Dormant Comets in the NEO Population: A Meteor-based Survey

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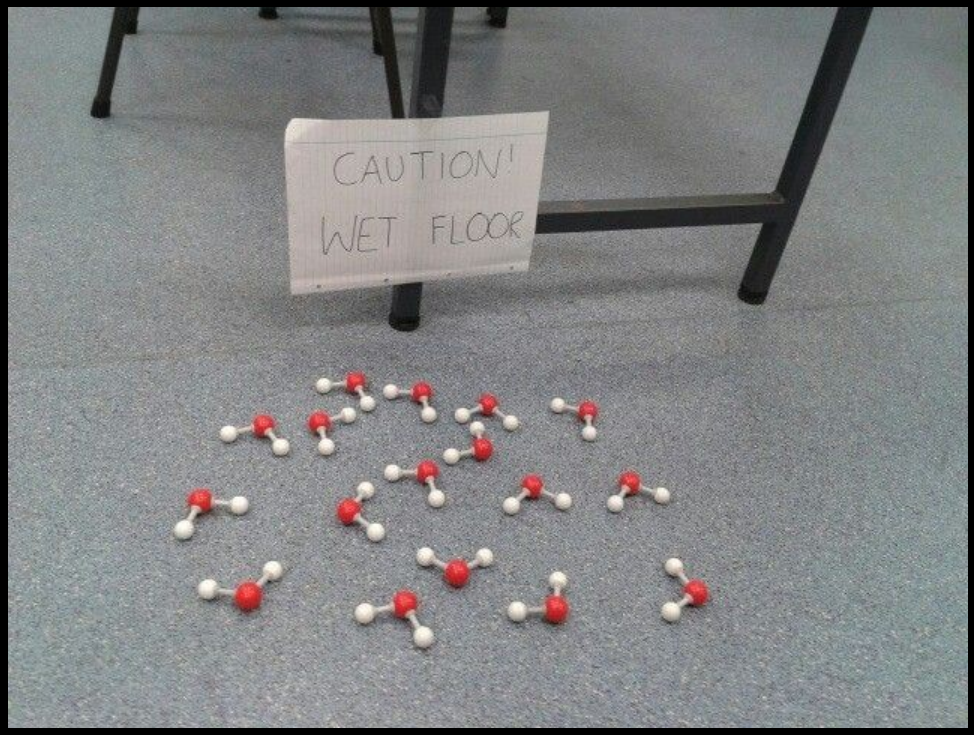
Motivation

- Why we are here?
  - Deposition of water and organic materials on the Earth
- Likely source: near-Earth objects (NEOs)
- Comets among NEOs; Jupiter-family comets (JFCs)



The problem

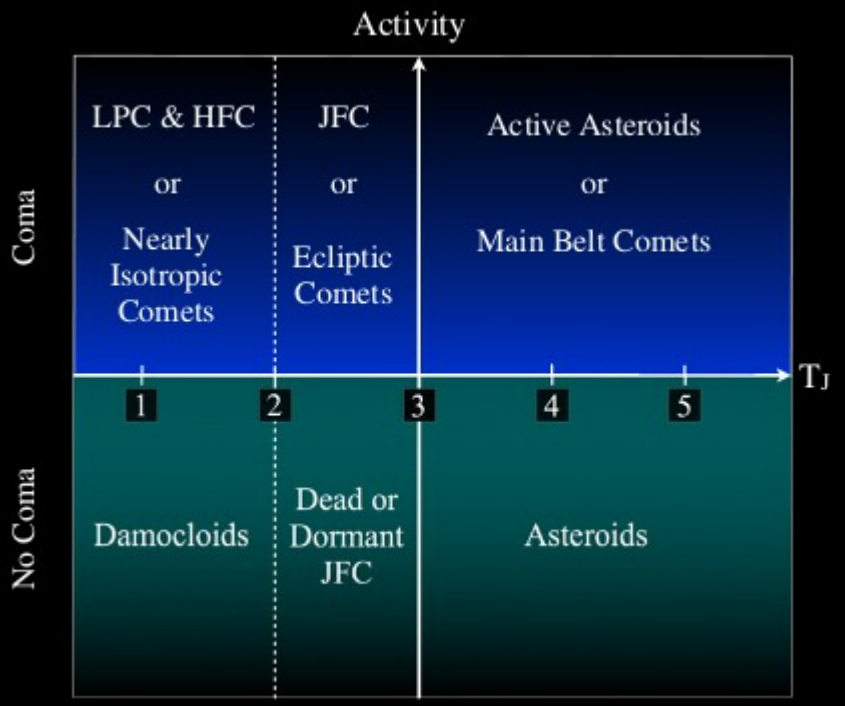
- Dynamical lifetime of near-Earth JFCs are much longer than their physical lifetime → dormant, extinct or defunct comet may be common
- Dormant comets are observationally indistinguishable from asteroids
- Demographics of JFCs are poorly known

