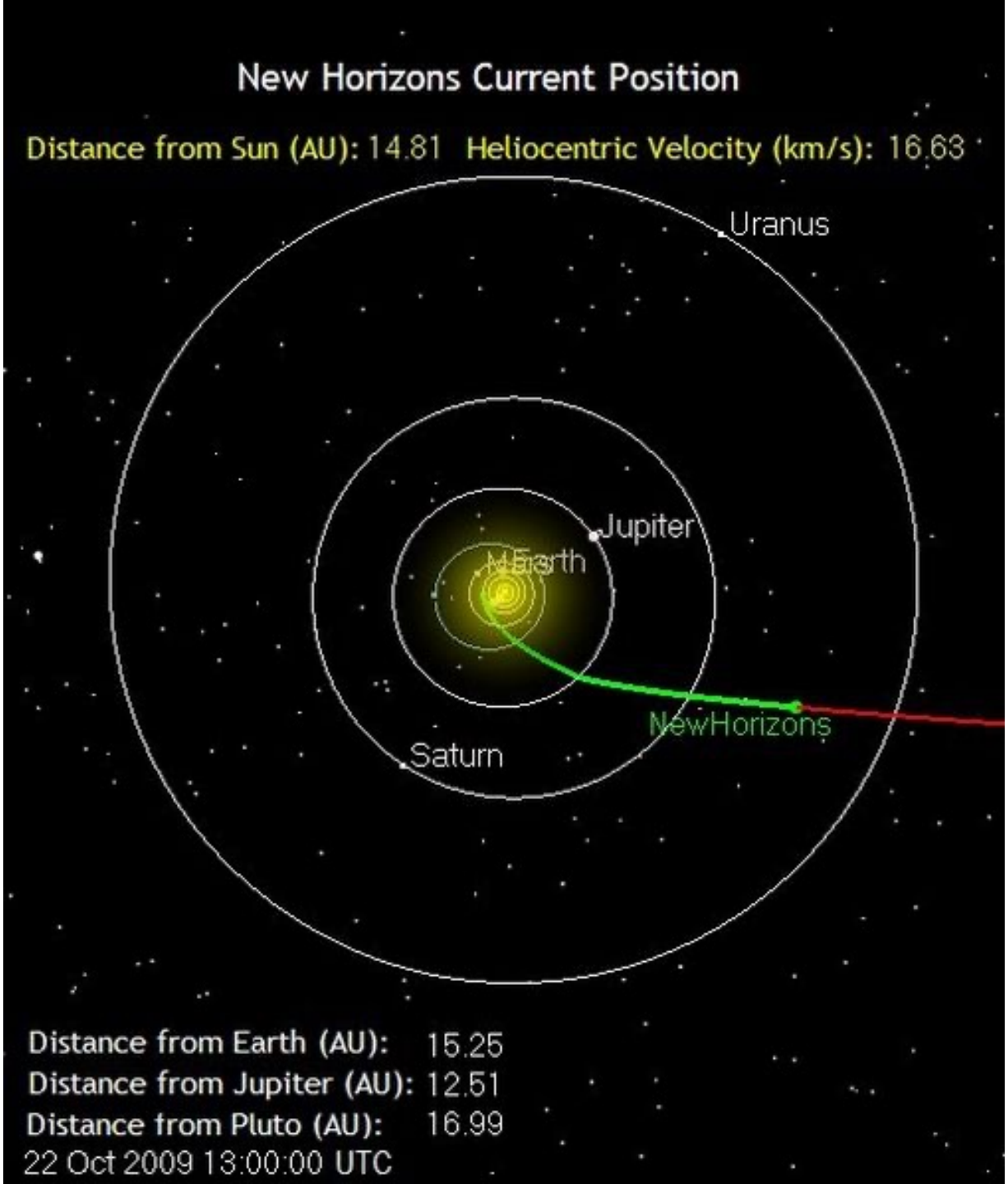
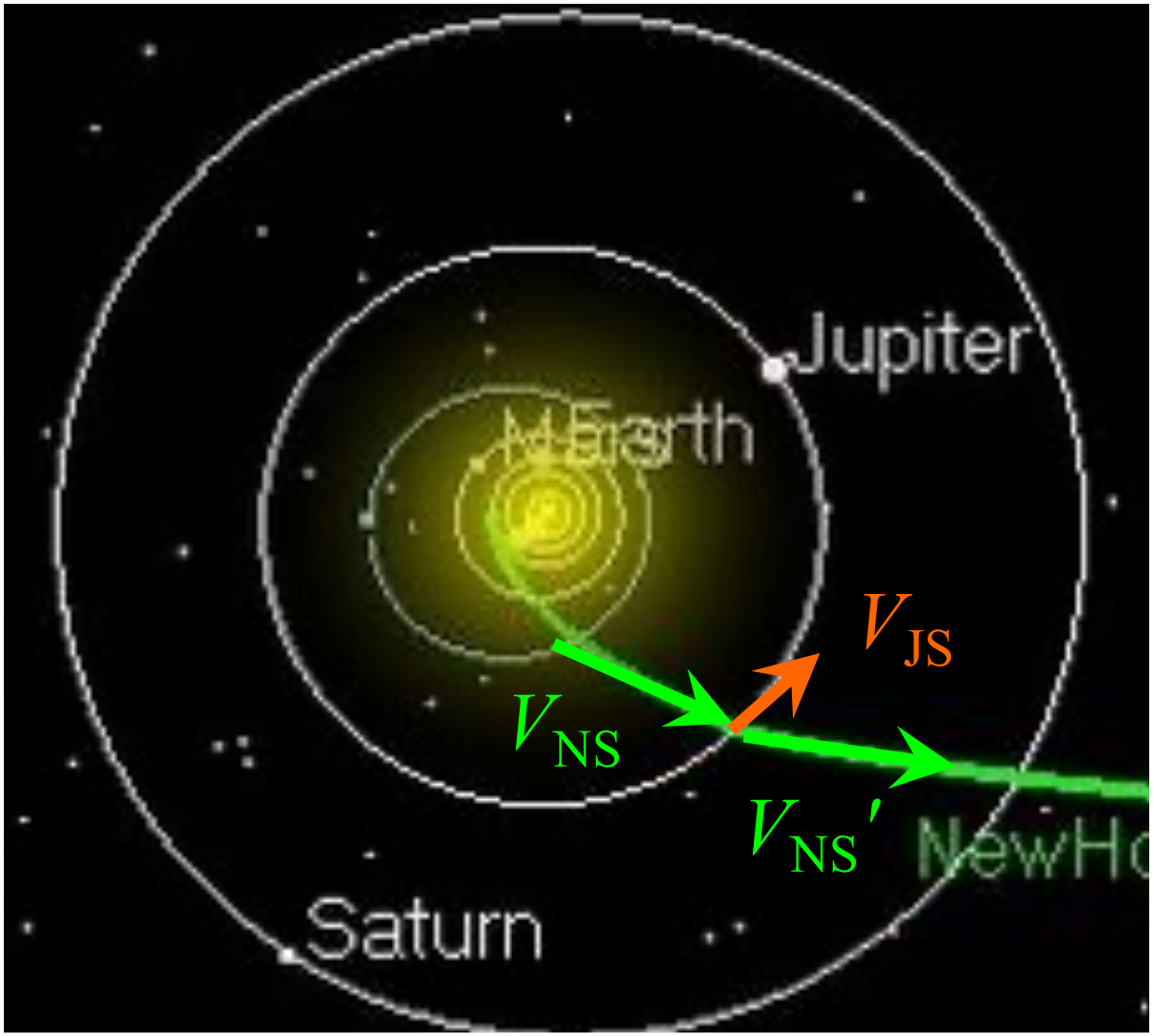
Gravitational Slingshot

a kind of “elastic collision”?


