The Comet Interceptor mission – selected for ESA F-class call

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+ comet interceptor team

Comet Interceptor

- F-class mission to a DNC
- Fly-by, multi-point measurements
  - Mothership and released probes architecture
- Proposal led by Geraint Jones (MSSL)

How?

- The only way to encounter a dynamically new comet (DNC) is to discover it inbound with enough warning to direct a spacecraft to it

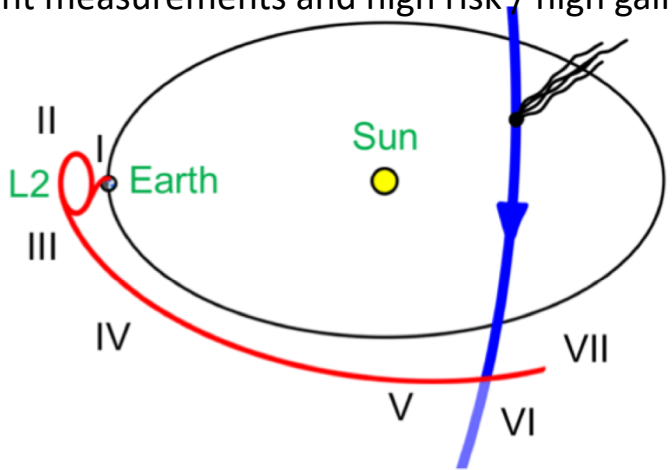
- The likelihood of this happening will soon be greatly increased by LSST
  - LSST probably won't increase the number of DNCs found every year, but will increase the distance at which they're discovered inbound
  - F-class mission will involve delivery to L2 (with ARIEL): spacecraft can wait in dynamically-stable location until the target is found

F-class mission to a DNC

- Mission ‘parked’ at L2 after launch, waits for new target discovery (2-3 years)
- Short cruise and fast flyby near 1 AU
- F-class call encouraged multi-point measurements – useful at a comet:
  - To separate time and space variation in coma
  - To enable simultaneous coma + nucleus + magnetic fields studies at different distances
  - Separating safe / distant measurements and high risk / high gain close approaches

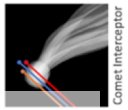
Mission Phases

I	Launch & delivery to L2
II	Station-keeping at L2
III	Departure from L2
IV	Cruise and instrument commissioning
V	Separation of spacecraft elements
VI	Target Encounter
VII	Data playback and solar wind studies, if possible



