Colors of Asteroid Families

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Outline

I. **<u>Introduction:</u>**

<u>A. Gaia Contribution</u> : Visible spectra diagnostic of asteroid composition, family hetero/homogeneity, space weathering, etc

<u>B. Complementary Datasets</u>: e.g., WISE, Spitzer, ground-based

II. **<u>Asteroid Families</u>:** Primitive families, Themis family, Beagle sub-family, “Main Belt Comets”, water-ice and organics

III. **<u>Expected Results and Conclusions</u>**

I. Introduction

A. Gaia

- **Visible spectra diagnostic of asteroid surfaces**
- **Relevant to asteroid families**

I. B. <u>Gaia + other datasets</u> (WISE, Spitzer, ground):

- **Family Origin and Evolution:**
  - **Family hetero/homogeneity (structure of parent body, differentiated?)**
  - **Spectral properties as function of asteroid size**
  - **Other properties: albedo, shape, rotation state, density, thermal properties**
- **Nature of “Main-Belt Comets”**
- **Space Weathering**
- **Comparisons between families**
- **Identify main-belt sources of NEAs & meteorites**

IB. (Cont):

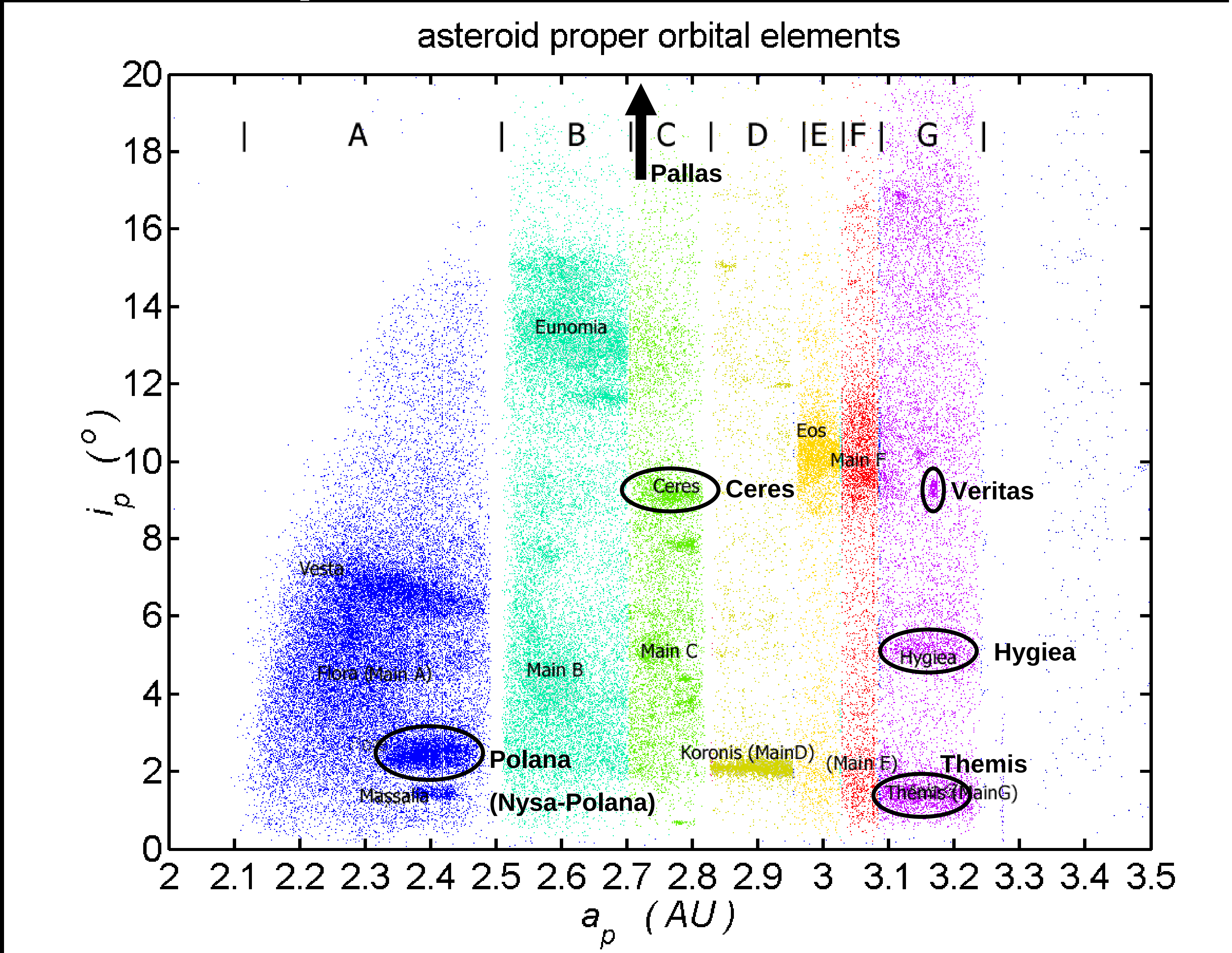
Other datasets:

- WISE and Spitzer observations add albedo, diameter and thermal properties
- Complementary ground-based observations, particularly near-infrared spectroscopy

IB. (Cont):

- Compare primitive families from the inner belt (142 Polana) to Jupiter Trojans (3548 Eurybates)
- Compare neighboring outer-belt families such as Themis, Veritas (Ziffer et al. 2011) and Hygiea
- Identify main-belt sources of primitive NEAs and meteorites, e.g., 3200 Phaethon-2 Pallas de León et al. 2010, 1999 RQ36-146 Polana Campins et al. 2010b)

IB. Some primitive families of interest:



