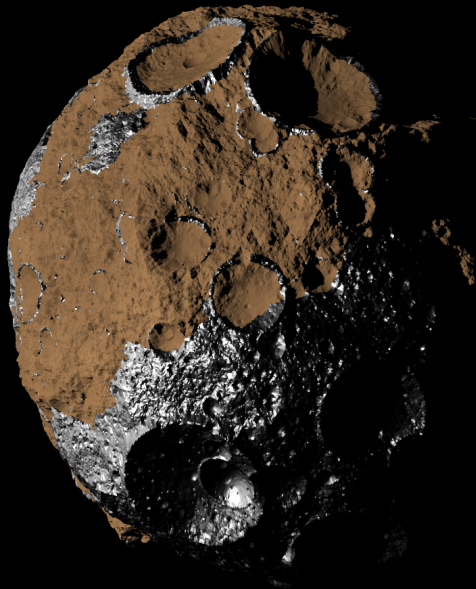
Vulcan Terrestrial

Strange new worlds...



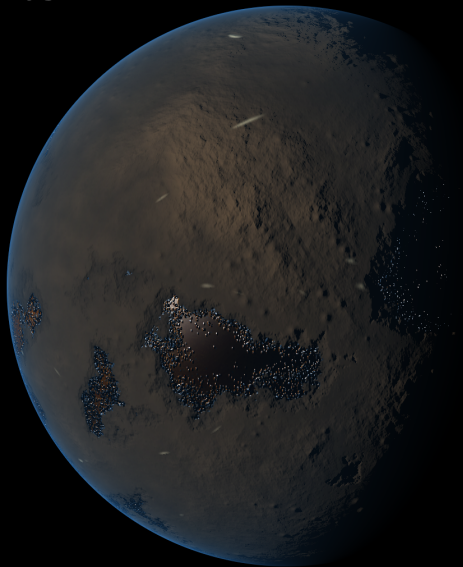
Rock Terrestrial

Strange new worlds...



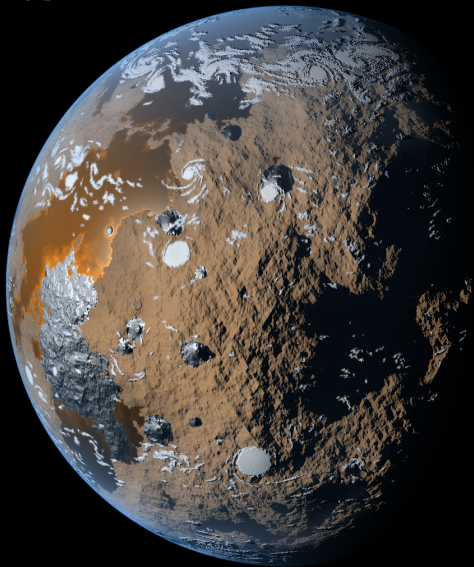
Metal Asteroid

Strange new worlds...



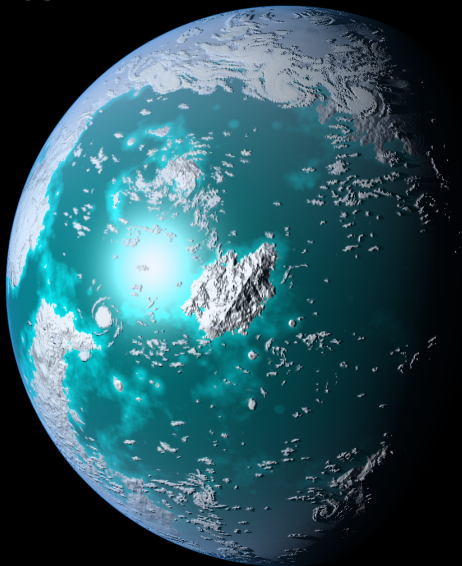
Carbon Terrestrial

Strange new worlds...



Carbonyl Terrestrial

Strange new worlds...



Ammonia Terrestrial

Strange new worlds...



Water Terrestrial

Life...



Water Terrestrial
(Garden variant)

Life... but not as we know it!