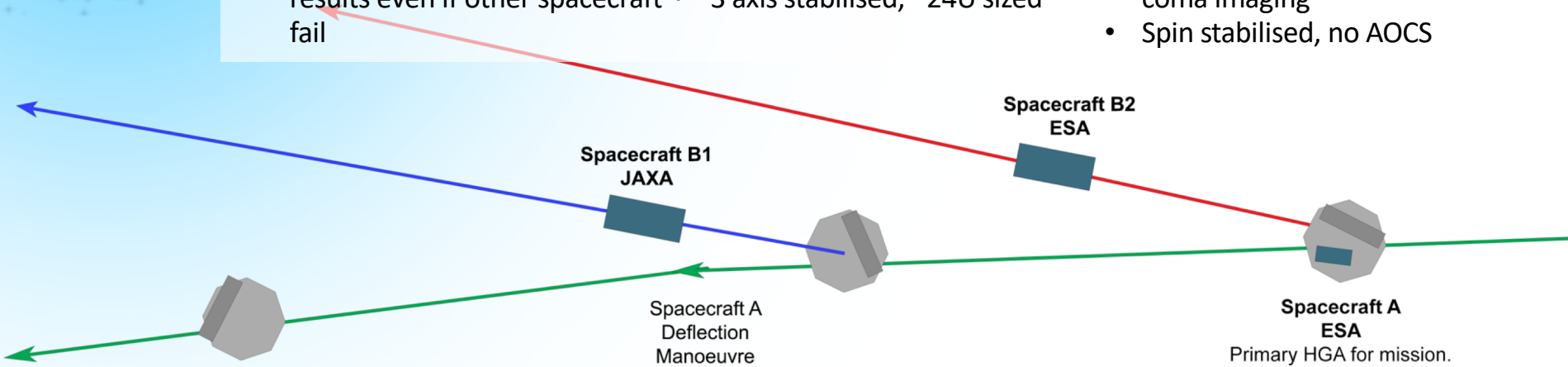
Not to scale

Multiple spacecraft architecture



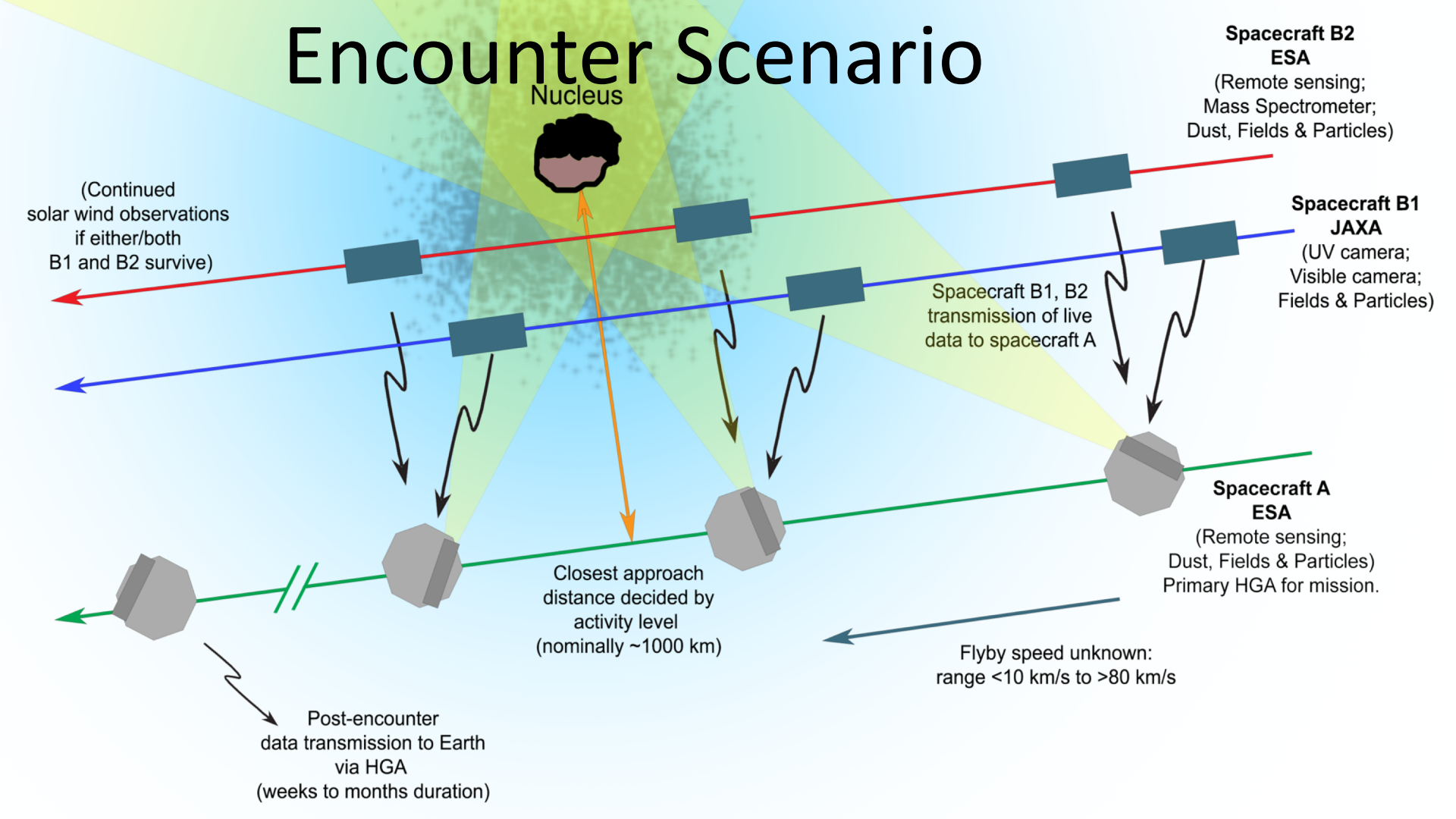
Nucleus

- **A: main spacecraft (ESA)**
  - Passes sunward of comet at ~1000 km ('safe' distance)
  - Data relay for other spacecraft
  - Propulsion + communication
  - Minimum payload to ensure results even if other spacecraft fail
- **B1: inner coma (JAXA)**
  - Targeted to pass through inner coma
  - Will probably survive encounter
  - In-situ sampling, coma imaging
  - 3 axis stabilised, ~24U sized
- **B2: nucleus + coma (ESA)**
  - Targeted near nucleus (but unlikely to actually hit it)