II. Asteroid Families

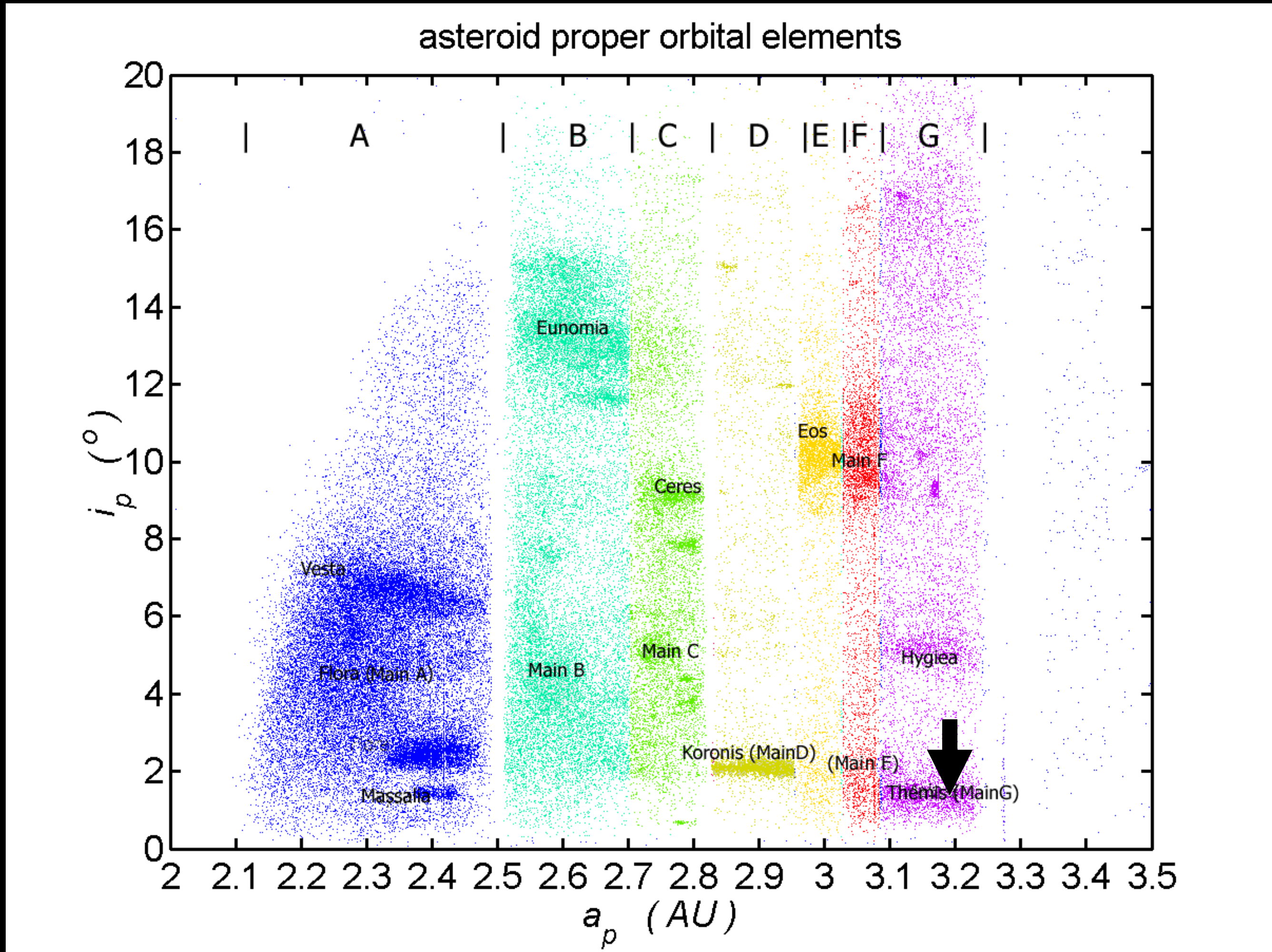
- Product of collisions
- Help understand origin/evolution of asteroids and Solar System
- Focus on Primitive Families: low albedo C, P, D types

II. Asteroid Families (Cont.)

Themis family particularly illustrative case:

- Primitive
- Large, numerous, old
- Beagle sub-family (very young), dust band
- Activated asteroids: aka “Main Belt Comets”
- Water-ice and organics on 24 Themis

II. Asteroid Families: 24 Themis



- Largest fragment of family
- Semi-major axis ~ 3.2 AU
- Diameter ~ 198 km

II. Themis Family

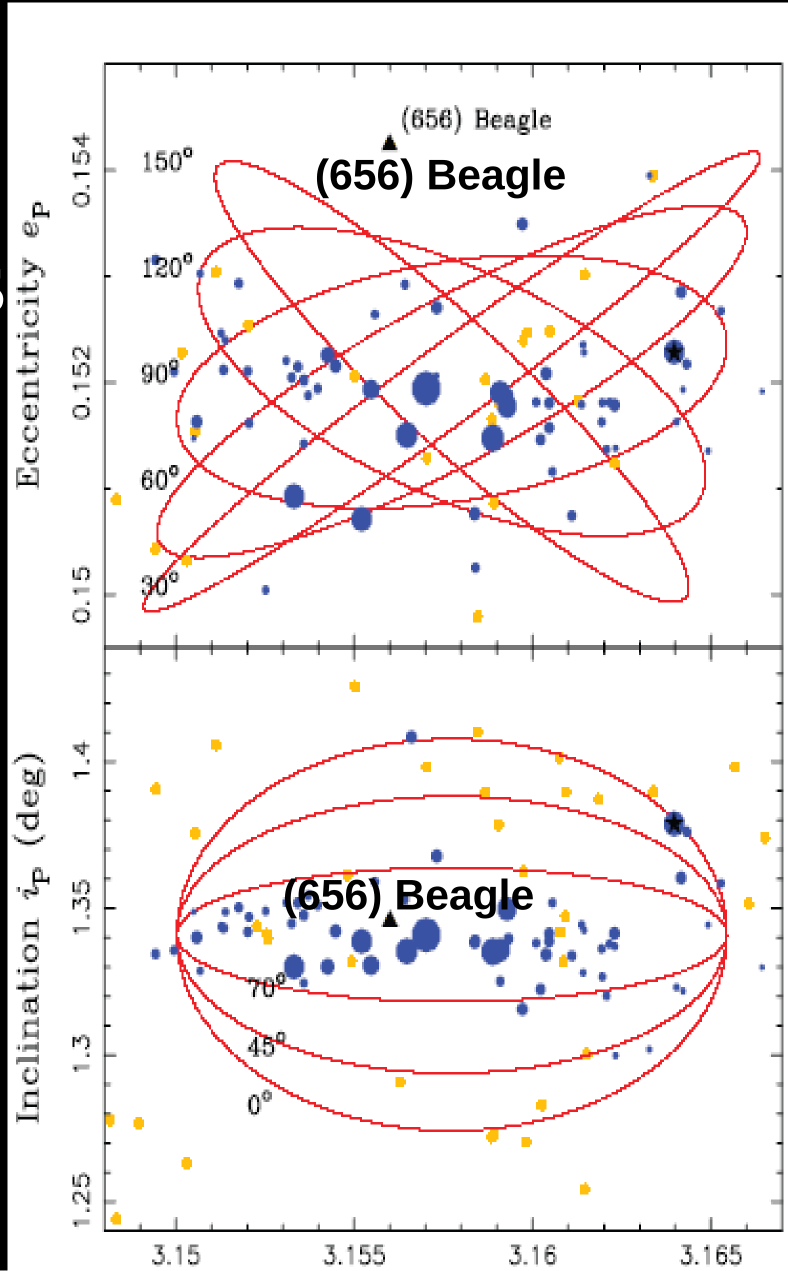
- Age > 1 Gyr
- Contains Beagle sub-family, age ≤ 10 Myr (source of one of the zodiacal bands)
- Contains two “Main Belt Comets” :
  - 133P/Elst-Pizarro
  - 176P/Linear
  - one more MBC just outside the Themis family P/2005 U1 (Read)
- Water-ice and organics detected on 24 Themis