New Horizons Current Position
Distance from Sun (AU): 14.81 Heliocentric Velocity (km/s): 16.63
Uranus
Jupiter
Earth
NewHorizons
Saturn
Distance from Earth (AU): 15.25
Distance from Jupiter (AU): 12.51
Distance from Pluto (AU): 16.99
22 Oct 2009 13:00:00 UTC

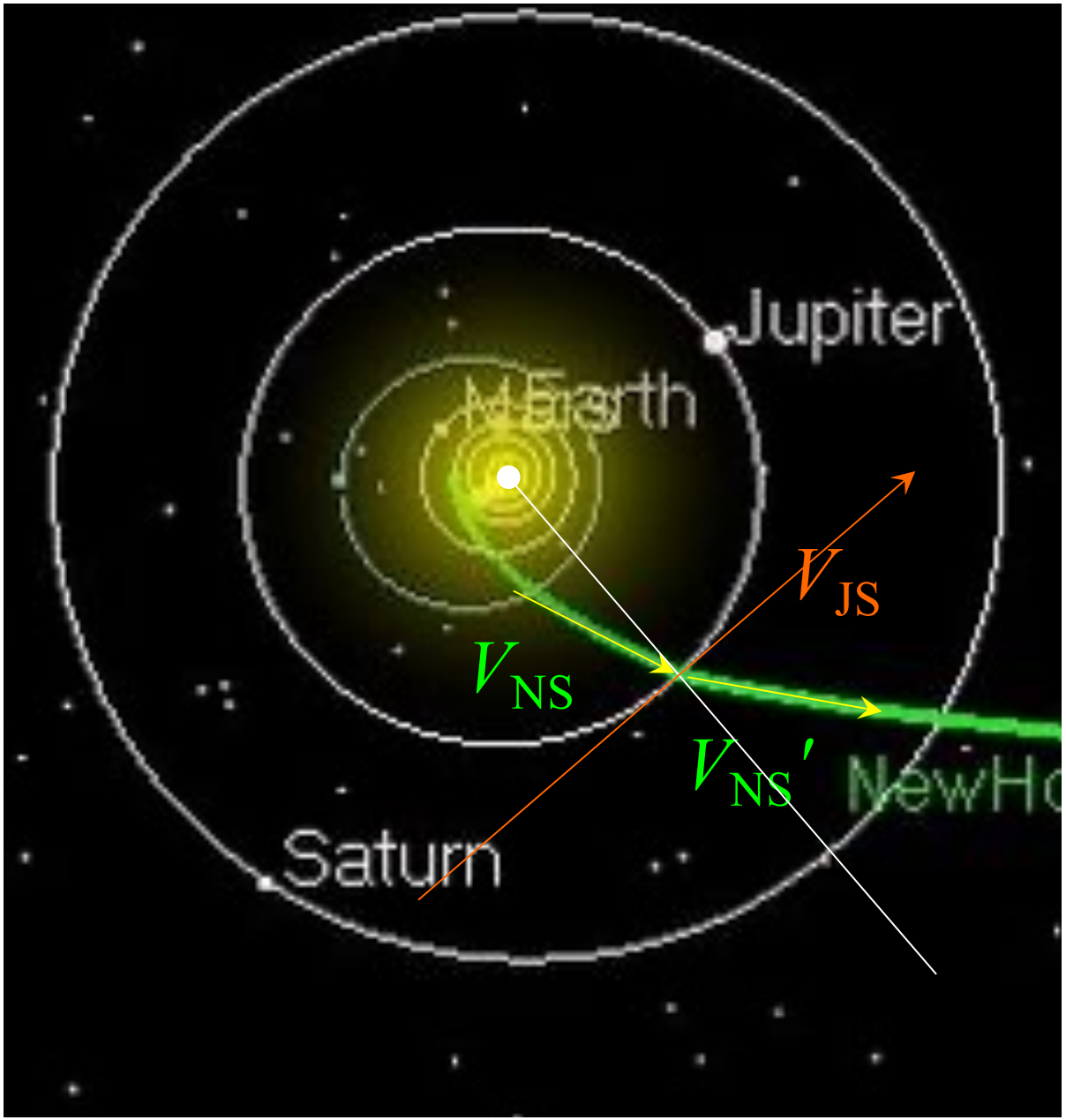


Velocities:

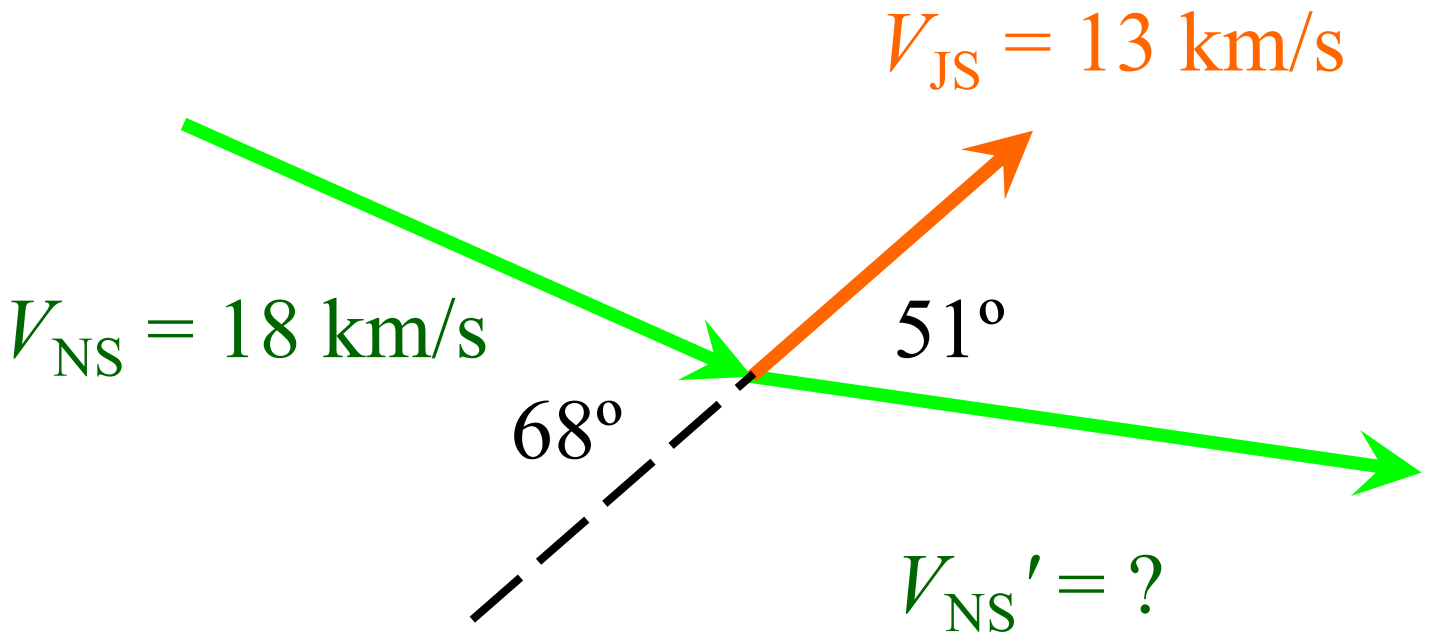
V_{NS} = New Horizons relative to Sun before encounter