Past studies

- Dynamical
  - Asteroids in cometary orbits (ACOs)

$$T_{\rm J} = \frac{a_{\rm J}}{a} + 2\sqrt{\frac{a(1-e^2)}{a_{\rm J}}}\cos i$$

  - $T_{\rm J}$>3: asteroidal orbits; $T_{\rm J}$<3: cometary orbits
  - JFC: 2<$T_{\rm J}$<3
  - ACOs: asteroids with $T_{\rm J}$<3


Activity
Coma
No Coma
LPC & HFC
or
Nearly
Isotropic
Comets
JFC
or
Ecliptic
Comets
Active Asteroids
or
Main Belt Comets
Damocloids
Dead or
Dormant
JFC
Asteroids
1
2
3
4
5
TJ

(Jewitt 2012)

Past studies

- Dynamical + compositional
  - ACOs that resemble comet-like albedos (p_v<0.05)
- Issues: asteroidal interlopers
  - Asteroids do end up in JFC-type orbits
  - Difficult to distinguish dark asteroids and true comets

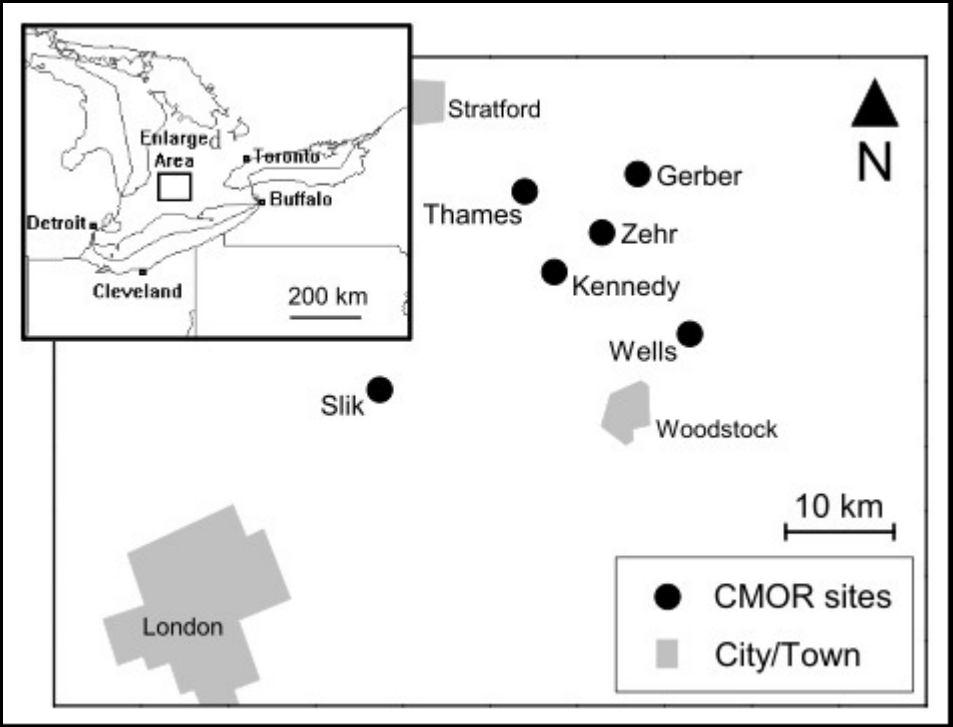
Our approach

- Dormant comets should have produced dust (meteoroids) when they were active, which may still be detected as meteor showers at the Earth
- We start with known NEOs and look for the showers they produced