Beagle sub-family

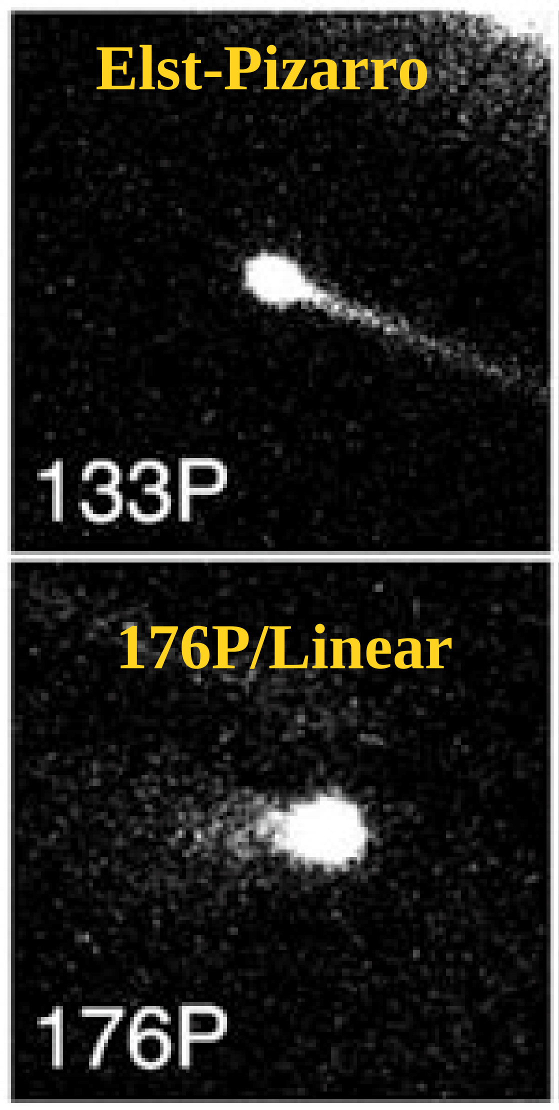
- Less than 10 Myr old (Nesvorny et al. 2008)

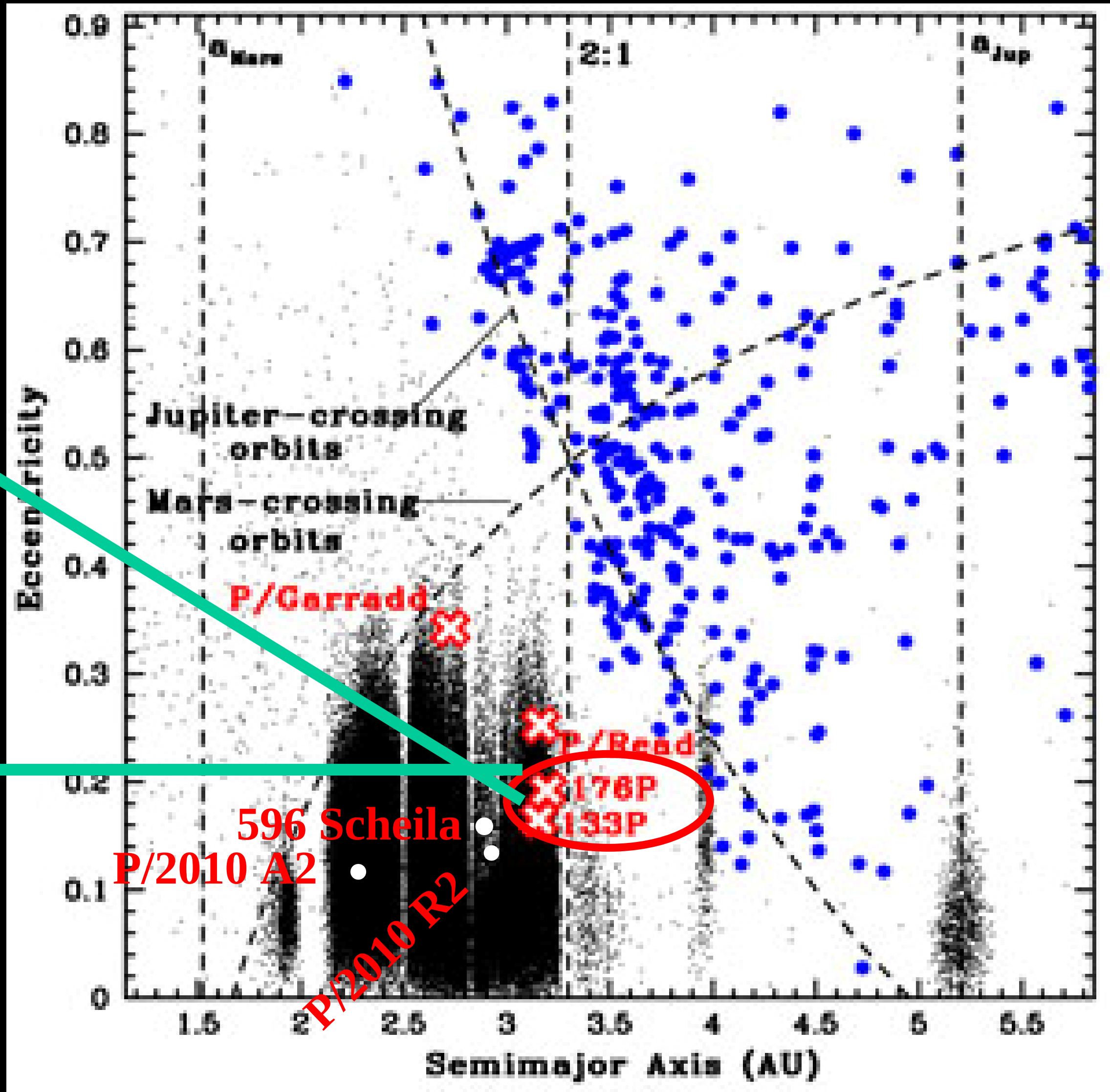
- Compare Gaia spectra with older Themis members to search for evidence of space weathering

