

# It's Not Rocket Science!

**It's Not Rocket Science!**

Well, actually, it is...  
...but it's not THAT hard  
if you just skip the maths

Dr Steve Barrett  
BASoc  
16 Mar 2026

**It's Not Rocket Science**

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- Rocket Science**  
What does a rocket do?
- Orbits**  
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Earth to Mars  
Gravity assists to the rest of the solar system
- Parking Places**  
What are Lagrange points all about?

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**What Does a Rocket Do?**

Q: What is the primary function of a rocket?

A: To lift objects up above the atmosphere.

Well, yes ... sort of.

The ISS and the HST are actually still **in** the atmosphere – it's just rather thin up there at an altitude of ~500 km.

To put an object into Earth orbit what is needed is **horizontal** speed.

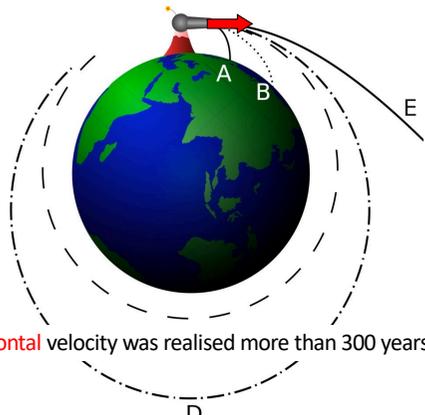
( Getting as high as possible to reduce atmospheric drag is a good idea, but it is not strictly necessary. )

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# It's Not Rocket Science!

### Newton's Cannonballs



Isaac Newton  
*Principia* 1686

The need for **horizontal** velocity was realised more than 300 years ago



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### Saturn V Launch



Although initially the rocket lifts off vertically ...



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### Saturn V Launch



... it's not long before it tilts over to increase its horizontal speed



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### Otherwise: What Goes Up ...



Blue Origin  
New Shepard

It goes vertically up ...  
it comes vertically down

Altitude = 100 km  
Flight time = 10 min



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**Orbits**

**Orbit:** The path of an object affected by (only) gravity.

We are all used to the idea of planets in orbit around the Sun, or moons in orbit around their planets.



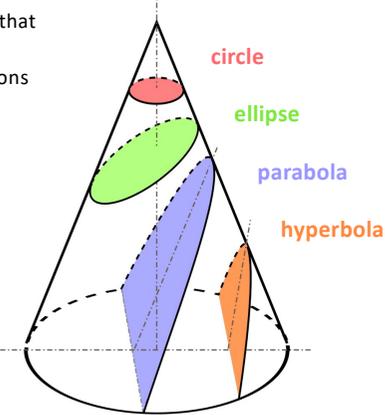
Kepler observed that the planets orbit in ellipses and Newton figured out why – his law of universal gravitation.

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**Conic Sections**

Newton found that orbits have the shapes of sections through a cone



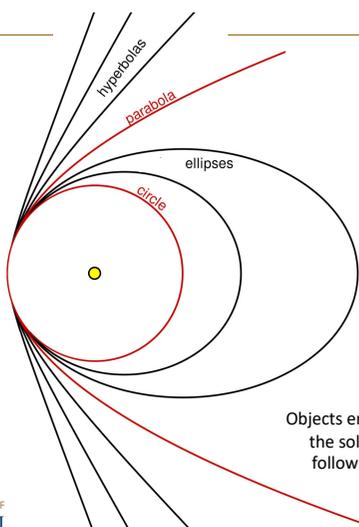
circle  
ellipse  
parabola  
hyperbola

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**Conic Sections**

These curves that describe orbits around the Sun are also the curves that define the shapes of mirrors that are suitable for focusing light.



circle  
ellipses  
parabola  
hyperbolas

Planets follow closed elliptical orbits, but a comet falling into the solar system from way out in the Oort cloud follows a parabolic path.