Observational data

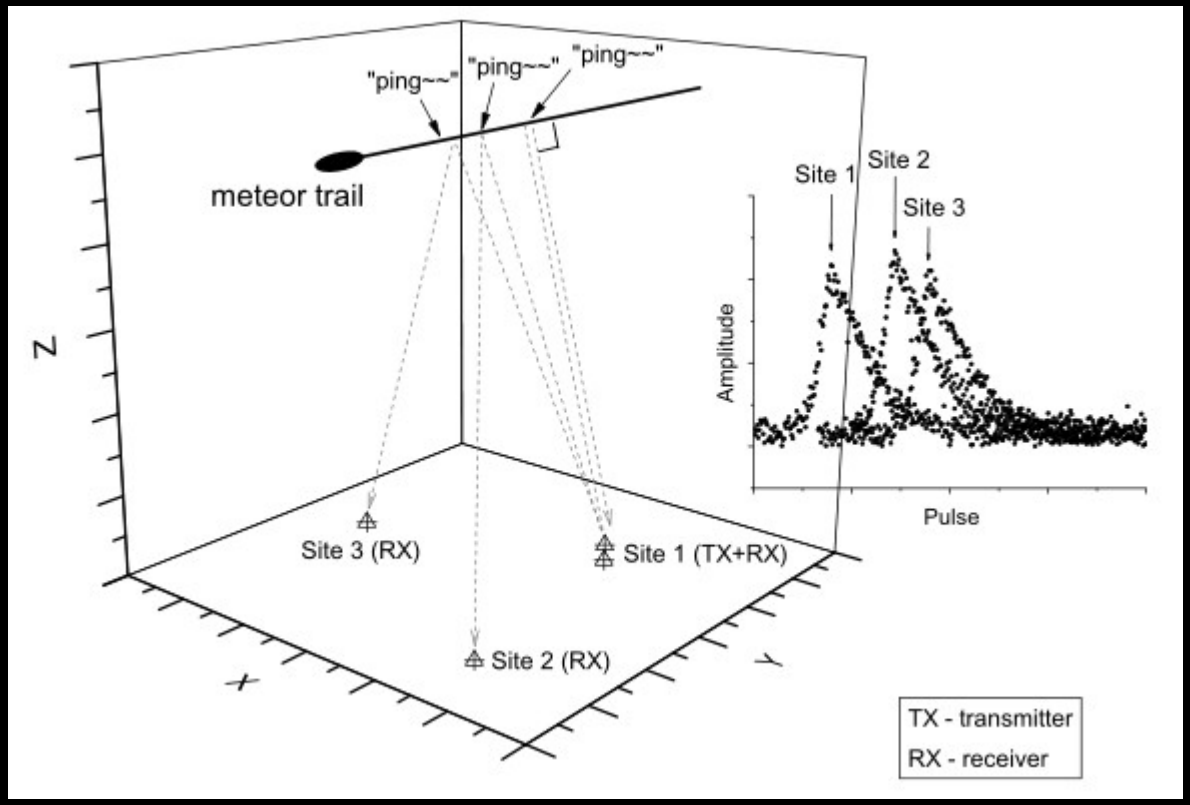
- Canadian Meteor Orbit Radar (CMOR)
  - About 14 million meteor orbits in 2002-2015, representative magnitude +7
  - Sensitive to milligram-sized meteoroids
  - Insensitive to weather and sunlit conditions (good temporal coverage)

CMOR basics



Ye et al. (2013)

CMOR basics



Ye et al. (2013)