- Contains one “Main Belt Comet”: 133P



Main Belt Comets in the Themis Family



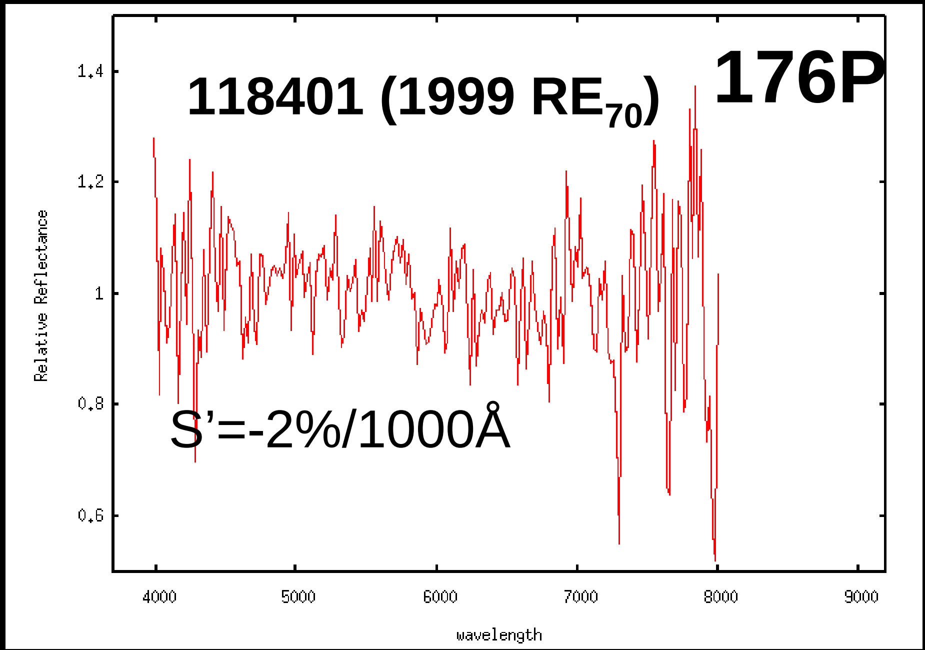


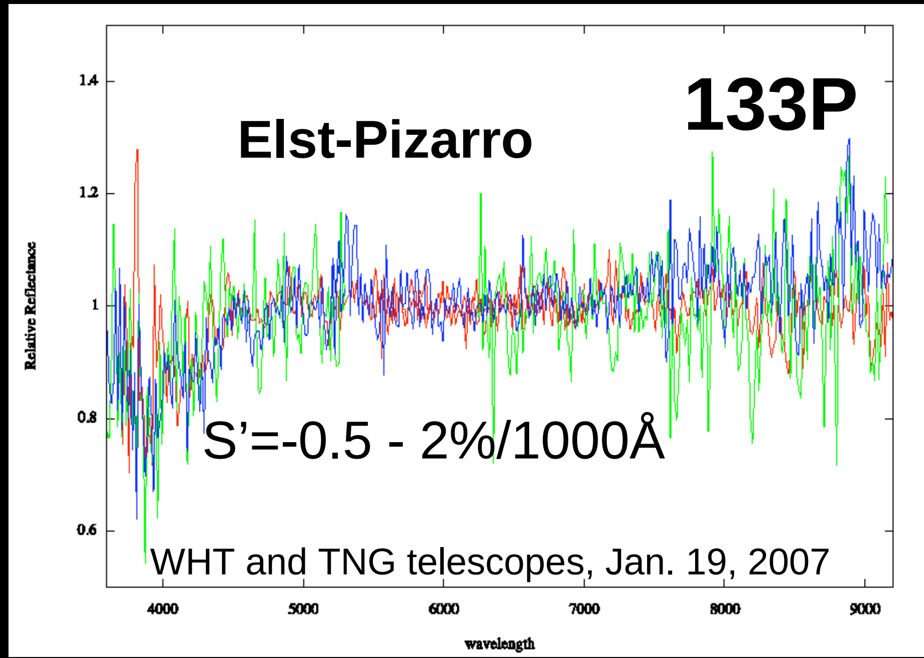
Main Belt Comets in the Themis Family

- Orbits of Themis-family MBCs not likely to evolve from comet reservoirs i.e., Oort cloud or Transneptunian region
- Visible spectra of both Themis-family MBCs resemble larger family members and not cometary nuclei (Licandro et al. 2011)

Main Belt Comets in the Themis Family

Spectra of MBCs (Licandro et al.)



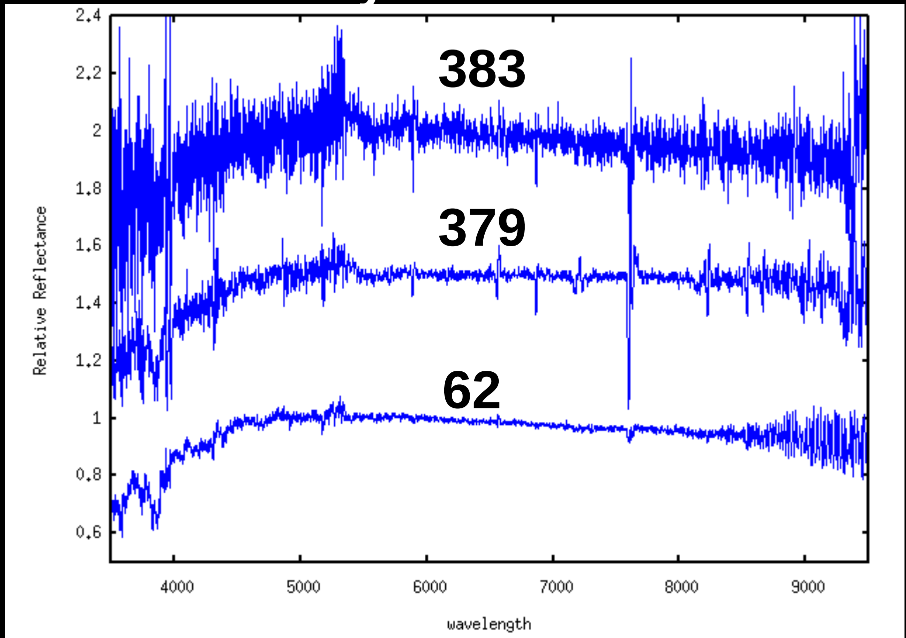


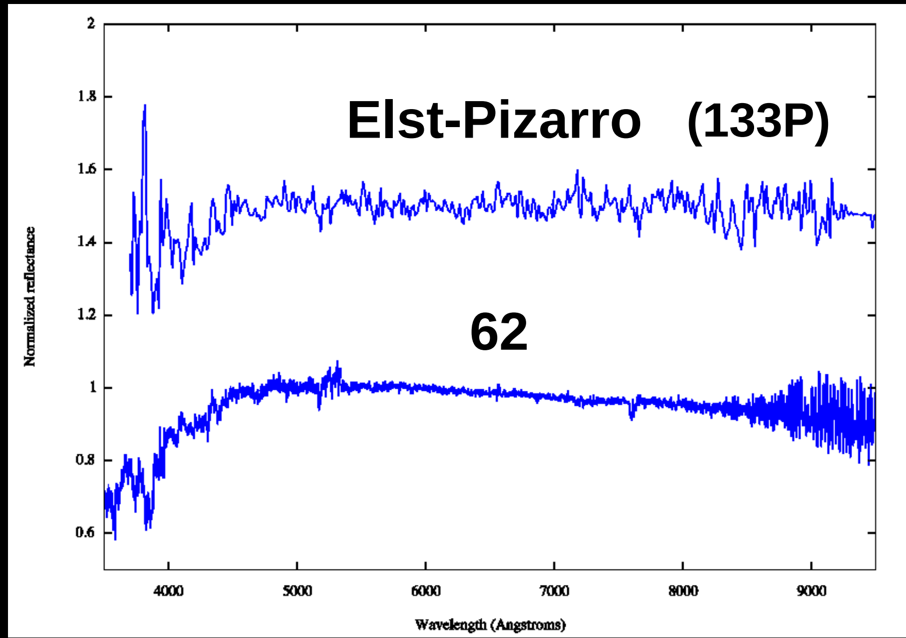
Spectra of MBCs: same as other family members