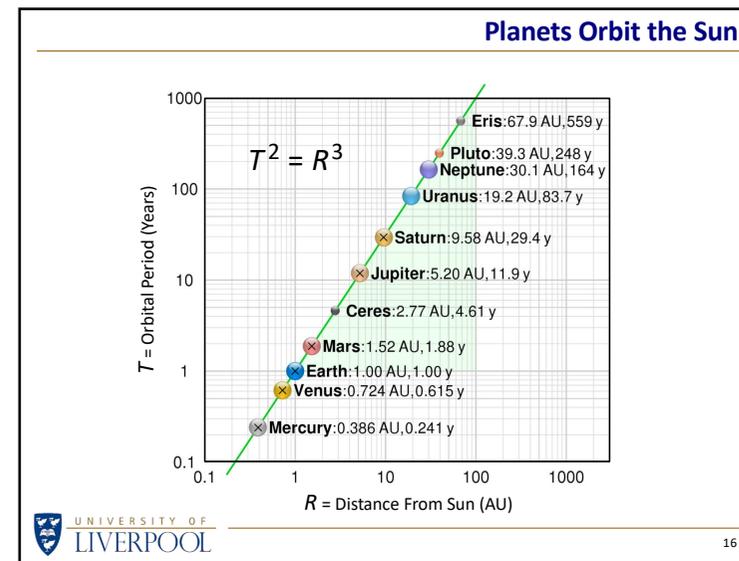
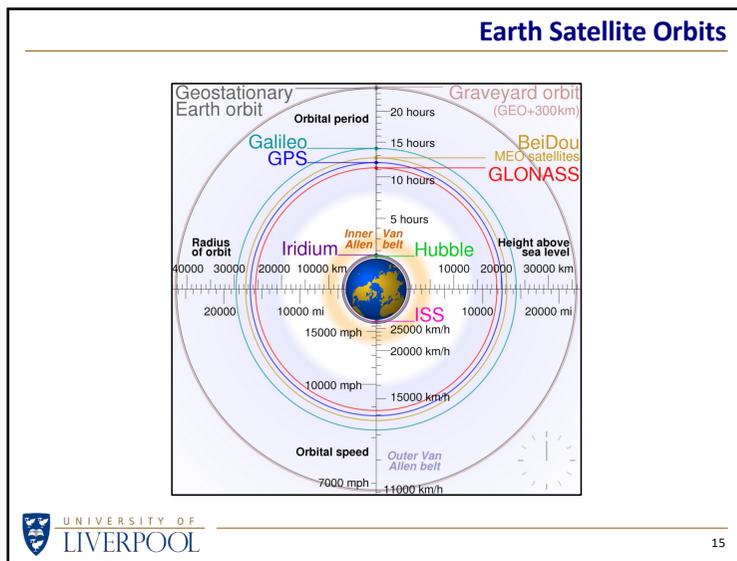
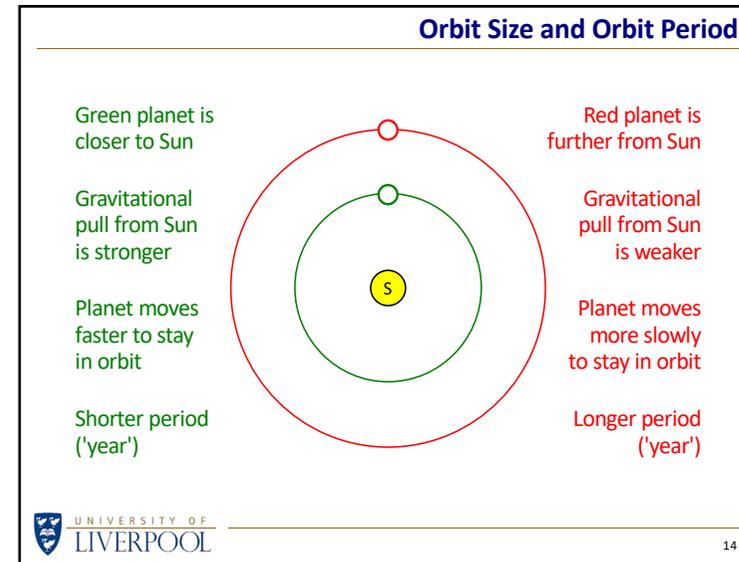
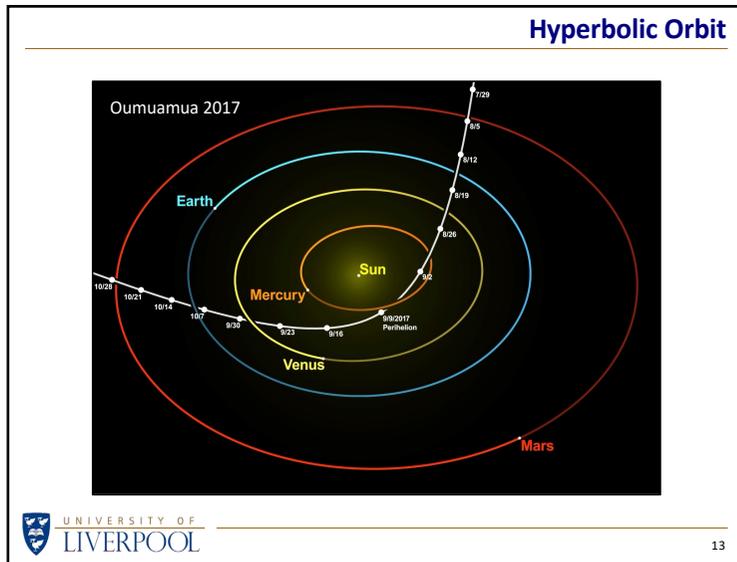
Objects entering and leaving the solar system at speed follow a hyperbolic orbit.

This is because the maths is basically the same for both.

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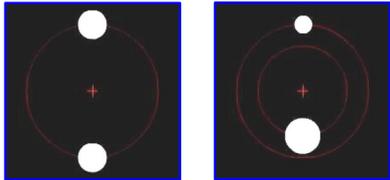
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# It's Not Rocket Science!