  - May survive, but designed to be expendable
  - In-situ sampling, nucleus + coma imaging
  - Spin stabilised, no AOCS



Separation ~days before flyby (depending on desired distances, accuracies, comet activity level)

Encounter Scenario



Proposed payload

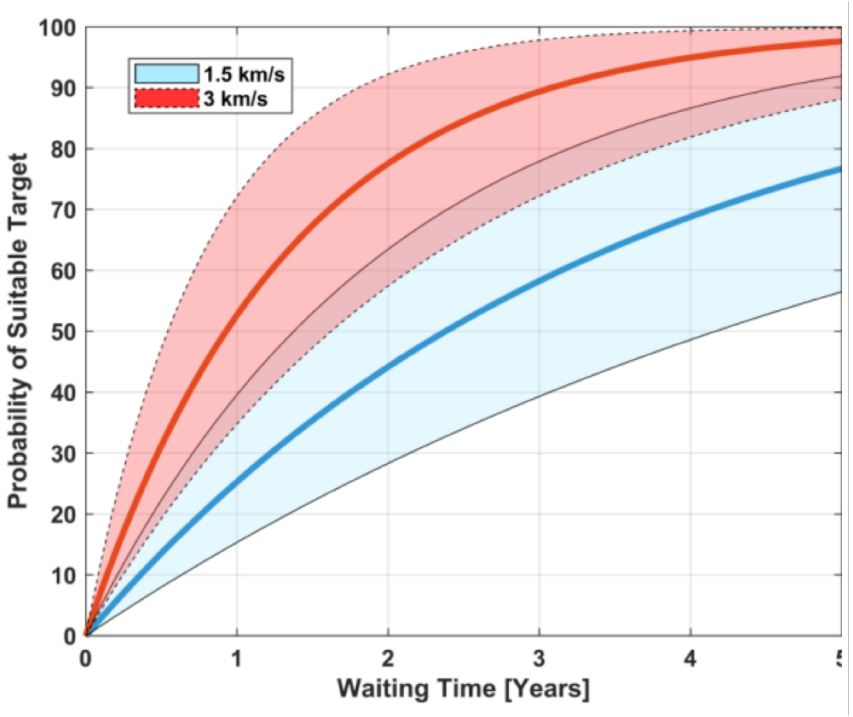
Spacecraft	Instrument	Description
A ESA	CoCa	Visible/NIR imager
	MIRMIS	NIR/Thermal IR spectral imager
B2 ESA	DFP	Dust, Fields & Plasma (similar on A and B2)
	MANIaC	Mass spectrometer
	EnVisS	All-sky multispectral visible imager
	OPIC	Visible/NIR imager
B1 JAXA	HI	Lyman-alpha Hydrogen imager
	PS	Plasma Suite
	WAC	Wide Angle Camera