Main Belt Comets in the Themis Family

Spectra of MBCs & Themis asteroids

Themis family asteroids

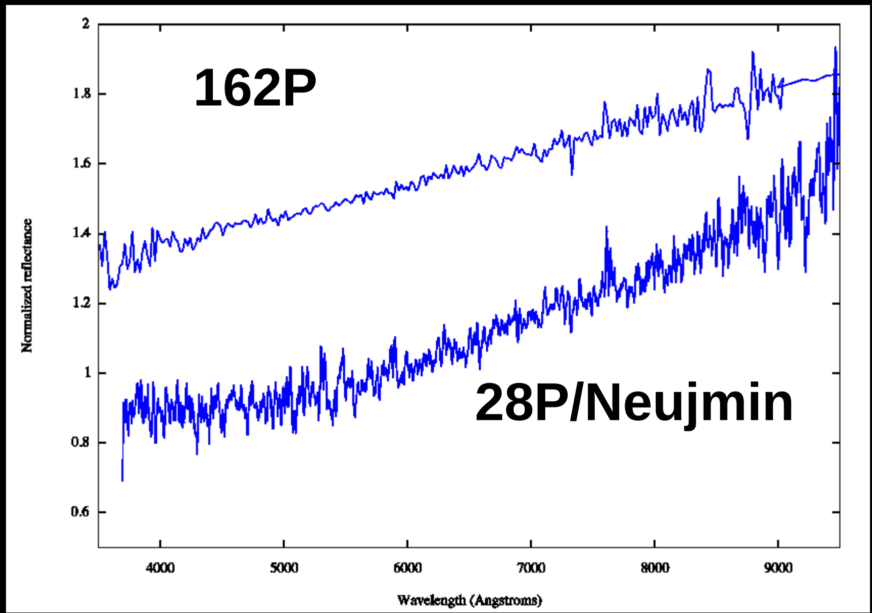


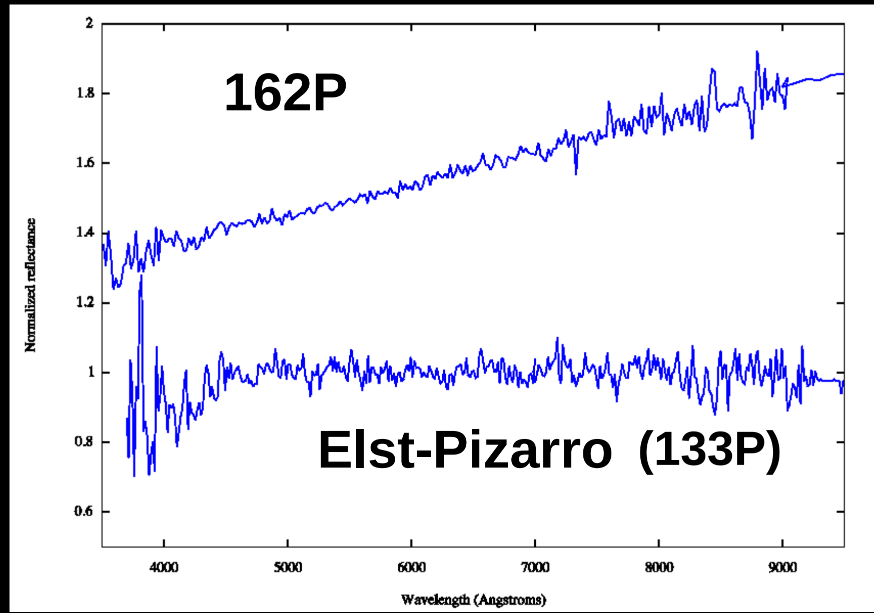


Compositionally MBCs are Themis family members

Spectra of MBCs ≠ Comet Nuclei

Comet nuclei





- Spectra of MBCs different from comet nuclei
- MBCs are not captured transneptunians

MBCs Compositionally Related to Themis Family and not Captured Comets

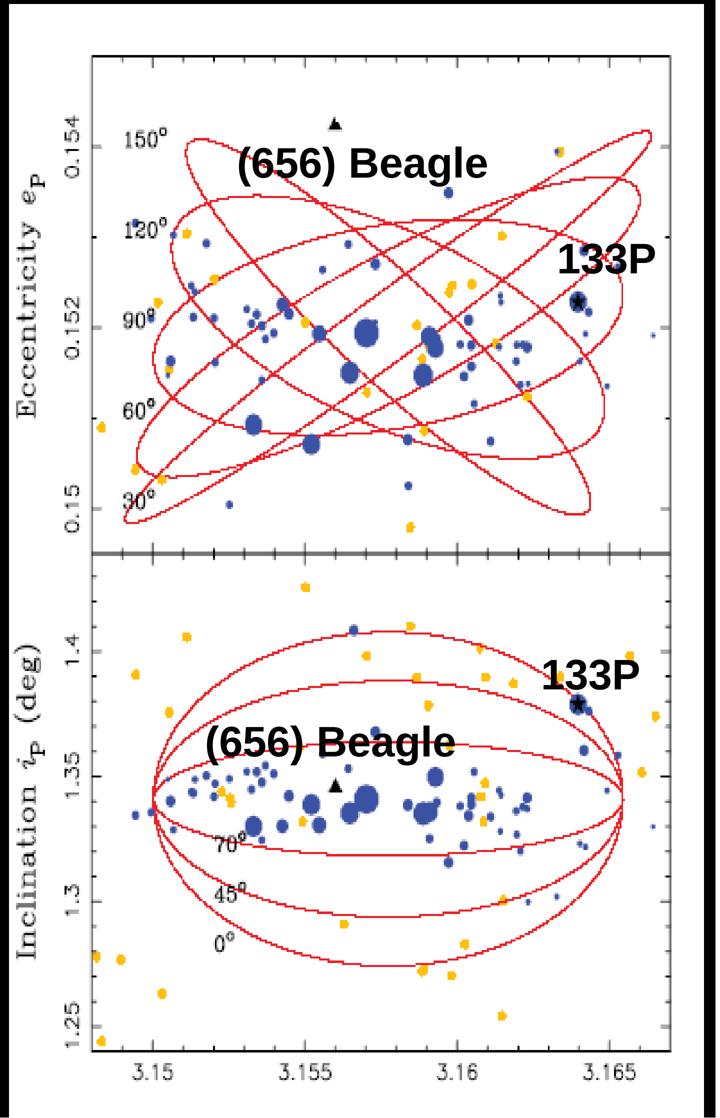
1. We prefer the term "activated asteroids"
2. If MBCs' activity is driven by water-ice sublimation, it may have been exposed recently by a collision
3. Consistent with 133P member of Beagle sub-family, which formed recently
4. 24 Themis has surface water-ice
5. Why are some Themis family asteroids active and not others?

Beagle sub-family

- Contains MBC 133P Eslt-Pizarro (Nesvorny et al. 2008) <u>but not MBC 176P Linear</u>