V_{NS}' = New Horizons relative to Sun after encounter

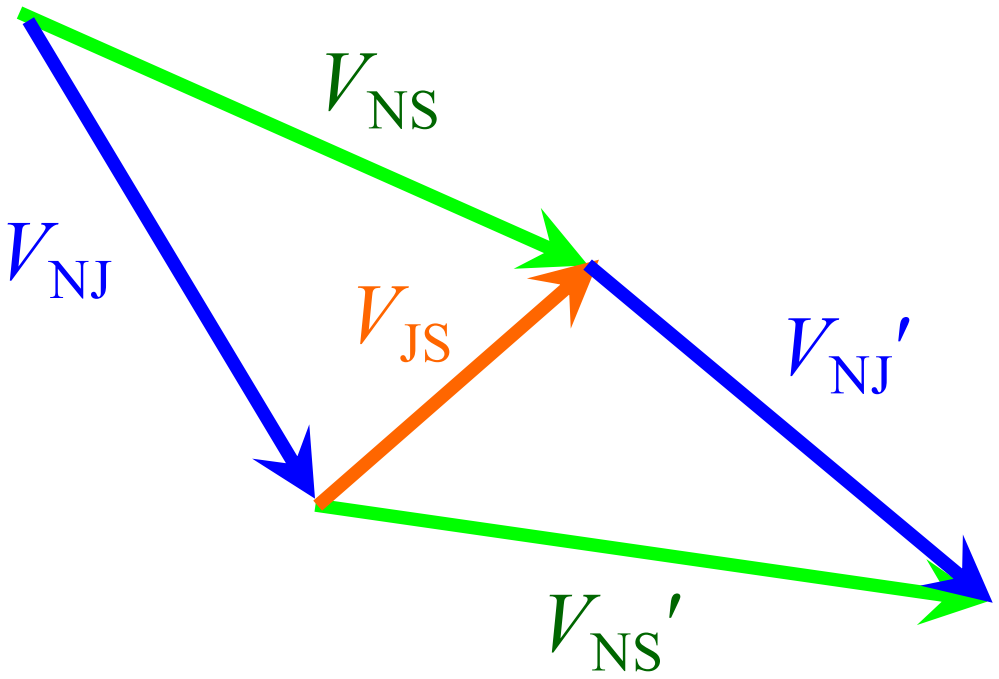
V_{JS} = Jupiter relative to Sun


Jupiter
Earth
V_{JS}
V_{NS}
V_{NS}'
Saturn

Relative to the Sun:



$$V_{NJ} + V_{JS} = V_{NS}$$



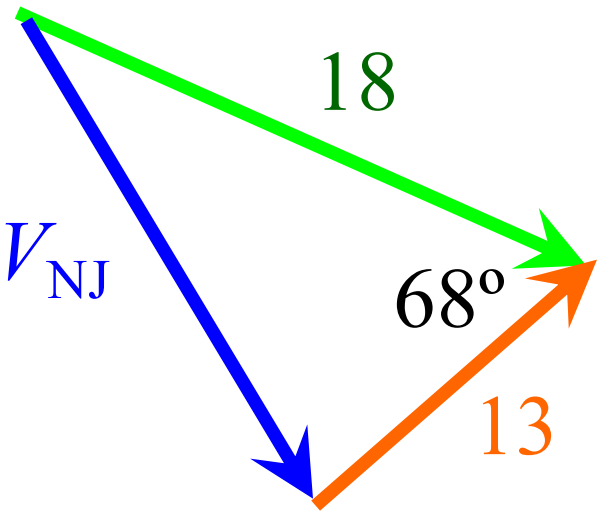
Velocities:

V_{NJ} = New Horizons relative to Jupiter before encounter

V_{NJ}' = New Horizons relative to Jupiter after encounter

V_{JS} = Jupiter relative to Sun

$$V_{NJ} + V_{JS} = V_{NS}$$

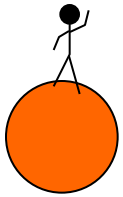


$$V_{NJ}^2 = 18^2 + 13^2 - 2(18)(13)\cos(68º)$$

$$V_{NJ} = 17.8 \text{ km/s}$$

In Jupiter's reference frame:

$V_{NJ} = 17.8$ km/s



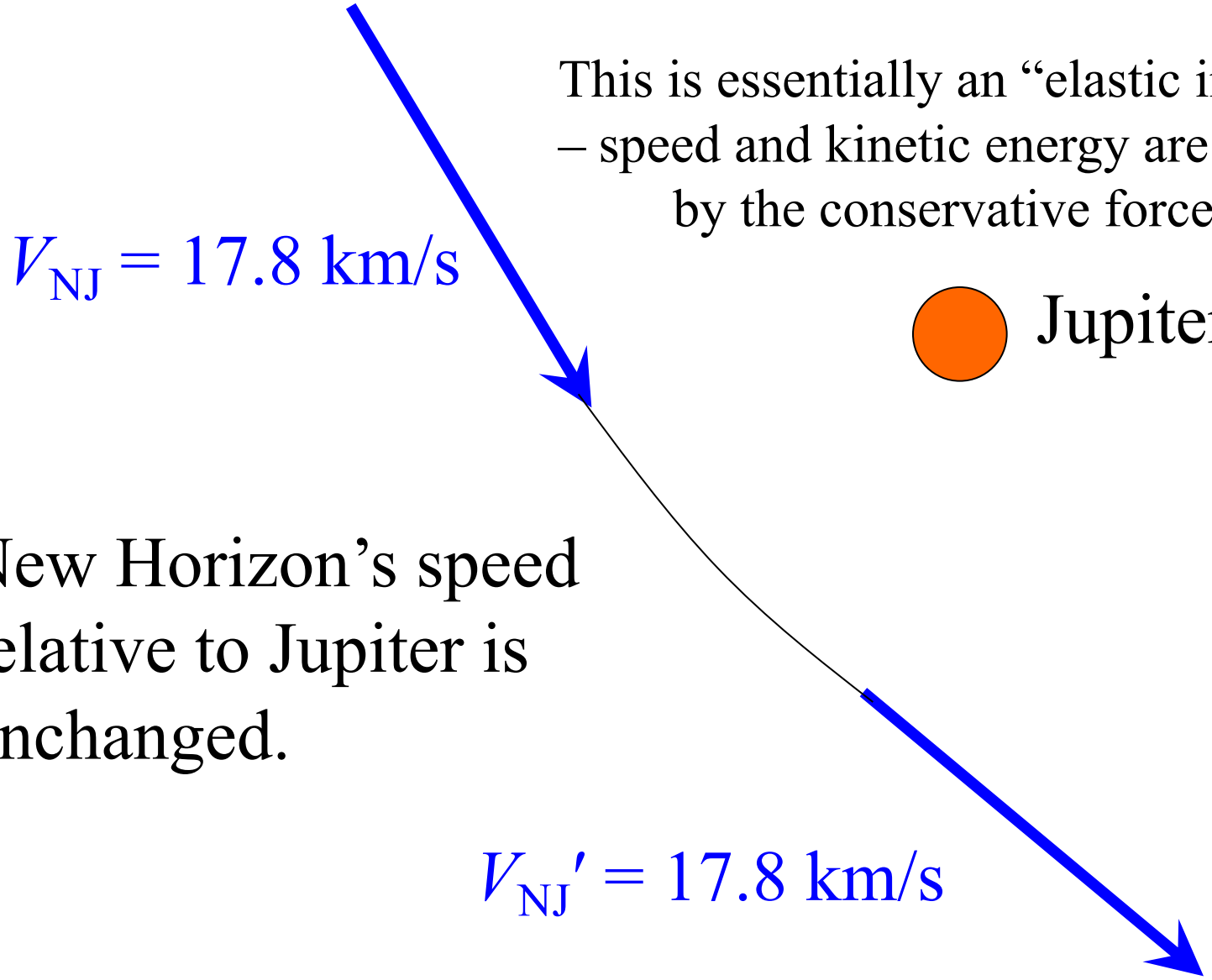
Jupiter

The center of mass of the two object system is essentially always at the center of Jupiter. In this frame of reference the speed before and after is unchanged – a little like the elastic bounce of a tennis ball hitting the surface of a much more massive object – the Earth!

V_{NJ}'

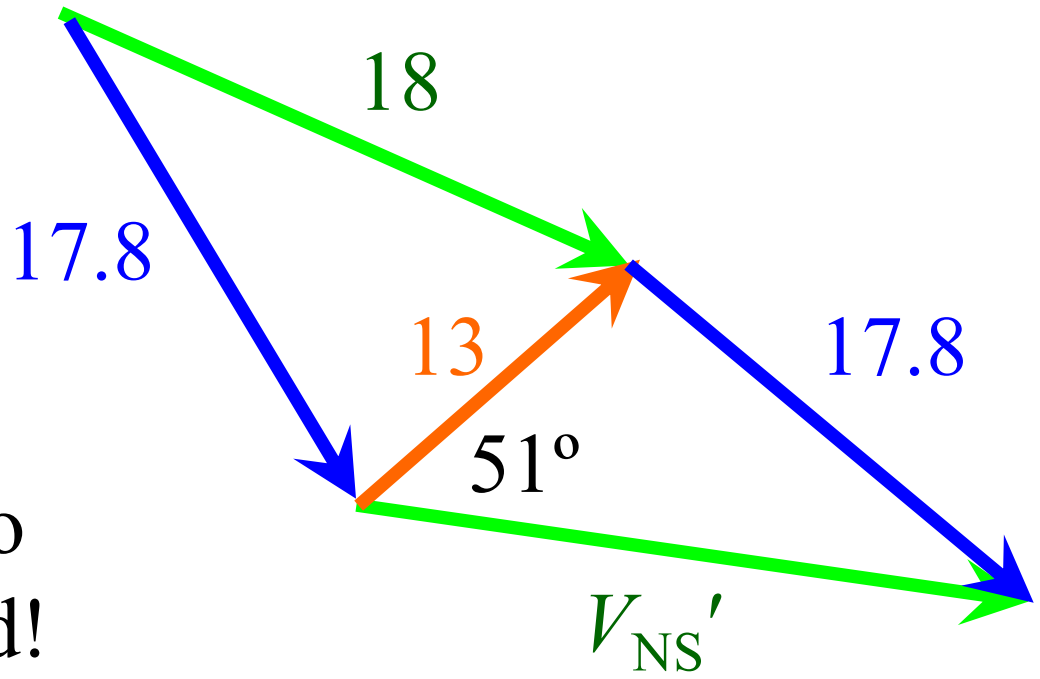
In Jupiter's reference frame:

This is essentially an "elastic interaction" – speed and kinetic energy are unaffected by the conservative force of gravity.



New Horizon's speed relative to Jupiter is unchanged.

$$V_{NJ} + V_{JS} = V_{NS}$$

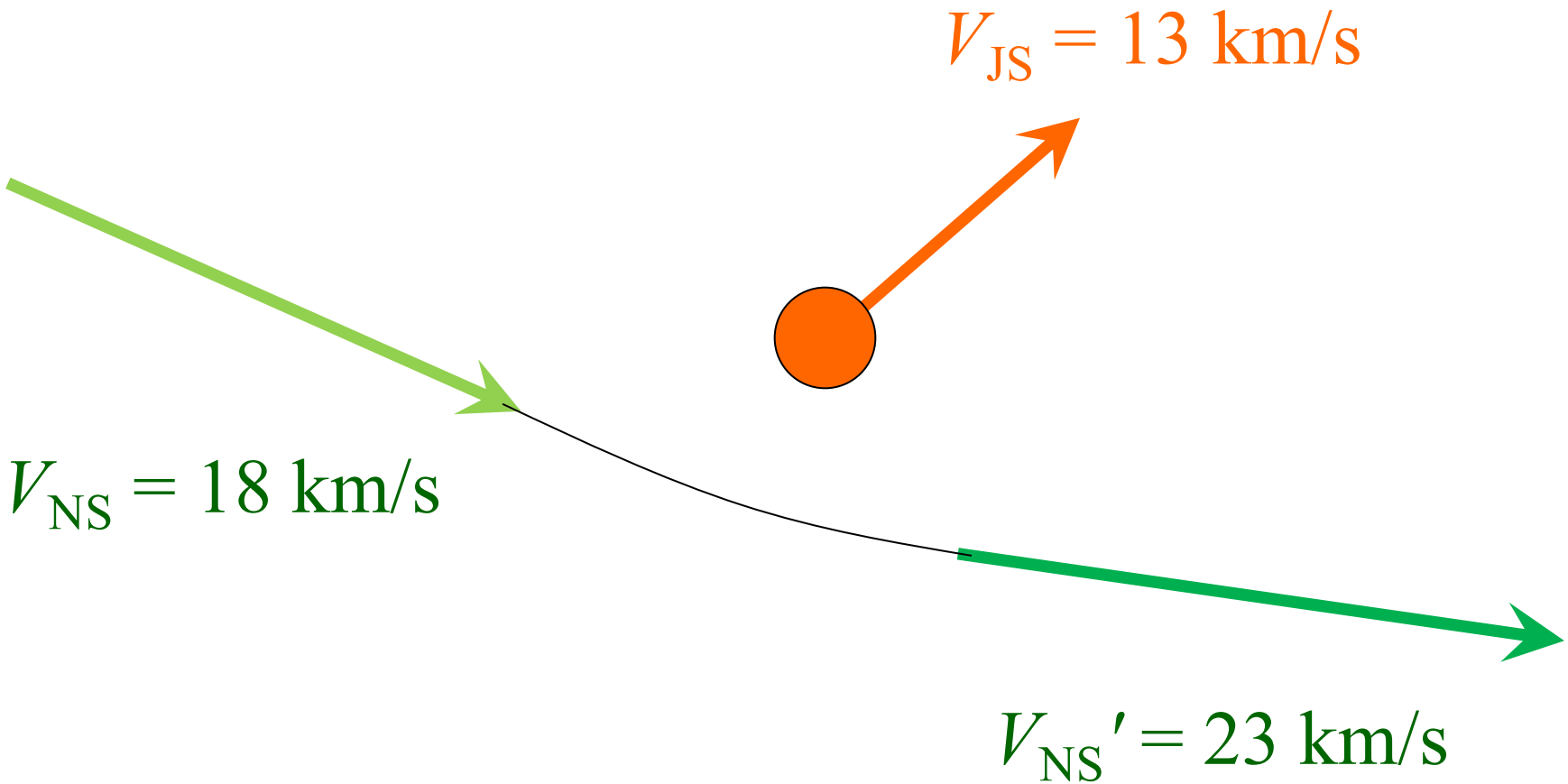


New Horizon's speed relative to Sun is increased!