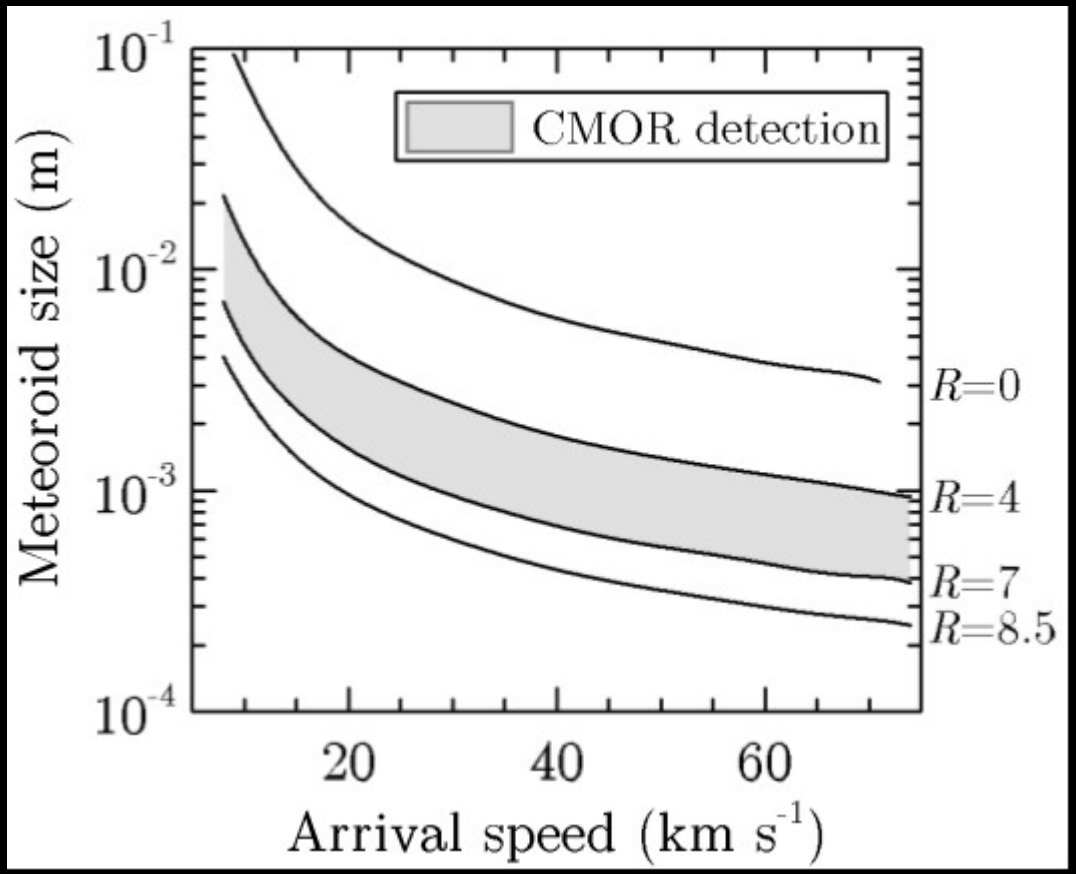
NEO sample

- We select 407 NEOs that
  - $H<22$
  - $1.95<T_J<3.05$
  - Orbit Uncertainty Parameter, U≤2
- Known NEO-shower pairs in the sample:
  - (196256) 2003 EH_1 & Quadrantids
  - 2004 TG_{10} & Taurid complex
  - 2009 WN_{25} & Northern i Draconids

Integration

- A modified MERCURY6 package is used for the integration of the meteoroids.
- Perturbation from major planets, radiation pressure, and Poynting-Robertson drag is considered.
- Size distribution of test meteoroids

Detection-speed relation



Ye et al. (in prep)

CMOR detectability

- CMOR detection limit: ~0.001 km^{-2} hr^{-1}

$$\mathcal{F} = \frac{\eta N_{\rm m} \tau_{\rm stream}}{P^2 \Delta t_{\rm shower}^2 V_\oplus^2}$$