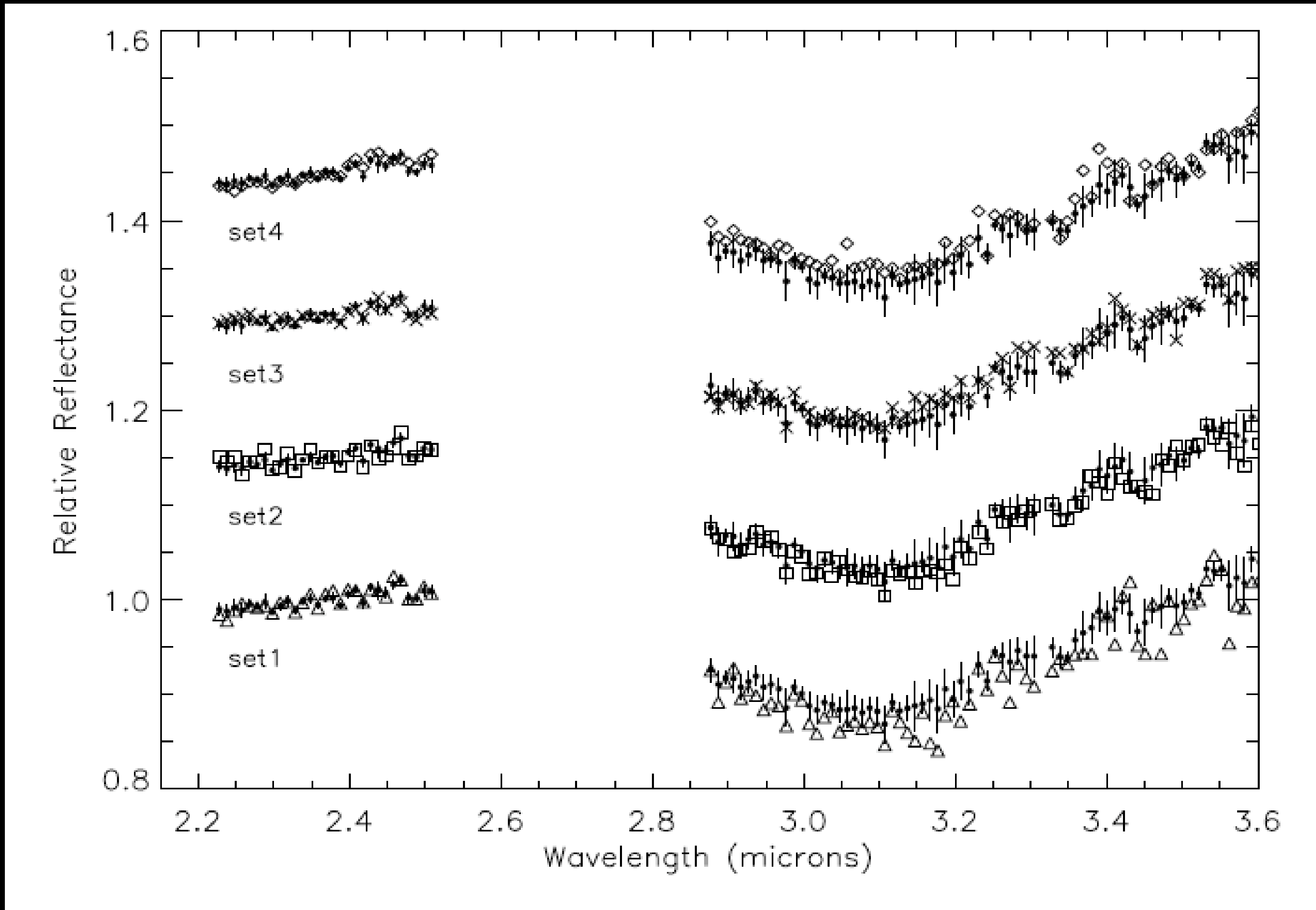
- Possibly water-ice on 133P recently exposed by collision

- Multiple collisional events may be needed to explain different MBCs in Themis family, e.g., 176P is not a member of Beagle family



Ice and Organics Widespread on 24 Themis

(Campins et al. 2010 and Rivkin & Emery 2010)



IRTF-Spex spectra over 7 hours (84% of rotation period)

Spectra of 24 Themis and 65 Cybele Very Similar (Licandro et al. 2011)

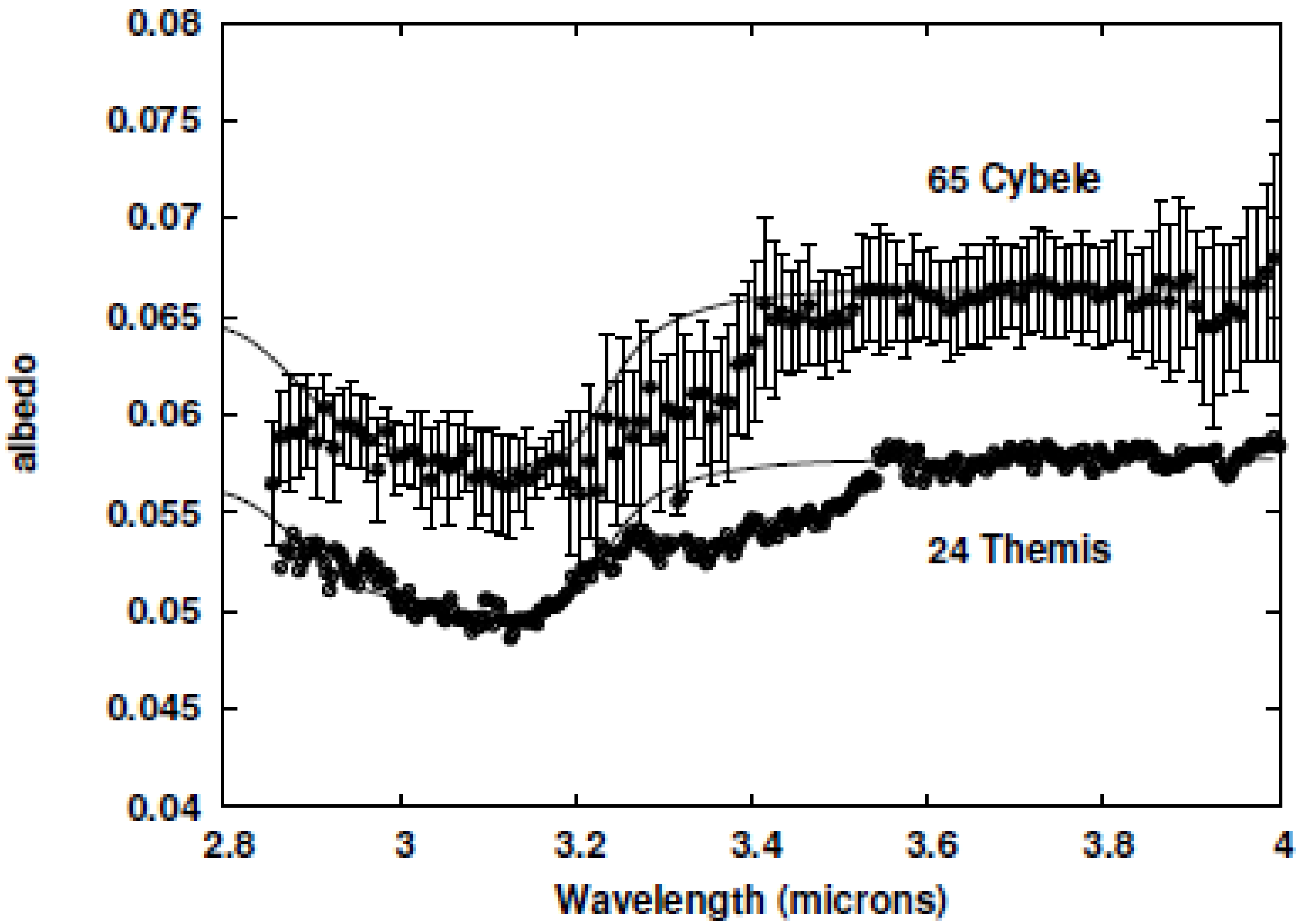


Fig. 7. Reflectance spectrum of Cybele and Themis in albedo units. Within the noise, both spectra looks very similar. Overplotted to Themis spectrum is the spectral model included in Fig. 1 of Rivkin & Emery (2010) . A similar model is overplotted to Cybele's spectrum. These models include a thin coating of H_2O ice on surface grains. Notice that models fit very well the left part of the band while at longer wavelengths there are additional absorptions.