- F-class call constraints required high TRL instrumentation: a minimum TRL of 5/6 attainable by the end of 2019
- Proposed payload has strong heritage from past missions and instruments already developed/built for future missions
- MIRMIS is a US led and (part) NASA funded contribution
- Payload being refined at the moment as part of ESA phase 0 study – will have to be reduced

Target selection

- Only a flyby is possible
- Encounter has to take place close to the ecliptic – each comet crosses the ecliptic at two locations
- Encounter location within a restricted heliocentric distance range, for thermal and power reasons (~ 0.8-1.2 AU)
- Relative speed at encounter can be very high if comet is retrograde (>60 km/s) – increases risk of dust impact damage
- Need to leave L2 within 2-3 years post-launch, < 5 year total mission
- Comet is preferably observable from Earth at the same time
- Preferably encounter is pre-perihelion (more pristine, less NGA)

Target selection



- Used previous hyperbolic comet orbits and calculations of population to look at how many reachable comets there will be
- With quite low delta-v requirements there will be targets within a few years
- With a little more delta-v it gets easier / more options
  - Trade of potential wait time vs fuel mass

Example – C/2001 Q4 (NEAT)

- Based on previous bright DNC
- Real comet found ~3 years out
- LSST would have found it ~8 years out
- Target known before launch
- ~1.5 year wait
- ~3 year cruise

Table 7.2.1. Dates of key events in example mission to C/2001 Q4 (NEAT).

Event	Date
LSST discovery	~July 1996
Launch	10-Dec-1999
Departure from L2	29-Jul-2001
Real discovery	*24-Aug-2001*
OP Nav images begin	Jan 2004
Flyby	14-May-2004
End of mission	Nov 2004

Example – C/2001 Q4 (NEAT)