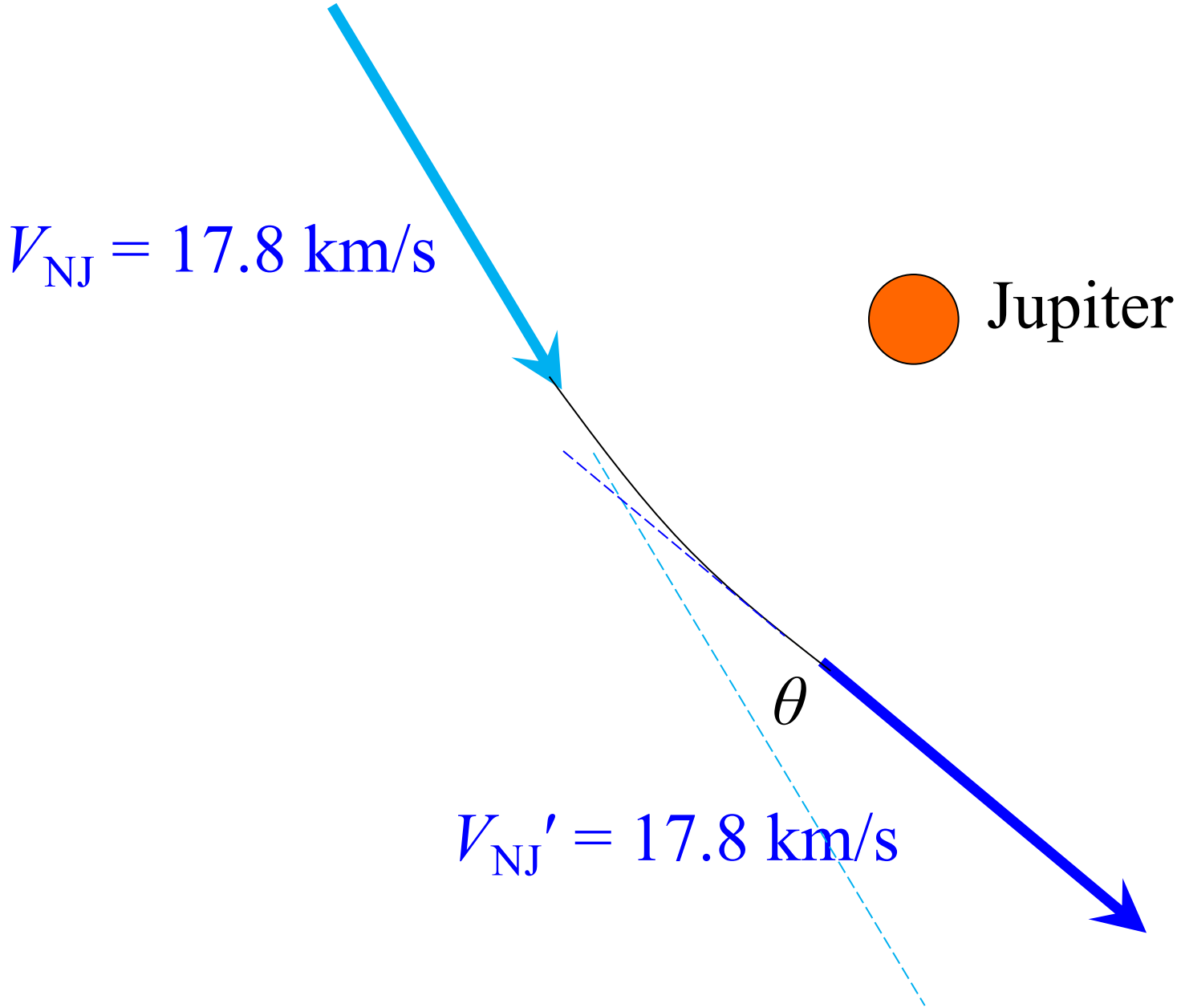
$$17.8^2 = V_{NS}'^{\,2} + 13^2 - 2(V_{NS}')(13)\cos(51°)$$