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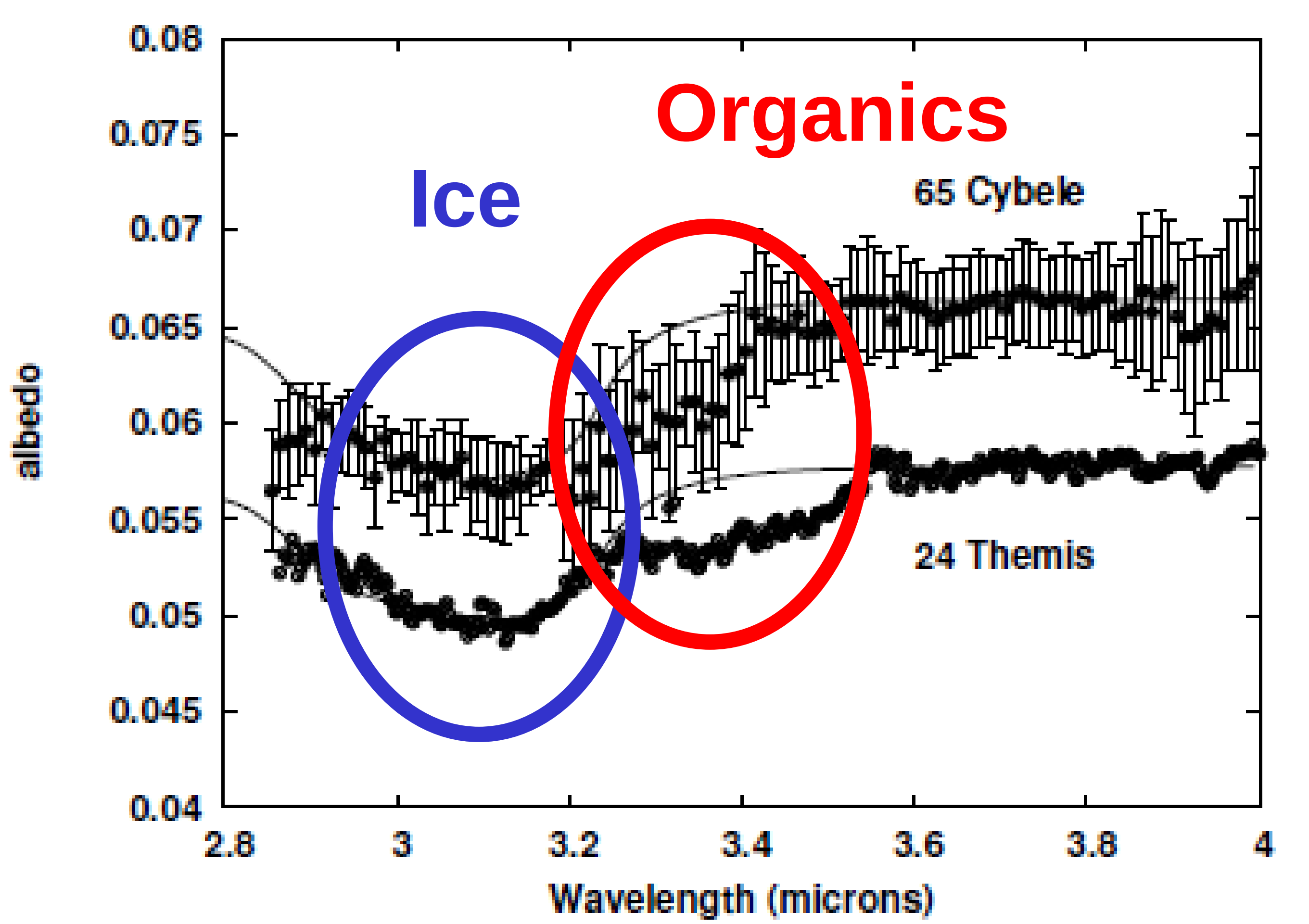

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MBCs Compositionally Related to Themis Family and not Captured Comets

4. Asteroid 24 Themis has surface water-ice

5. Why are some Themis family asteroids active and not others? Why is 24 Themis not active?

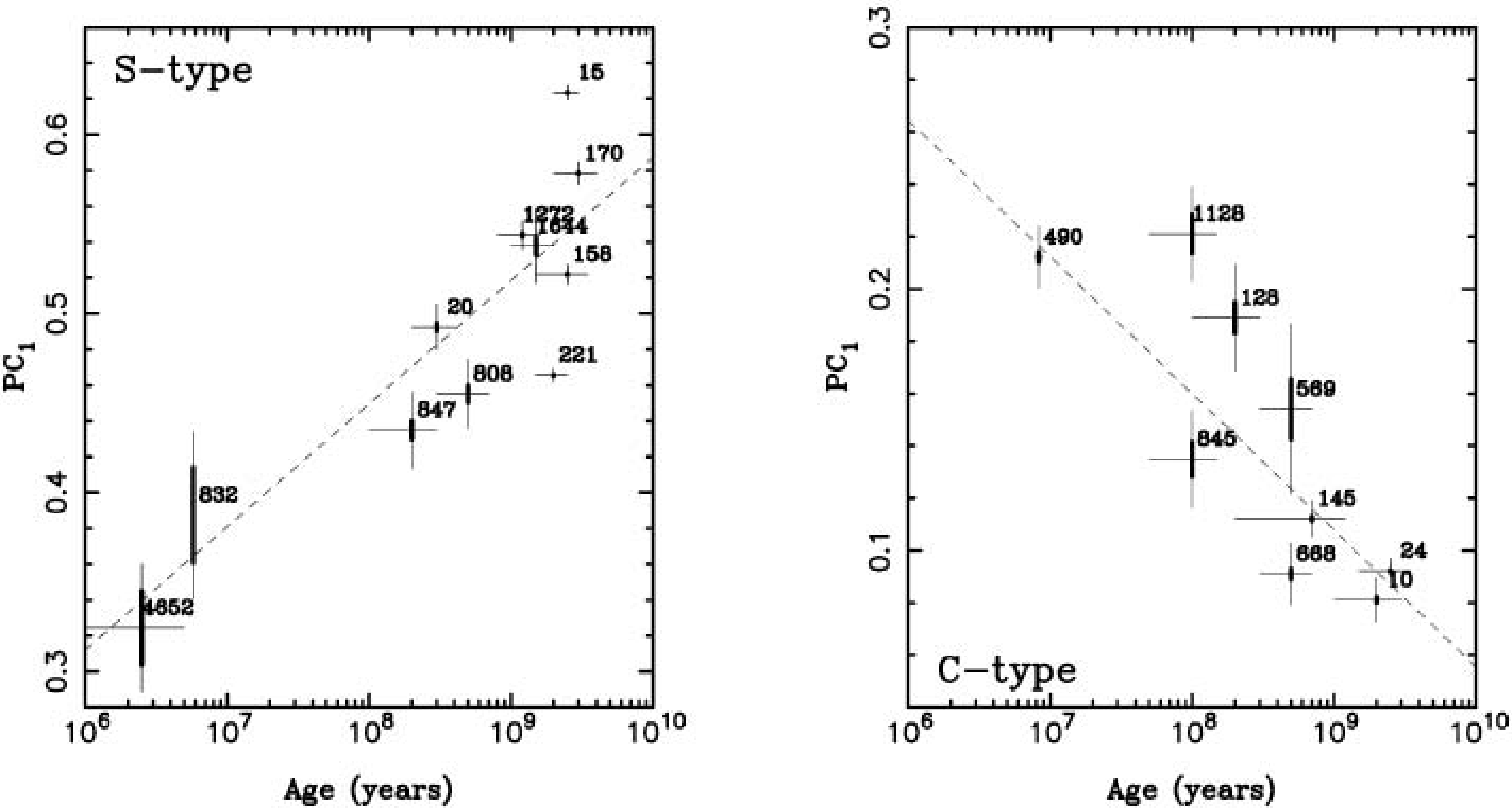
   - Not clear, gravity in 24 Themis prevents dust from escaping?
   - Heterogeneous compositions among small Themis fragments?
   - Gaia study will help