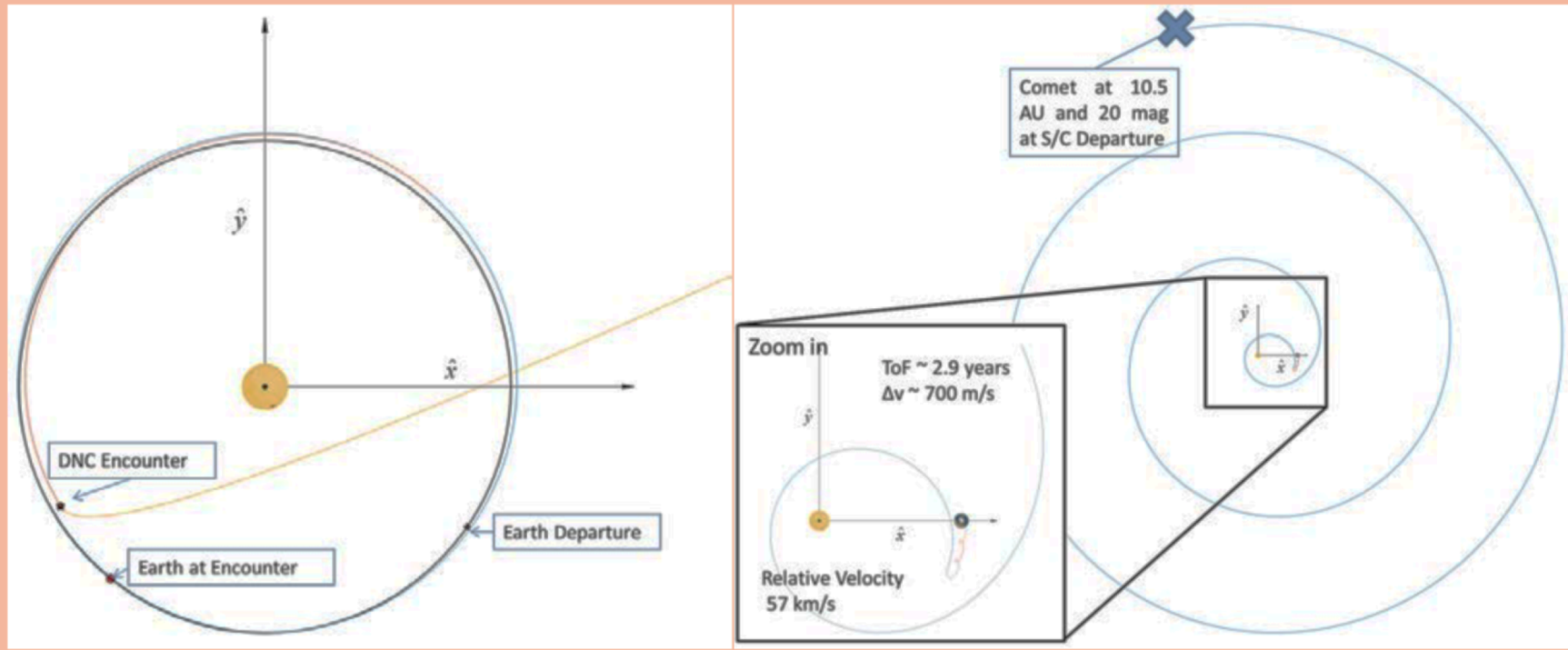


Fig. 7.2.2. Trajectory for the example mission to C/2001 Q4, in an inertial reference frame (left) and a Sun-centred Earth-rotating reference frame (right).

Summary

- Comet Interceptor: Multi-spacecraft encounter of a DNC
  - A ‘pristine’ object. Comparison with 67P, MU69
- Fast flyby near 1 AU heliocentric distance
- Proposed payload:
  - Cameras with wavelength coverage from FUV through thermal IR
  - In situ measurement (dust/gas/plasma)
- Launch in 2028, comet encounter sometime in early 2030s
- http://www.cometinterceptor.space/

@CometIntercept

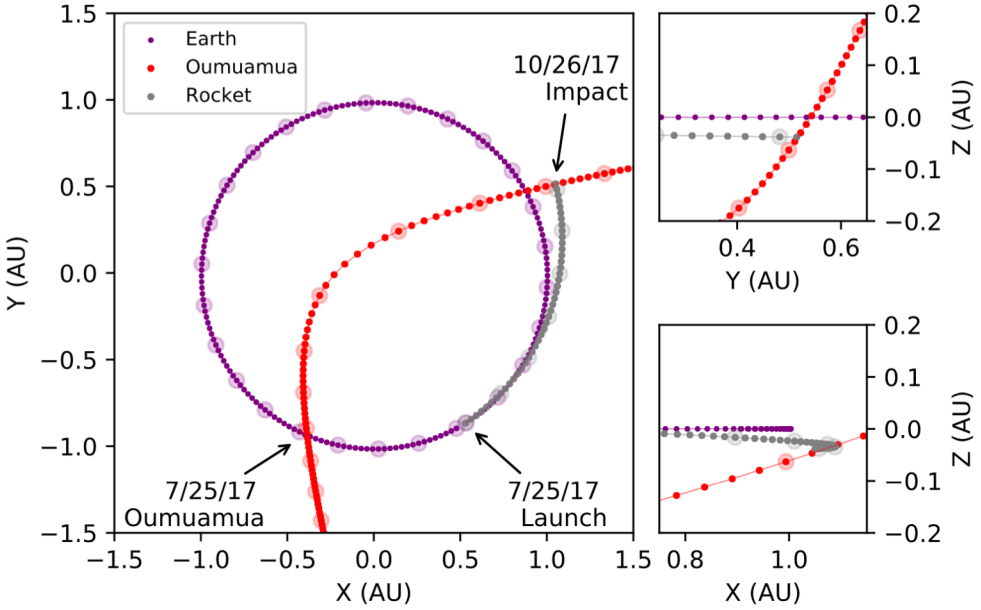
INTERSTELLAR TARGETS?