Water Terrestrial
(Garden variant)

Habitable worlds, by the numbers:

Density of stars:

 $\sim 0.004/\text{lyr}^3$

Mean distance: ~ 6 ly

Habitable worlds, by the numbers:

Density of stars: $\sim 0.004/\text{lyr}^3$
 Fraction that are Sunlike: $\sim 8\%$

Mean distance: ~ 15 ly

Habitable worlds, by the numbers:

Density of stars:	$\sim 0.004/\text{lyr}^3$
Fraction that are Sunlike:	$\sim 8\%$
Fraction that are singletons:	$\sim 40\%$

Mean distance: $\sim 20 \text{ lyr}$

Habitable worlds, by the numbers:

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Fraction with “habitable” worlds (water):	$\sim 10\%–50\%$

Mean distance: $\sim 30 \text{ lyr}$

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- Options: (a) Barren: engineer atmosphere and biosphere from scratch
(b) Living: eradicate competing ecosystem, then see (a)

Terraforming, by the numbers:

E.g.

Terraform Mars?



Or fix Earth?



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E.g.

Terraform Mars? 

Or fix Earth?



Temperature:

Raise 70°C

Lower 2°C

Heating:

Increase 300%

Decrease 3%

Atmosphere:

Add 4×10^{18} kg N₂, O₂

Remove 2×10^{15} kg CO₂

Hydrosphere:

Add 4×10^{20} kg H₂O

Purify 4×10^{15} kg H₂O/yr

Biosphere:

Add 2×10^6 species

Avoid 500 extinctions/yr

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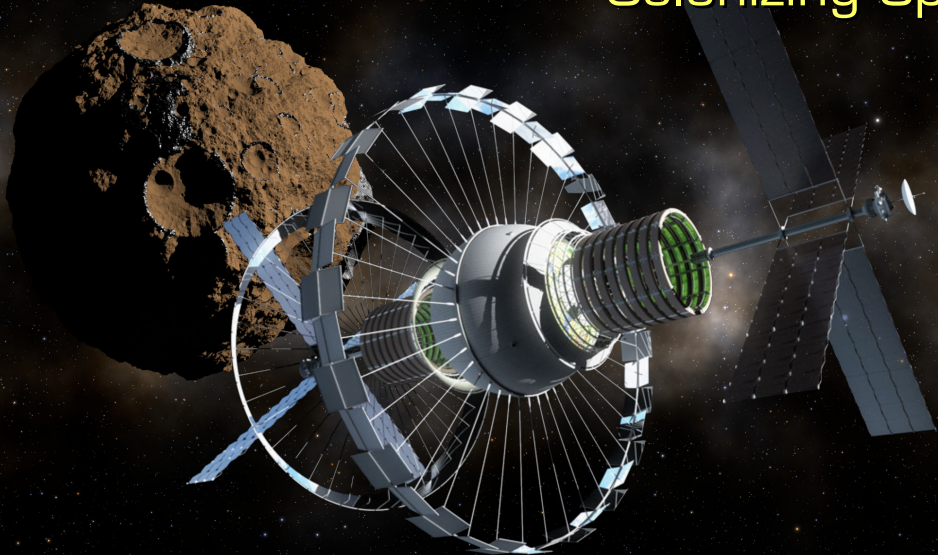
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⇒ At least 1000× cheaper to fix Earth than transform another world

Colonizing Space



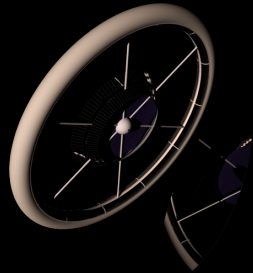
Why planets?

- ▶ Treks between stars will take *centuries*.
Starships will be autonomous and self-sufficient.
Voyagers must learn to live without planetary ecosystems.
 - ▶ Why mine or transform planets, when everything you need is available in space?
- ⇒ *Space habitats* will be the primary form of extraterrestrial colony.

Space habitats, by the numbers:

E.g. “Stanford” torus habitat:

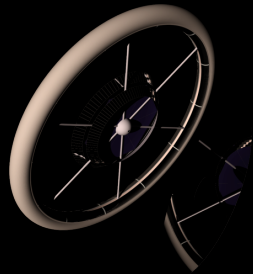
Size:	1.5 km
Population:	10000
Mass:	10^{10} kg (radiation shielding)
Supply:	200 m stony asteroid
# available:	> 6 million



Space habitats, by the numbers:

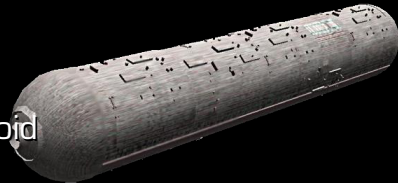
E.g. “Stanford” torus habitat:

Size: 1.5 km
Population: 10 000
Mass: 10^{10} kg (radiation shielding)
Supply: 200 m stony asteroid
available: > 6 million



E.g. “O’Neill” cylinder habitat:

Size: 10 km $\times$ 2 km
Population: 1 million
Mass: 4×10^{10} kg (shielding & air)
Supply: 300 m carbonaceous asteroid
available: > 200 000



Space habitats, by the numbers:

E.g. Ring megastructure habitat:

Size:	Up to 10,000 km diameter
Population:	10 billion
Mass:	2×10^{19} kg (structure & air)
Supply:	<200 km carbonaceous asteroid
# available:	>30

Space Mercantilism: “There’s gold in them thar hills!”

- ▶ Extract resources *in situ*
- ▶ Trade in refined/manufactured products

Spaceships Worlds Colonies

◀ ▶ ⏪ ⏩ 🔍 🔄 8 16/17

-
- # Space Mercantilism: “There’s gold in them thar hills!”
- ▶ Extract resources *in situ*
 - ▶ Trade in refined/manufactured products
- Spaceships Worlds Colonies
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Abundance in M asteroid:

Amount in 1 km asteroid:

Relative to world reserves:

Nickel

20%

700 Mt

×9

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Make up 20% of carbonaceous asteroids

Make up 100% of comets and small outer Solar system bodies

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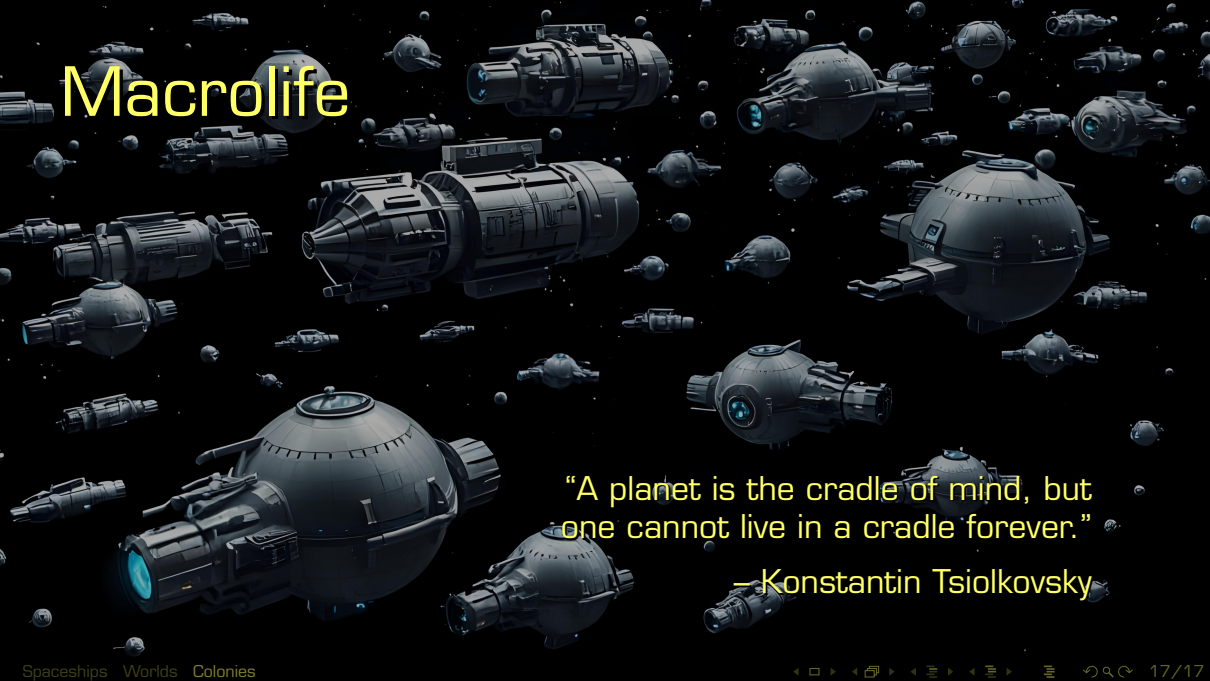
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Power:

Sunlight: over 1 GW/km² at Earth’s orbit.



Macrolife

“A planet is the cradle of mind, but
one cannot live in a cradle forever.”

—Konstantin Tsiolkovsky