III. Expected Results

1. Family hetero/homogeneity: nature of parent body
2. Test Space Weathering in Primitive Families:
   a. e.g., compare Beagle family members (~65 members down to ~ 2km diameter) with non-Beagle Themis asteroids
   b. Verify SDSS (Nesvorny et al. 2005) color trend among primitive families

III. Expected Results:
2. Test Space Weathering on Primitive Asteroids

D. Nesvorný et al. / Icarus 173 (2005) 132–152



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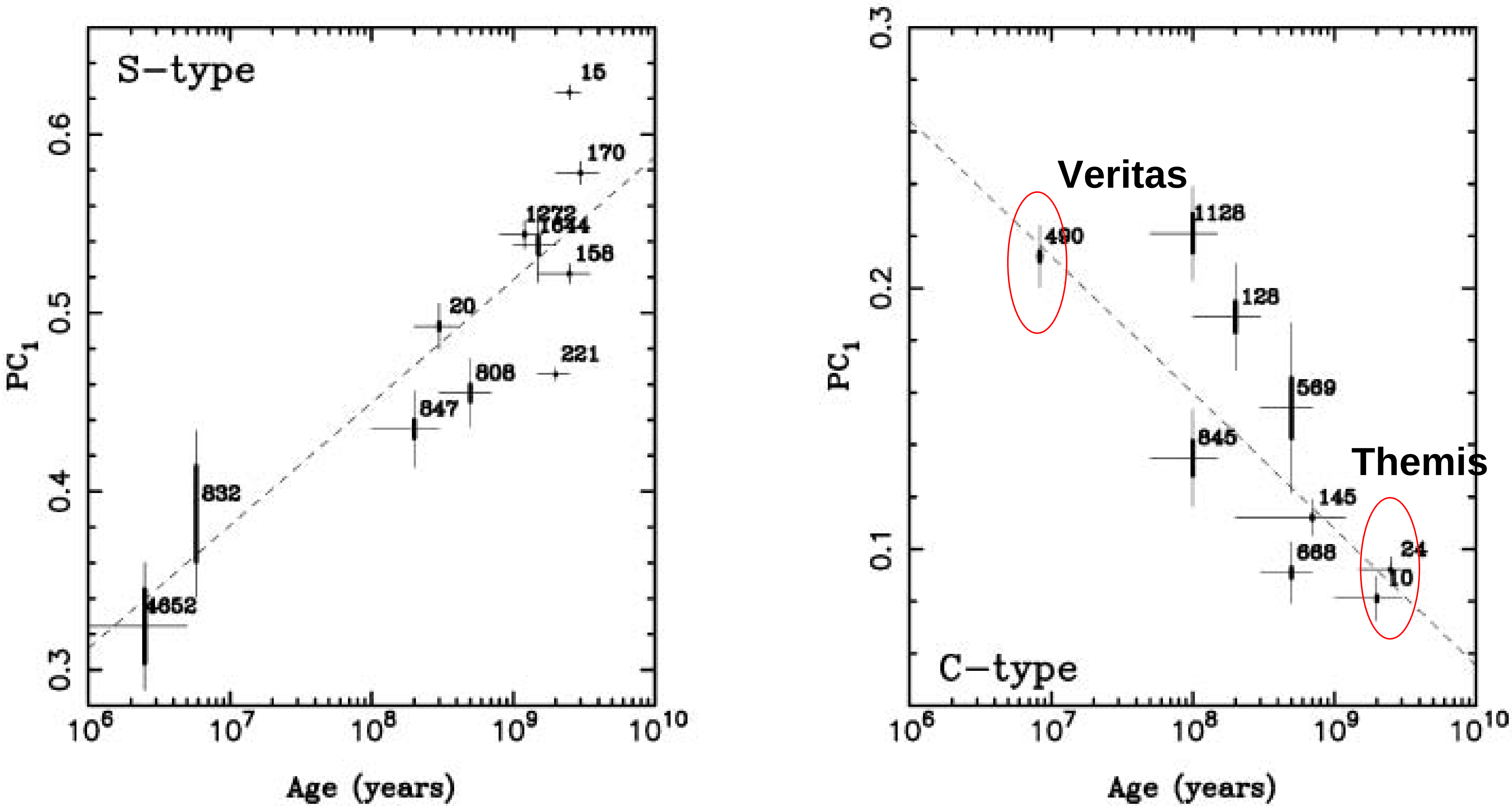
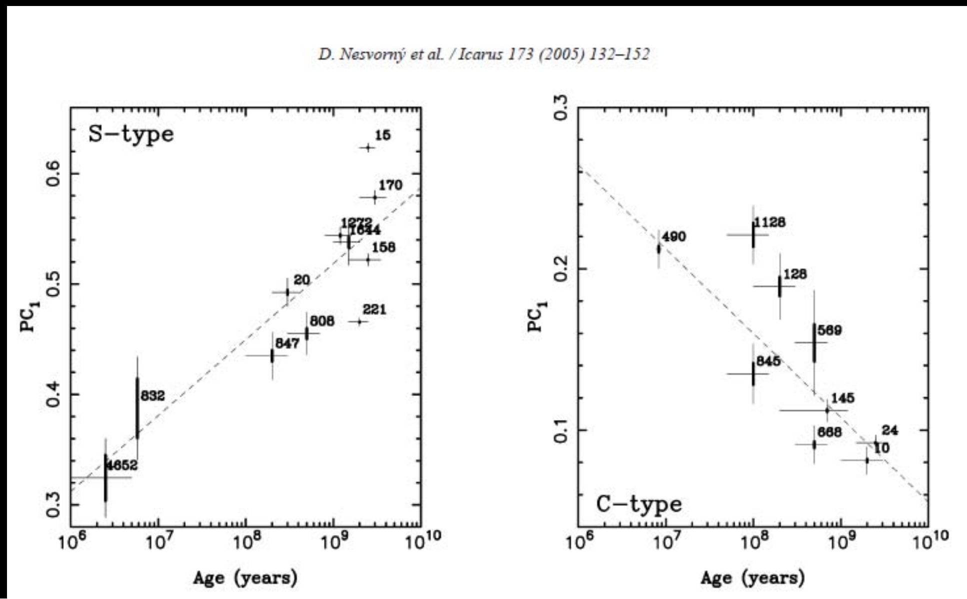


III. Expected Results:
2. Test Space Weathering on Primitive Asteroids

- Nesvorny et al. (2005) results not consistent with laboratory measurements (e.g., Brunetto 2009)
- Will SDSS results from Nersvorny et al. (2005) be confirmed by Gaia?
- Similar results evident for Themis vs. Beagle?



III. Expected Results (cont)

3. Spectral properties as function of asteroid size
4. Search for hydration (0.7 μm band) within families, e.g. Themis/Beagle
5. Compare primitive families from the inner belt (142 Polana) to Jupiter Trojans (3548 Eurybates)
6. Gaia spectra of main-belt asteroids will enhance search for parent families of NEAs and possibly meteorites e.g., 3200 Phaethon-2 Pallas (de León et al. 2010), 1999 RQ36-146 Polana (Campins et al. 2010b)