### Circular Orbits

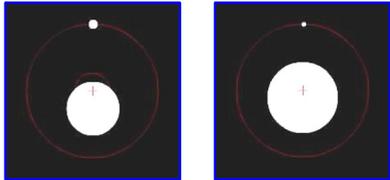
Two objects with equal mass orbit around the centre of mass (+)



If the objects have different masses, objects with larger mass move smaller distances



If the masses are very different, the centre of mass (+) may lie within the larger object



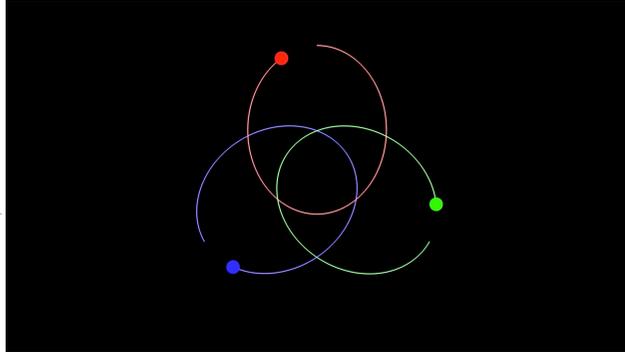
Even a small object (planet) can make a large object (star) wobble – this is how exoplanets can be detected

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### 3-Body Problem

Describing the relative motion of **two** objects is a soluble problem



Physics Simulations

but for **three** or more objects there are very few analytic solutions

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**Rocket Science**  
What does a rocket do?

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Kepler, Newton and Buzz Aldrin  
Circular – elliptical – parabolic – hyperbolic

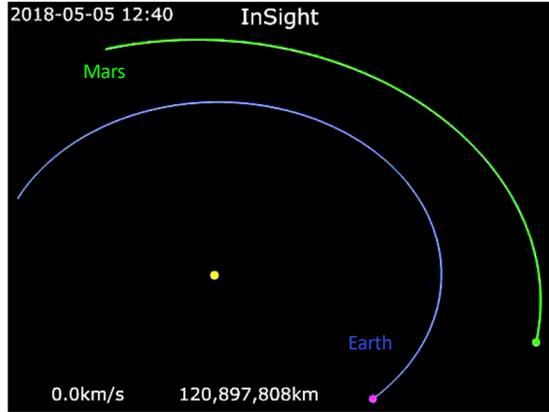
**Getting From A to B**  
Earth to Mars  
Gravity assists to the rest of the solar system

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### Earth to Mars



2018-05-05 12:40 InSight

Mars

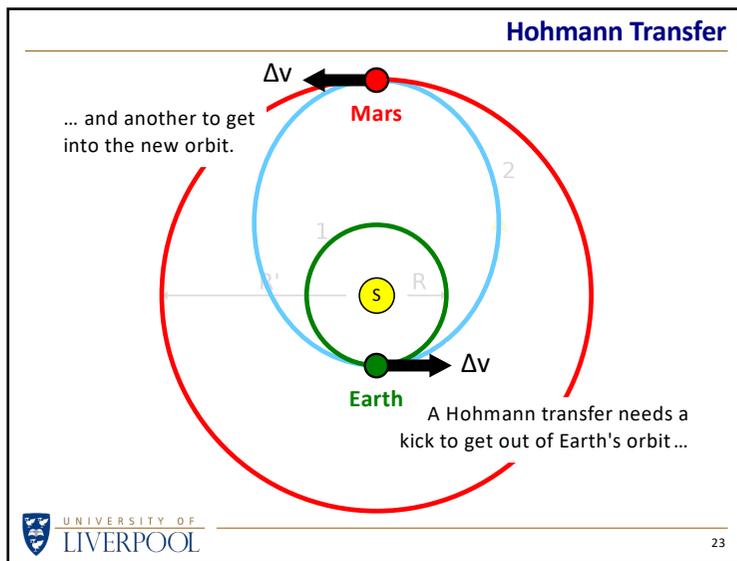
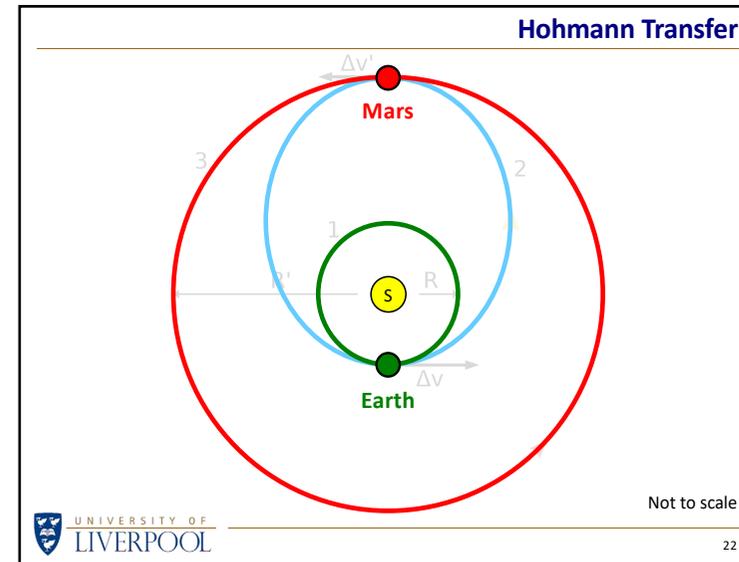
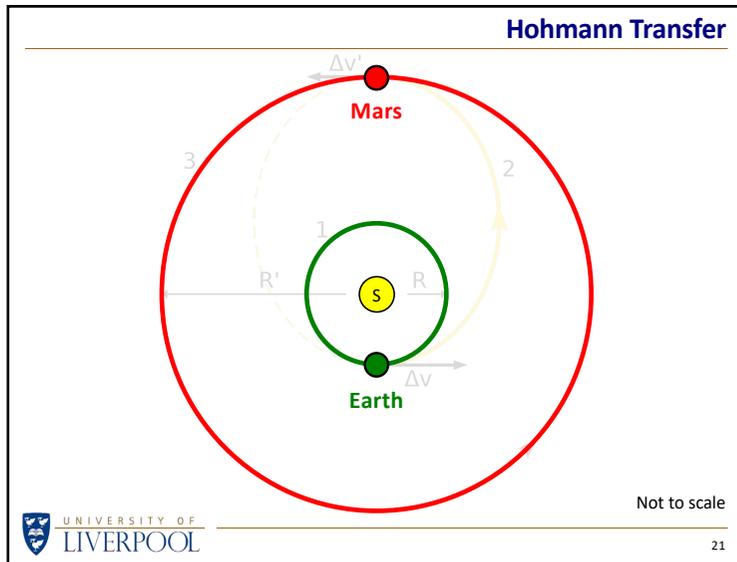
Earth