Interstellar Targets?

- Can we intercept an interstellar target instead of an Oort cloud DNC?
  - Still needs to come close enough and cross ecliptic where we can reach it
  - Likely less warning time, but worth a rapid response…
- Different science if apparently inactive like ‘Oumuamua (no dust), but would be hard to turn down such an opportunity
  - Remote sensing payload still useful. Late deployment of sub-s/c?
- If active, no real difference in the flyby (except that it could be even faster)
  - Potentially problematic if flyby speeds restricted for engineering reasons

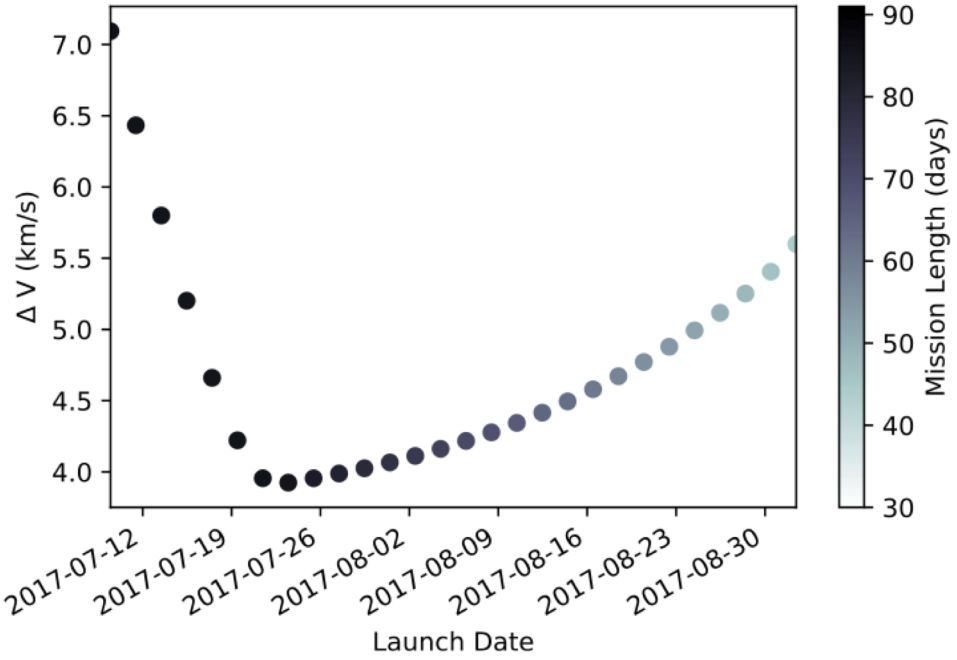
Probability of finding one

- Study of possibility of intercepting ‘Oumuamua-like objects (Seligman & Laughlin 2018 - 1803.07022)
- Proposed mission similar to Deep Impact with ‘launch on detection’
- Assumes Falcon Heavy and typical delta-V ~ 12km/s



Probability of finding one

- Best delta-v for ‘Oumuamua was ~4 km/s
- MC simulation:
  - (i) are visible using LSST (given both magnitude and angle constraints),
  - (ii) have a perihelion distance that is closer than 1 AU, and
  - (iii) are visible prior to the proposed impact dates.
  - This population is ~ 1/8 the total number that are visible by LSST
- LSST finds one accessible target in ~10 years