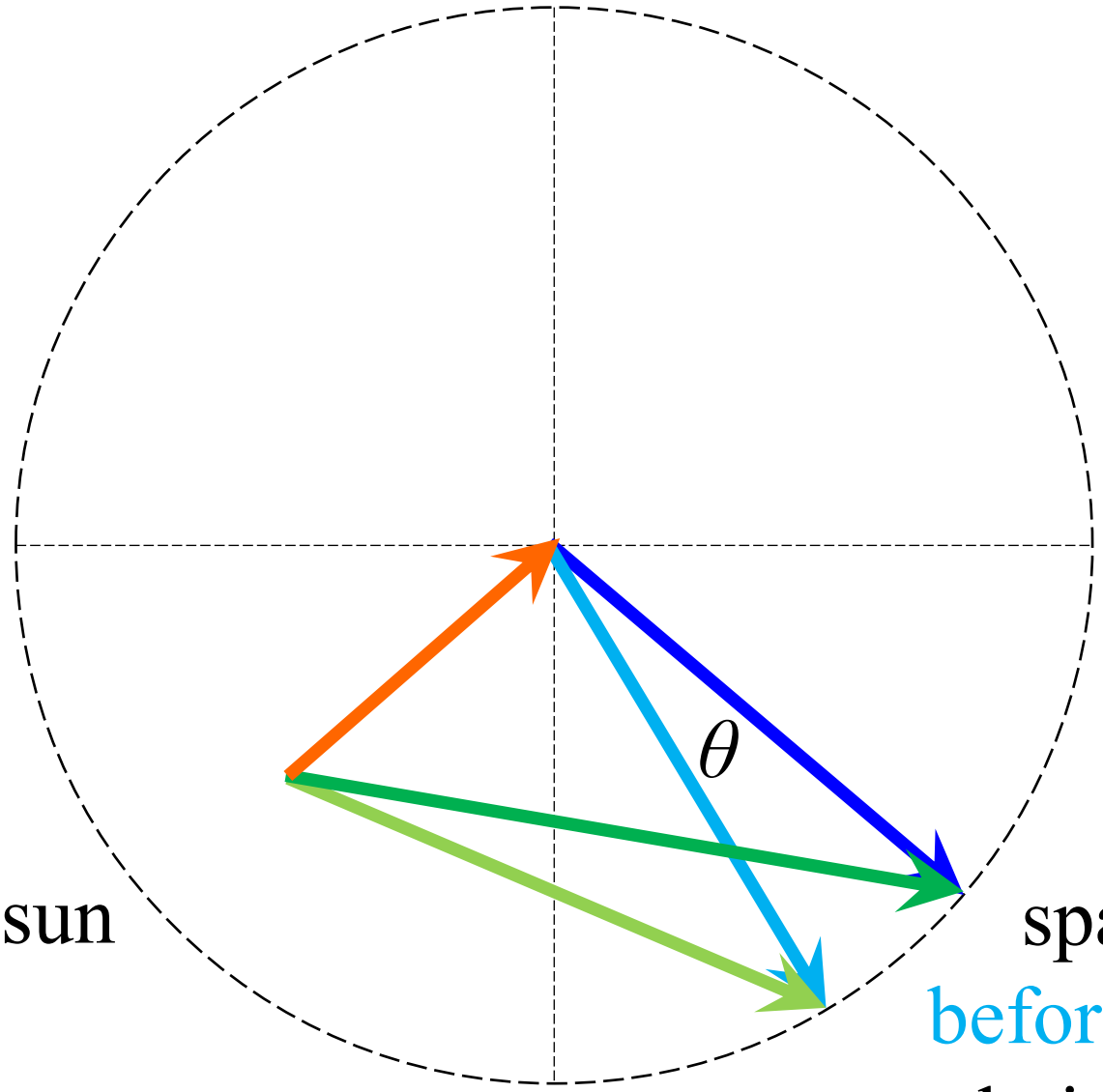
$$V_{NS}' = 22.8 \text{ km/s}$$

Relative to the Sun:



Relative to Jupiter:



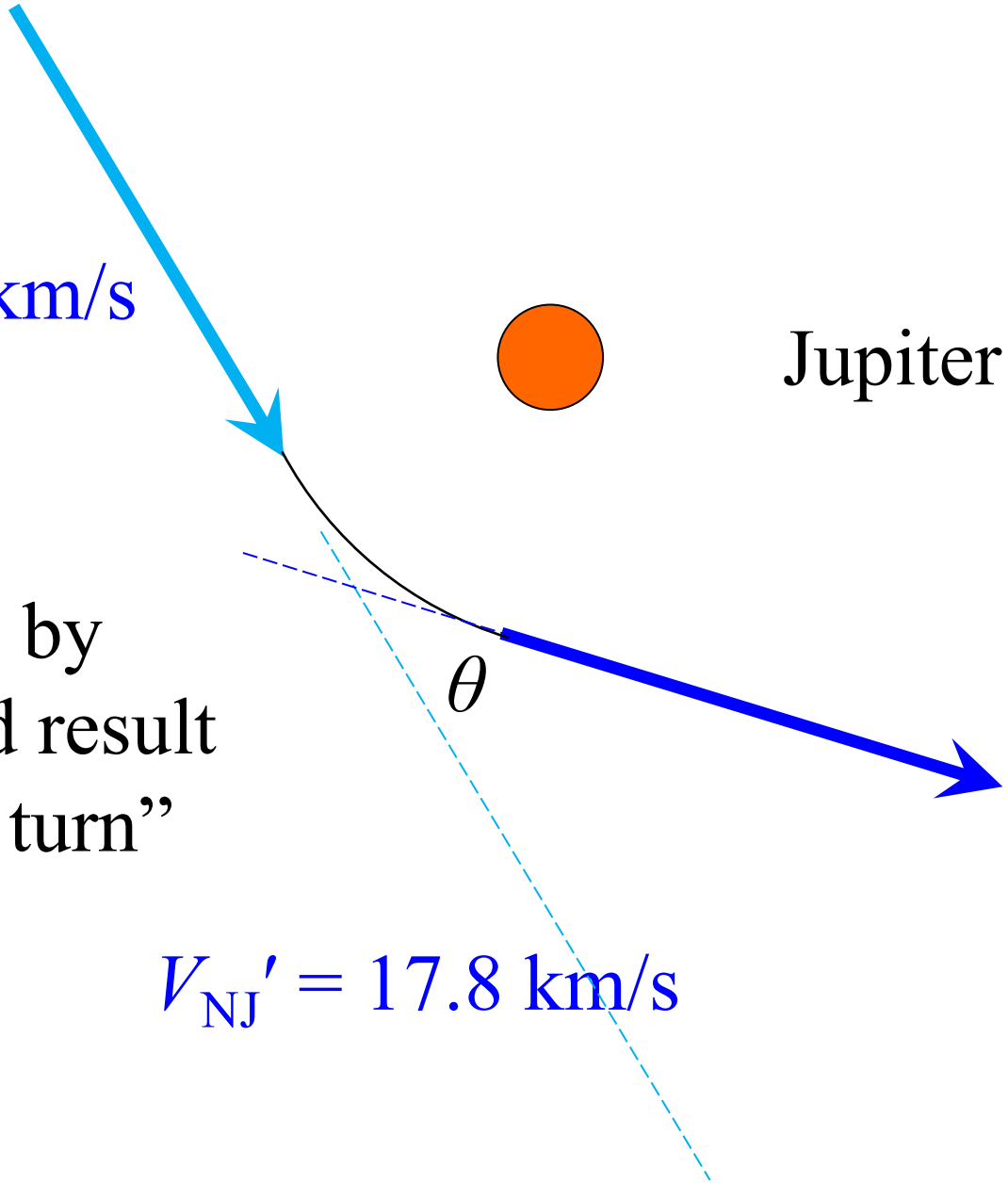


planet
relative to sun

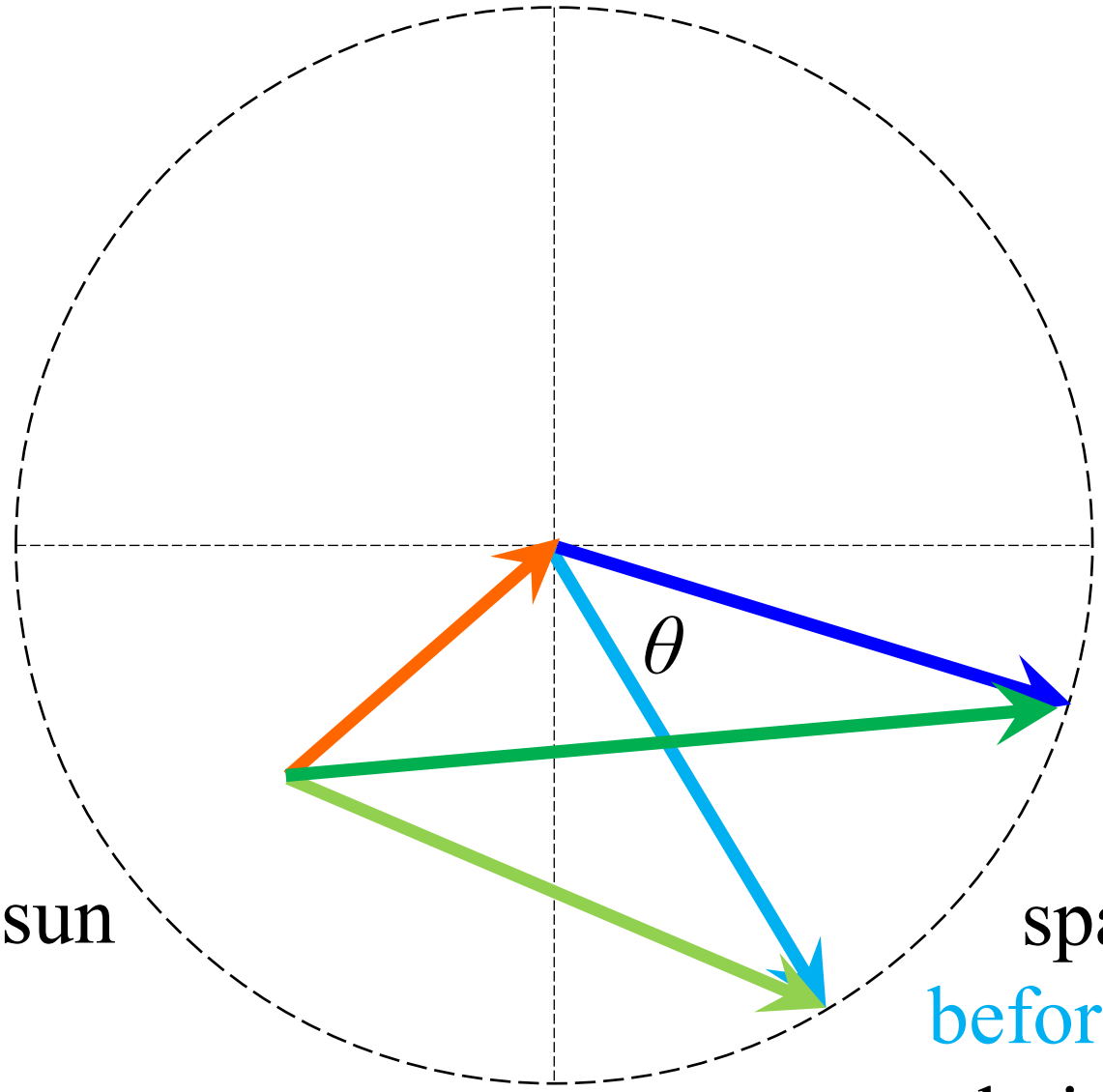
spacecraft
before and after
relative to planet

spacecraft
before and after
relative to sun

Relative to Jupiter:



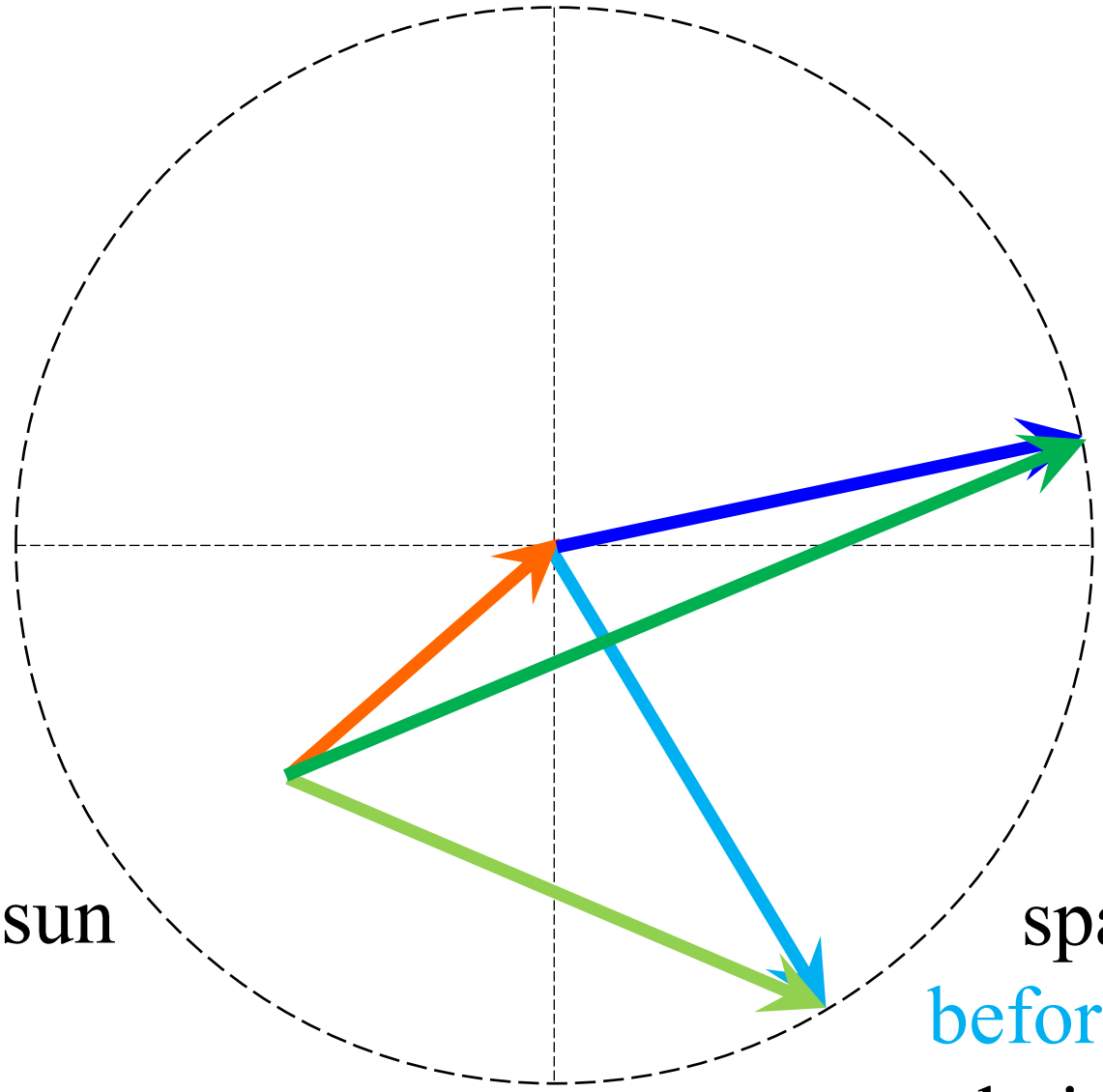
A closer pass by Jupiter would result in a "sharper turn"