0.0km/s 120,897,808km

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**Gravity Assists**

What about getting to other planets in the solar system?

In the 1960s it was realised that flying a spacecraft close to a planet can 'slingshot' it onwards at higher velocities.

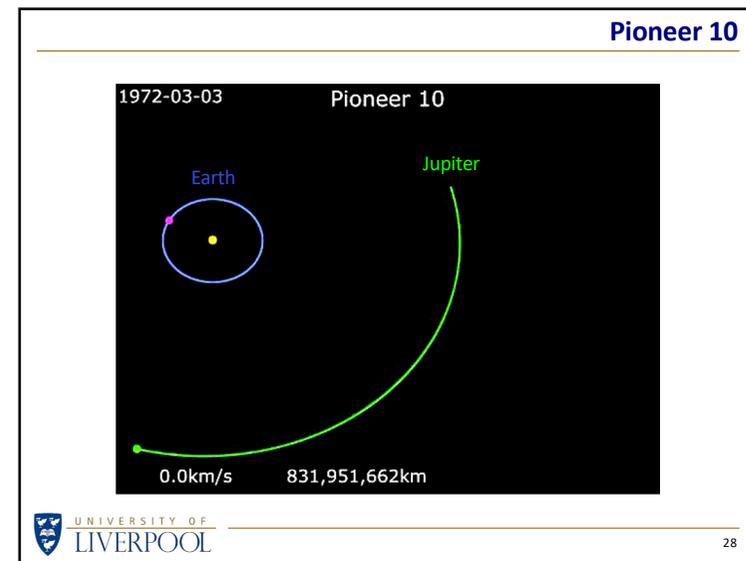
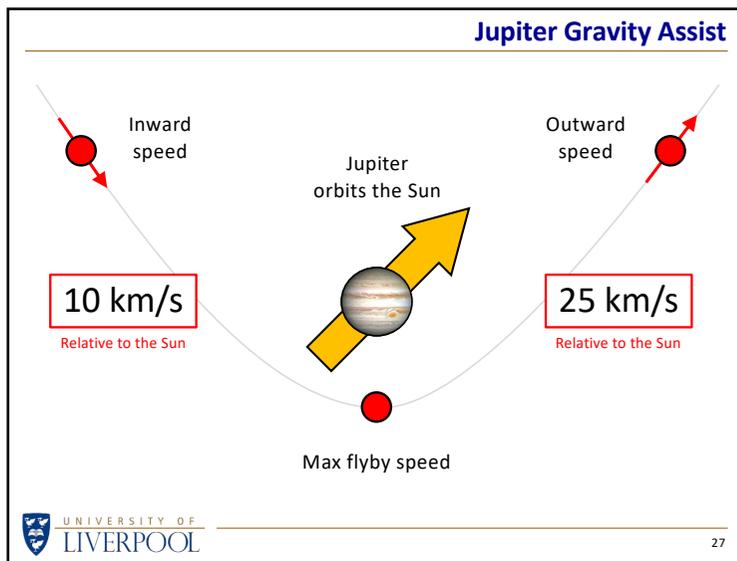
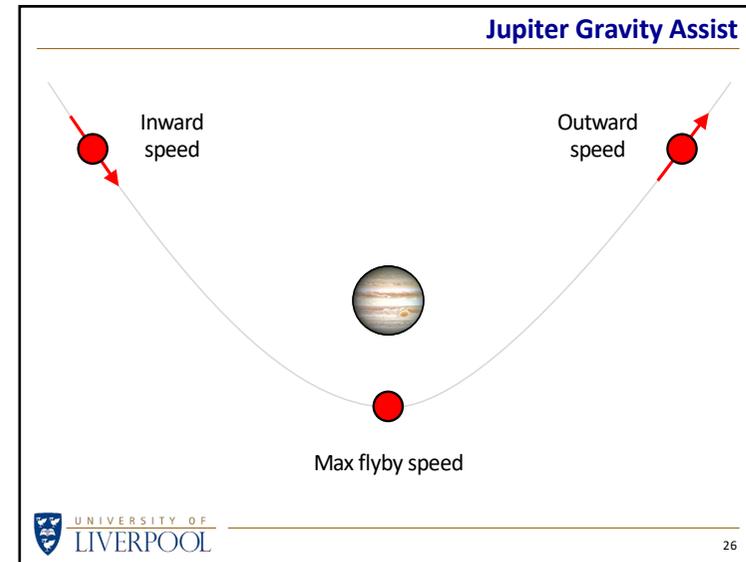
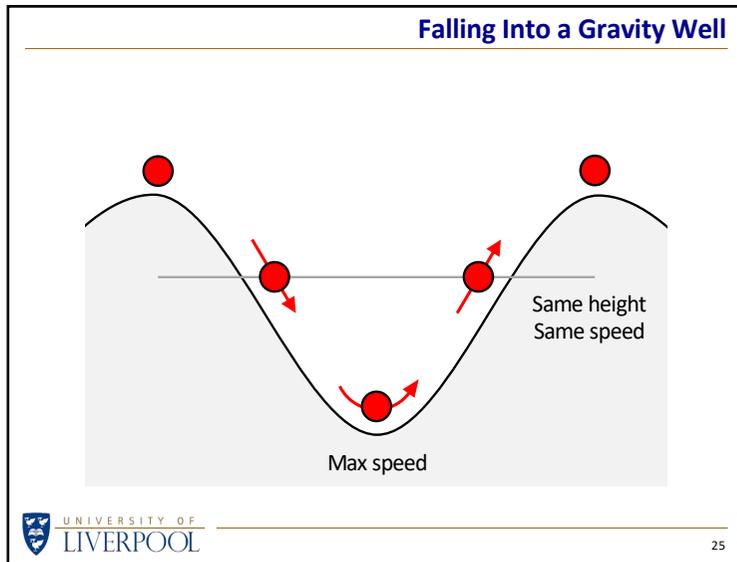
Hence exploring the outer solar system can be carried out faster and cheaper.