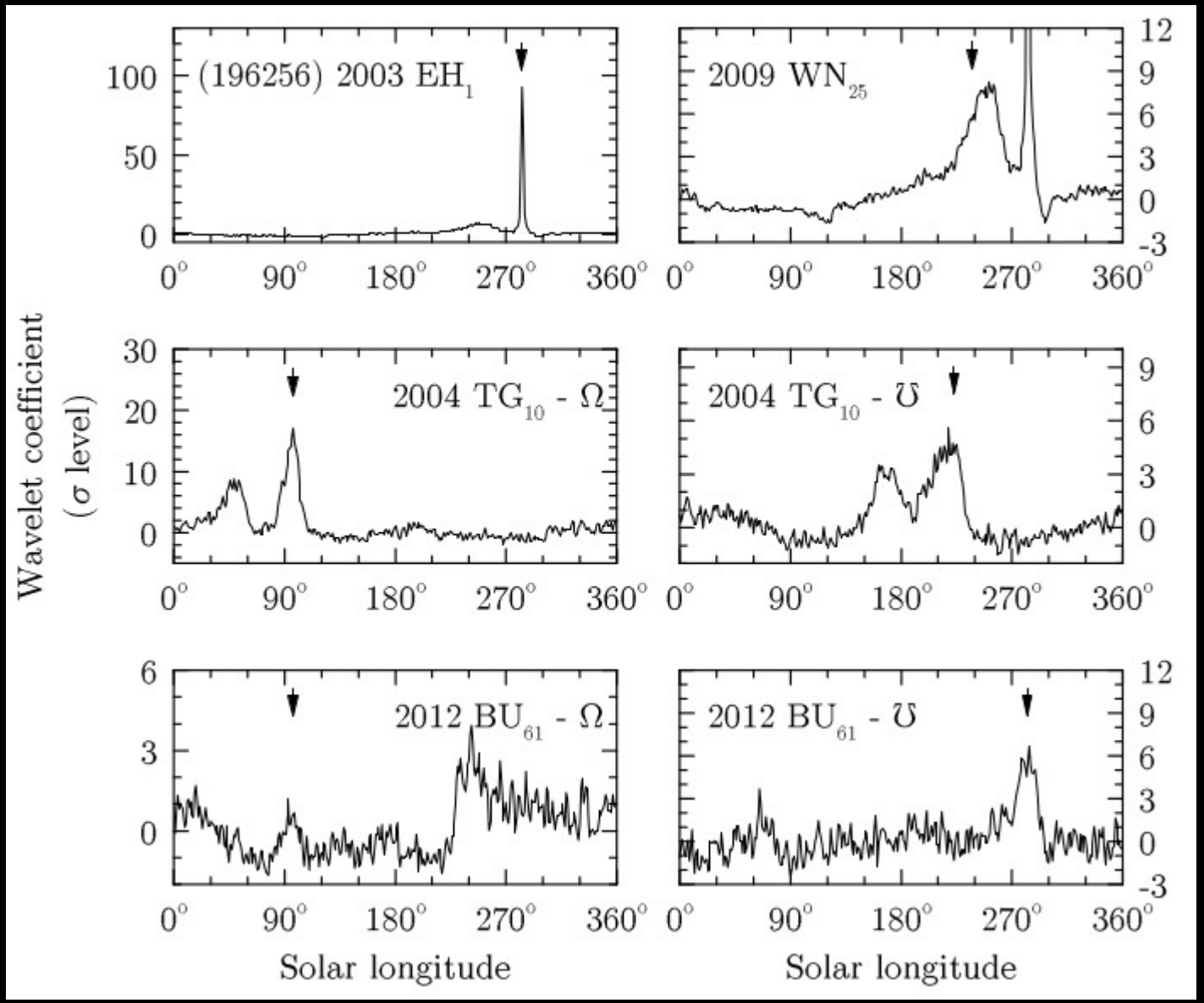
  - η: subset of meteoroids that may be visible (avai. from model)
  - $N_{\rm m}$: dust production of the parent (avai. from observation)
  - $\tau_{\rm stream}$: age of the stream (avai. from model)
  - P: orbital period (known *a priori*)
  - $\Delta t_{\rm shower}$: duration of the shower (avail. from model)
  - $V_{\rm O}$: orbital speed of the Earth (known *a priori*)

CMOR detectability

- We find 37 objects that could produce CMOR-detectable meteor showers.
- Predictions of (196256) 2003 EH_1, 2004 TG_{10}, and 2009 WN_{25} in line with observation*

Results

- We find 4 positive detections, including 3 known pairs:
  - (196256) 2003 EH_1 (Quadrantids)
  - 2004 TG_{10} (Taurid complex)
  - 2009 WN_{25} (November i Draconids)
- 1 previously unreported detection:
  - 2012 BU_{61}



Ye et al. (in prep)

Quick calculation

- 4 positive out of 37 tested $H<22$ ACOs: ~10% dormant comets in $H<22$ ACOs
- 2 positive out of 16 tested $H<18$ ACOs: ~10% dormant comets in $H<18$ ACOs
- 20% NEOs are ACOs

- Dormant comets in NEOs: ~2%*

Fine prints

- We have assumed dormant comets must be ACOs
- If there are large number of active asteroids → dormant comet fraction probably >>2%, but unlikely >10% (future work!)

Quick conclusion

- JFC residence time in NEO region: ~10^3 yr
- This implies a dormancy rate of 10^{-5} yr^{-1}, ~10x lower than disruption rate

- Disruption and dynamical removal (from NEO region) are more common than dormancy

Summary

- We conduct a survey for dormant comets by looking for the meteors they produced at their active phase.
- We determine the lower limit of dormant comet fraction to be ~2% and a dormancy rate of 10^{-5} yr^{-1}.

Thank you!