planet
relative to sun

spacecraft
before and after
relative to planet

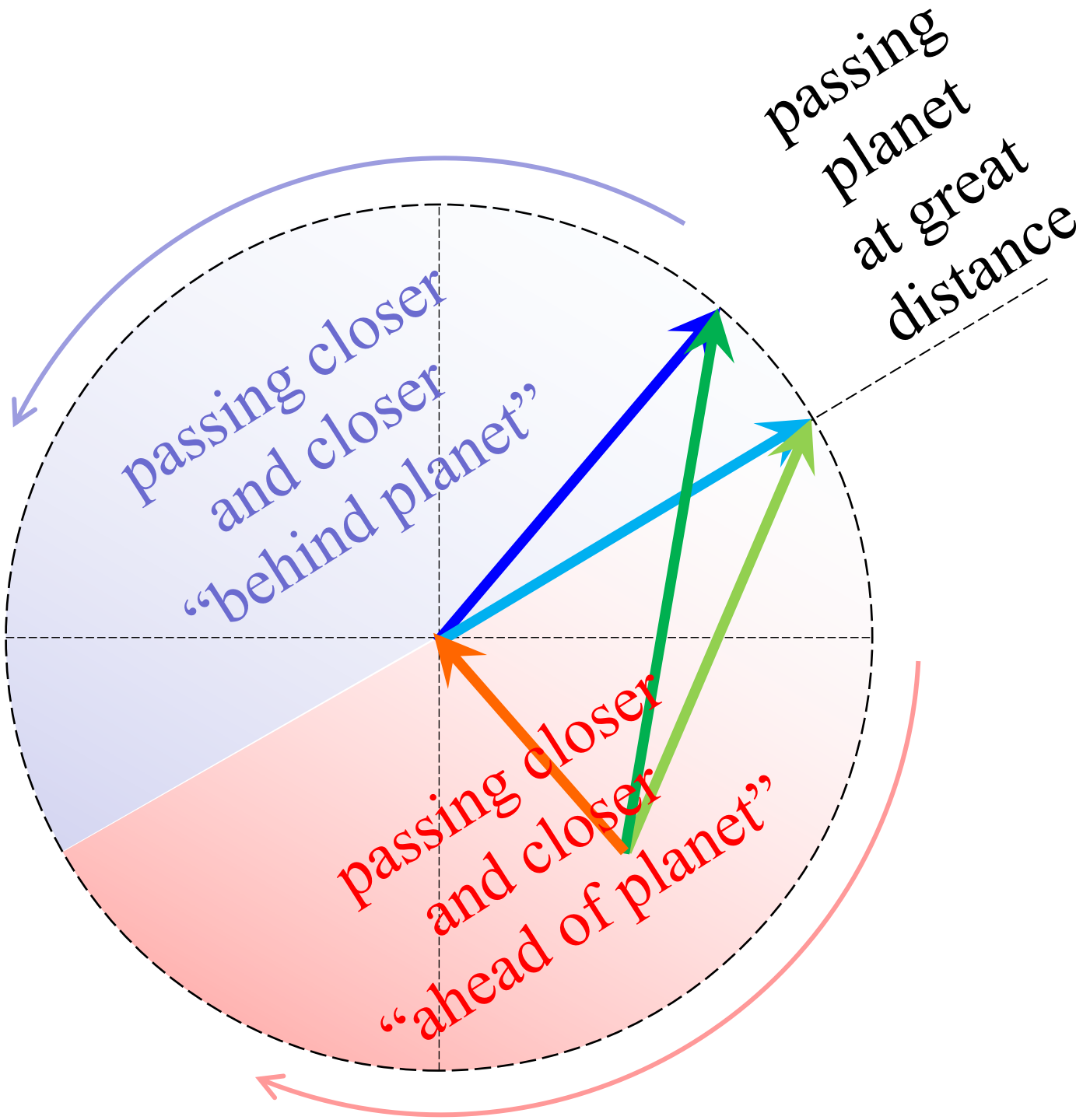
spacecraft
before and after
relative to sun

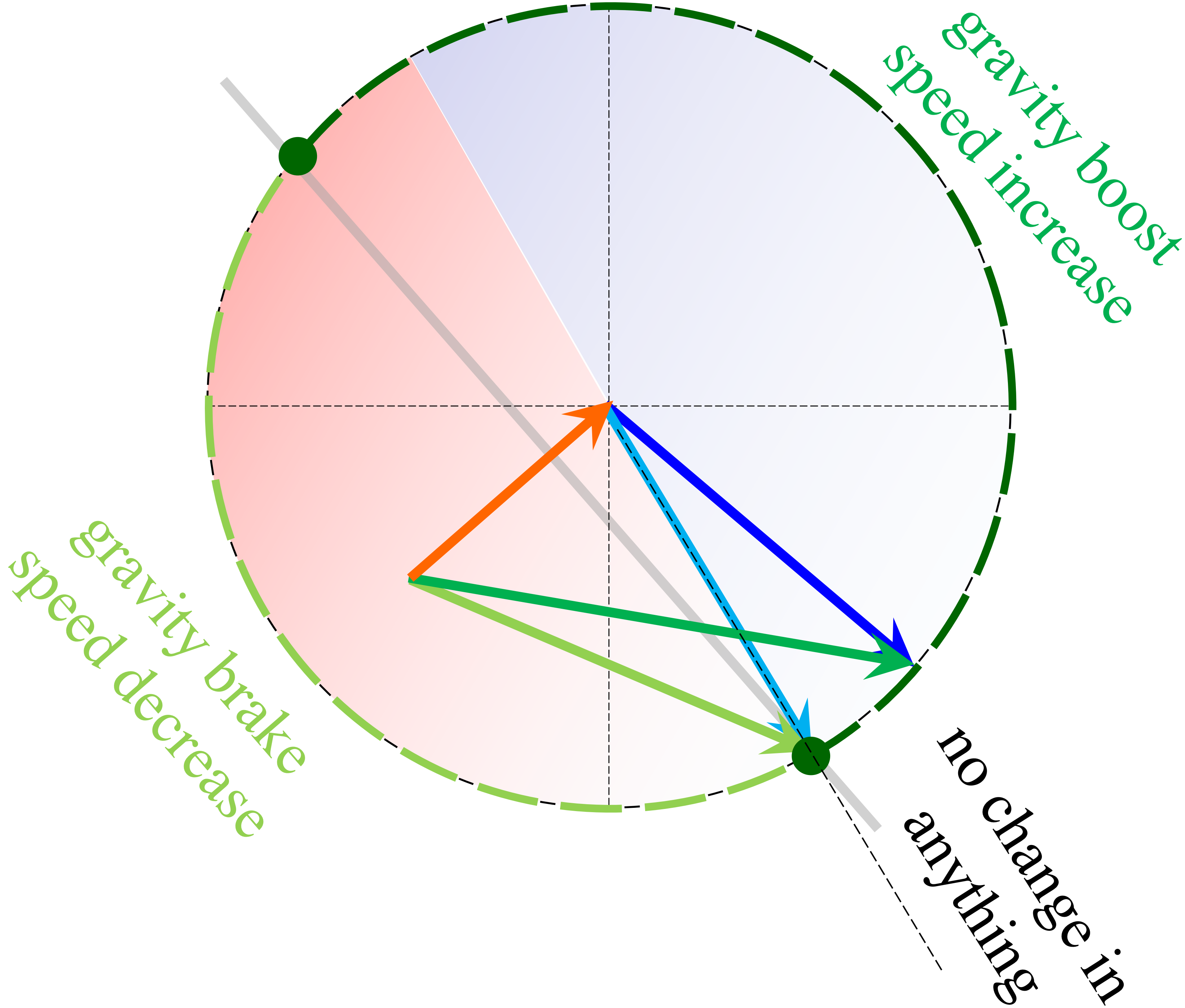


planet
relative to sun

spacecraft
before and after
relative to sun

spacecraft
before and after
relative to planet


passing
planet
at great
distance
passing closer
and closer
"behind planet"
passing closer
and closer
"ahead of planet"


gravity boost
speed increase
gravity brake
speed decrease
no change in
anything