19.5km/s    1,438,307,736km

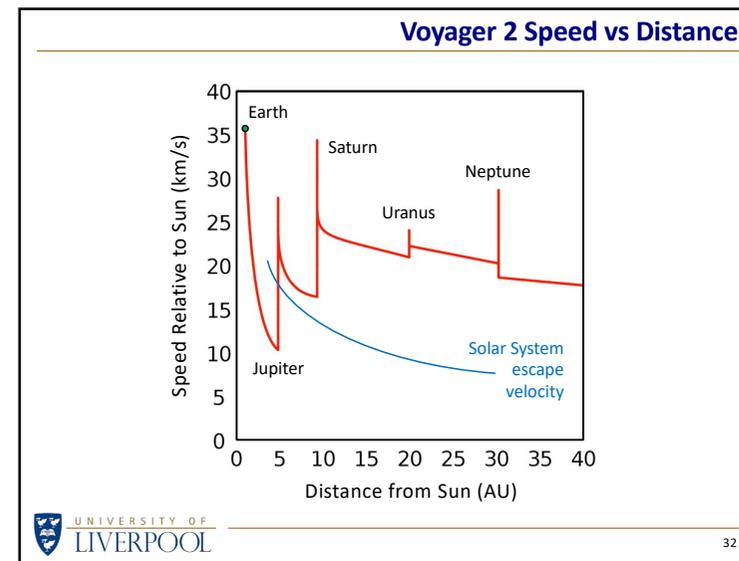
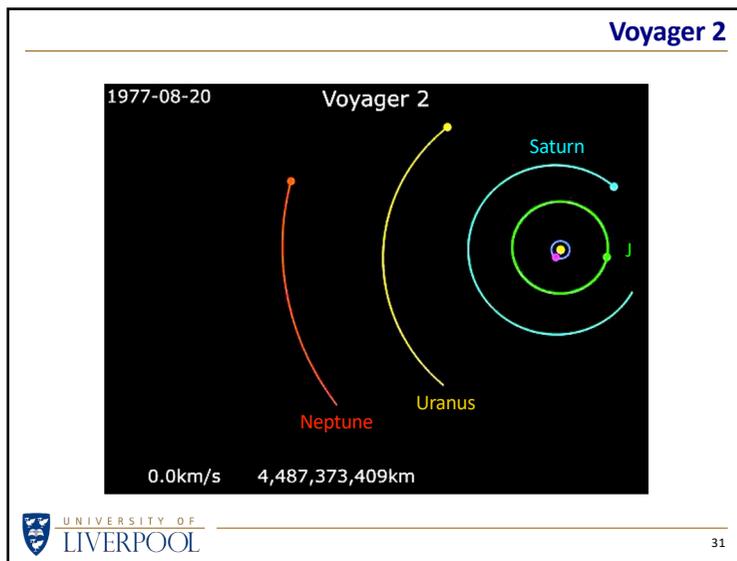
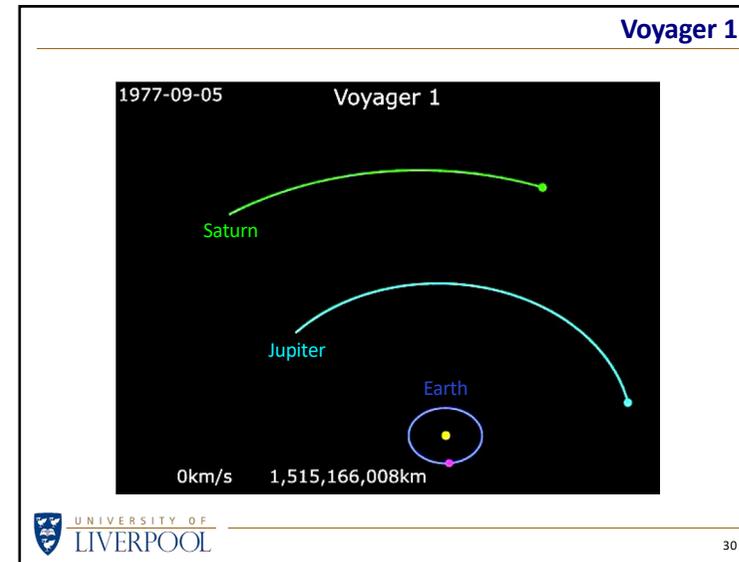
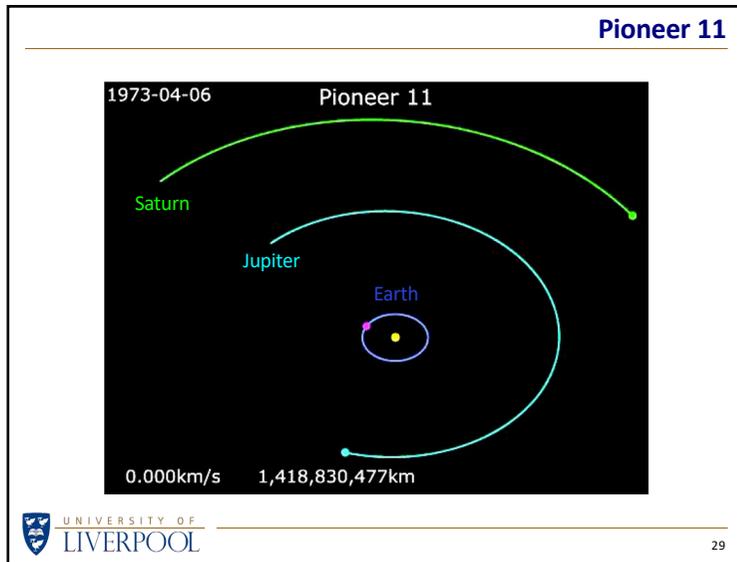
In effect, the spacecraft robs the planet of some of its momentum.

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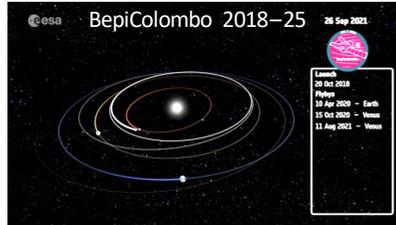
## Gravity Assists

Using gravity assists to help cover the enormous distances between planets in the outer solar system seems like a very sensible idea.

What is not so obvious is that gravity assists are also used to visit the *inner* planets.

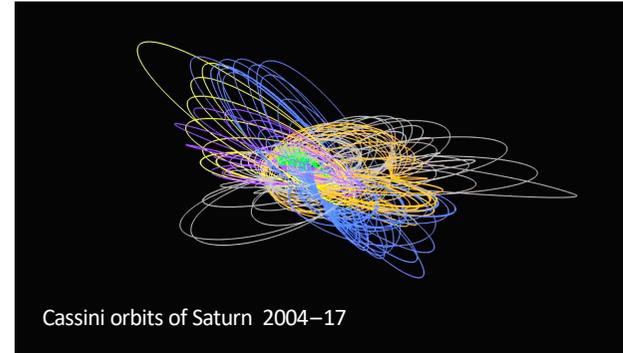
A planet flyby can be used to *lose* speed as a spacecraft 'falls' into the inner solar system.