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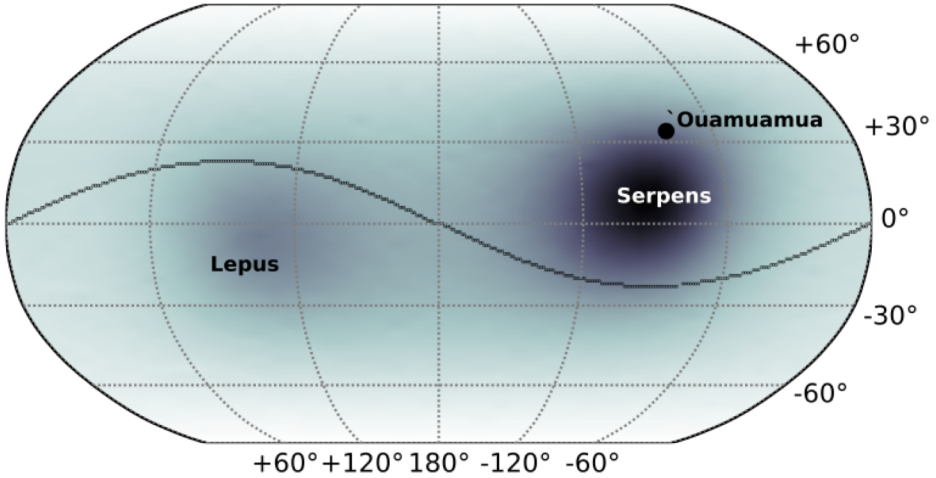

Model has most objects coming from apex

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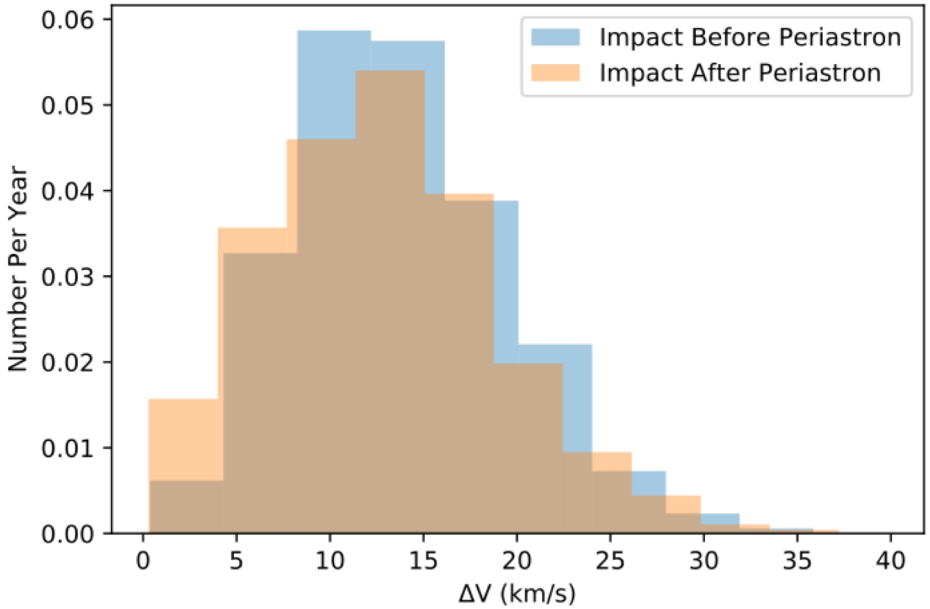

ISO with Comet Interceptor

- Already waiting in space an advantage in terms of reaction time
- Delta-v limitations may restrict us to only the most favourable ones
  - Probably 1-2 km/s available
- Will still need a very fast response
  - Not planned for DNCs
  - Would expect to have months to characterise comet, improve orbit, calculate optimum trajectories, plan and rehearse manoeuvres
  - Could we get ESA to scramble in case we find something?
- Not in baseline mission plan
- Not driving any design constraints
- Was mentioned as a possibility in science case, as very exciting (if unlikely)

What could we do?

- Future similar proposal to Comet Interceptor (i.e. waiting in ‘parking’ orbit)
- Stripped down payload, single spacecraft
  - Remote sensing only?
- Most of mass for fuel to maximise available delta-v
- Might be suitable for a future ESA F-call, but probably a larger class (M) to have a dedicated launch and more mass available for fuel
- NASA options? SIMPLEX? Could it be done with cubesats?
- Useful to do more detailed simulations on expected rates