A flyby can accelerate *or* decelerate, but in both cases fuel is saved.



## Changing Orbits Uses Fuel

Some spacecraft go into orbit around their target planet



Any orbital changes require fuel which reduces the mission lifetime

## Rocket Science

What does a rocket do?

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Kepler, Newton and Buzz Aldrin  
Circular – elliptical – parabolic – hyperbolic

## Getting From A to B

Earth to Mars  
Gravity assists to the rest of the solar system

## Parking Places

What are Lagrange points all about?

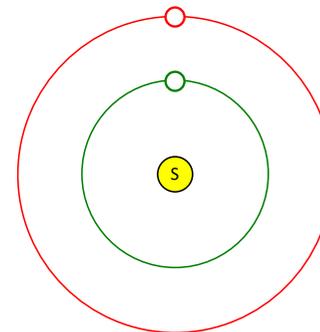
## Orbit Size and Orbit Period

Green planet is closer to Sun

Gravitational pull from Sun is stronger

Planet moves faster to stay in orbit

Shorter period ('year')



Red planet is further from Sun

Gravitational pull from Sun is weaker

Planet moves more slowly to stay in orbit

Longer period ('year')

# It's Not Rocket Science!

### Orbit Size and Orbit Period

The arrows show the gravitational force of the Sun on each planet.

At a greater distance, the force is less.

Is that always the case?

We can't change the gravitational pull of the Sun ...

... but we can arrange it so that an object in the red orbit feels an additional gravitational force.

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### Lagrange Points

Let's assume that green is planet Earth with an orbital period of exactly 1 year.

The red orbit has a period of *more* than 1 year.

What if the red orbit is close enough to the Earth that an object is pulled by both the Sun **AND** the Earth?

There is a red orbit at just the right distance such that the extra pull from the Earth makes the red object orbit faster with a period of 1 year.

That would mean that the red object would orbit the Sun 'with' the Earth.

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### Lagrange Point L2

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### Lagrange Point L2

Not to scale

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# It's Not Rocket Science!

### Lagrange Point L1

The idea is conceptually the same for L1 *inside* the Earth's orbit, but this time the Sun and the Earth pull in opposite directions.

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### Lagrange Point L1

L1 is a good location for spacecraft that observe the Sun, as the Earth never gets in the way.

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### Calculating Lagrange Points

Gravitational forces between two bodies fall off as the square of the distance between them, so we can use that to calculate the distance from Earth to L1 or L2:

$$\frac{M}{(R \pm r)^2} \pm \frac{m}{r^2} = \left( \frac{M}{M+m} \right) R \pm r \left( \frac{M+m}{R^3} \right)$$

$M$  = mass of Sun       $R$  = distance Sun–Earth  
 $m$  = mass of Earth     $r$  = distance Earth–L1/2

Just solve for  $r$ . Simple!

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### Calculating Lagrange Points

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Just solve for  $r$ . Simple!~~

**...but it's not THAT hard if you just skip the maths**

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# It's Not Rocket Science!

### Lagrange Points 1–5

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### Why Park at L2?

At L2 a sunshield can block light from the Sun, Earth and Moon

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### Why Park at L2?

L2 is in Earth's shadow, so spacecraft like Gaia and JWST orbit around L2

If a spacecraft moves away from L2 then the pull of the Earth brings it back

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### Why Park at L2?

L2 is in Earth's shadow, so spacecraft like Gaia and JWST orbit around L2

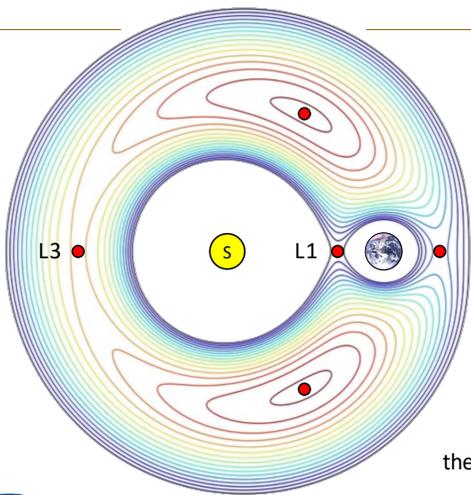
If a spacecraft moves towards or away from Earth then it will continue to drift

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# It's Not Rocket Science!

### Parking at L2



The ability of a spacecraft to 'park' at a Lagrange point is sometimes visualised using this doughnut.

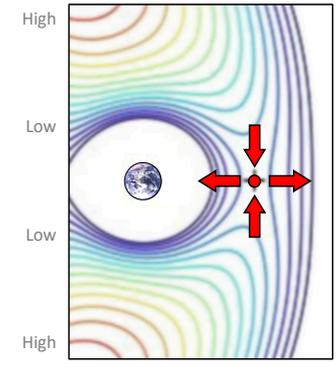
Imagine that the contours represent height and think about a ball wanting to roll 'downhill'.

Look more closely at the contours around L2...

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### Parking at L2



The arrows show the directions of 'downhill' in the vicinity of L2.

L2 is *not* on a 'hilltop'.

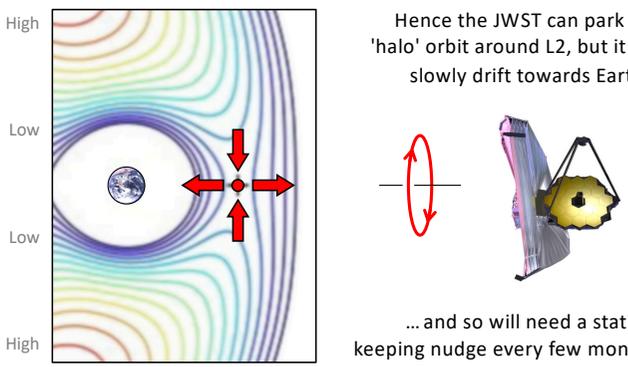
L2 is *not* in a 'well'.

L2 is at a saddle point.

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### Parking at L2



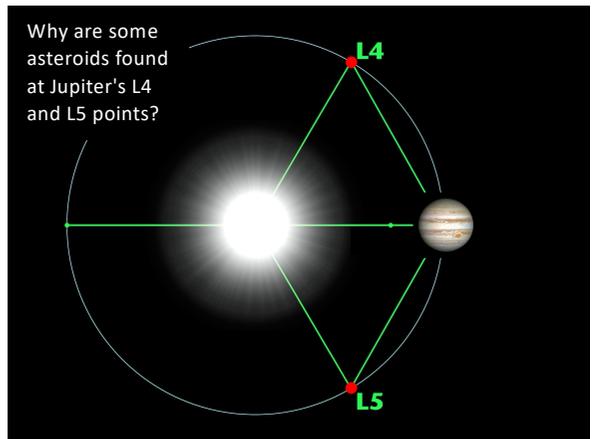
Hence the JWST can park in a 'halo' orbit around L2, but it will slowly drift towards Earth...

... and so will need a station-keeping nudge every few months.

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### Objects at L4 and L5



Why are some asteroids found at Jupiter's L4 and L5 points?

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# It's Not Rocket Science!

### Objects at L4 and L5

Objects can orbit loosely around the L4 and L5 points.

There's not much there at the Earth L4 and L5 points.

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### Objects at L4 and L5

Objects can orbit loosely around the L4 and L5 points.

There's not much there at the Earth L4 and L5 points.

Jupiter's stronger gravitational pull has collected some Trojan asteroids at its L4 and L5 points.

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### Horseshoe Orbits

Some orbits look really weird...  
... but they still obey the rules:

When closer to the Sun the object goes faster than the Earth.

When further from the Sun the object goes slower than the Earth.

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### Open Orbits

Perhaps the weirdest of orbits are those that are *not* closed loops

Is it possible for the stars in a triple-star system to move this way?

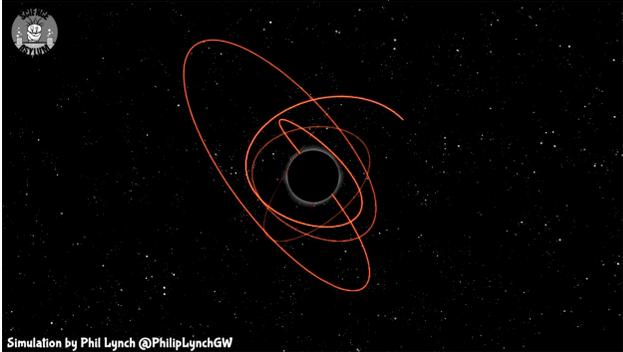
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# It's Not Rocket Science!

**Open Orbits**

...and don't get me started on orbits around black holes



The Science Asylum

Simulation by Phil Lynch @PhillipLynchGW

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**Summary**

**Rocket Science**  
What does a rocket do?

**Orbits**  
Kepler, Newton and Buzz Aldrin  
Circular – elliptical – parabolic – hyperbolic

**Getting From A to B**  
Earth to Mars  
Gravity assists to the rest of the solar system

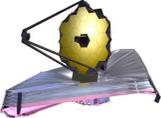
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What are Lagrange points all about?

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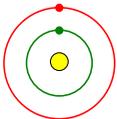
**Summary**

Why is "rocket science" considered to be so hard?

Yes, there are some objects in the solar system that move in ways that are not, at first sight, intuitive.



Yes, calculating how to put the JWST into orbit around L2 was not trivial (especially given the accuracy achieved).



But the underlying idea is straightforward enough: stronger gravitational pull leads to faster motion. (The Earth moves around the Sun faster than Mars)

That's really all there is to it. The rest is *just* maths.

After all ... it's not rocket science!

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**It's Not Rocket Science!**

Well, actually, it is...  
...but it's not THAT hard  
if you just skip the maths

[www.liverpool.ac.uk/~sdb/Talks](http://www.liverpool.ac.uk/~sdb/Talks)

**Dr Steve Barrett**  
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**16 Mar 2026**