MAIN-BELT INFRARED SPECTRAL ANALOGUES FOR (101955) BENNU: AKARI AND SPITZER IRS ASTEROID SPECTRA. L. F. Lim[1], H. H. Kaplan[2], V. E. Hamilton[2], P. R. Christensen[3], A. A. Simon[1], D. C. Reuter[1], J. P. Emery[4], B. Rozitis[5], M. A. Barucci[6], H. Campins[7], B. E. Clark[8], M. Delbo[9], J. Licandro[10], R. D. Hanna[11], E.S. Howell[12], D. S. Lauretta[12], [1]Goddard Space Flight Center, Greenbelt, MD, USA (lucy.f.lim@nasa.gov), [2]Southwest Research Institute, Boulder, CO, USA, [3]Arizona State University, Tempe, AZ, USA, [4]University of Tennessee, Knoxville, TN, USA, [5]Open University, Milton Keynes, UK, [6]LESIA, Paris Observatory Meudon, France, [7]University of Central Florida, Orlando, FL, USA, [8]Ithaca College, Ithaca, NY, USA, [9]CNRS, France, [10]Instituto de Astrofísica de Canarias, Tenerife, Spain, [11]University of Texas, Austin, TX, USA, [12]University of Arizona, Tucson, AZ, USA.

Introduction: The Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) mission has measured the spectrum of asteroid (101955) Bennu in reflectance (OVIRS instrument; [1]) and thermal emission (OTES instrument; [2]). Here we place the global average spectra of Bennu [3] in the context of the wider asteroid population as represented by infrared reflectance spectra from the AKARI mission [4] and thermal emission spectra from the Spitzer Infrared Spectrometer (IRS) [5].

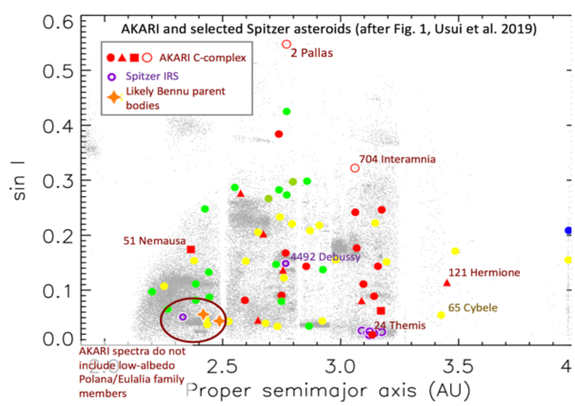

Figure 1: Dynamical context of AKARI and selected Spitzer asteroids in the asteroid main belt relative to the probable Bennu source region

On dynamical grounds (101955) Bennu has been considered most likely to have originated in the inner-Main-Belt families of (495) Eulalia (C-type, semimajor axis a = 2.49 AU) or (142) Polana (B-type, a = 2.42 AU) [6, Fig. 1]. However, neither Eulalia nor Polana nor their family members were observed spectroscopically either with AKARI or with the Spitzer IRS.

B-type Main Belt asteroids in the AKARI spectral catalogue: (2) Pallas, (704) Interamnia, and (24) Themis were observed spectroscopically by AKARI. Although all three asteroids are dynamically distant from the Polana/Eulalia complex and the ν_6 secular resonance, Pallas and Interamnia are close spectral matches in the 2.6–3.5 µm wavelength region, in which Bennu's strongest spectral feature is located (Figs. 2 and 3) [3]. Bennu's observable 2.7-µm band depth after thermal tail subtraction is weaker than that of Pallas by a factor of approximately 2 and weaker than that of Interamnia by a factor of 1.4. The shape of the band is a closer match to that of Pallas in the 2.85–3.0 µm region. Preliminary Gaussian fits (fig. 2b) show that the difference in shape can be explained by the Gaussian at ~2.89 µm.

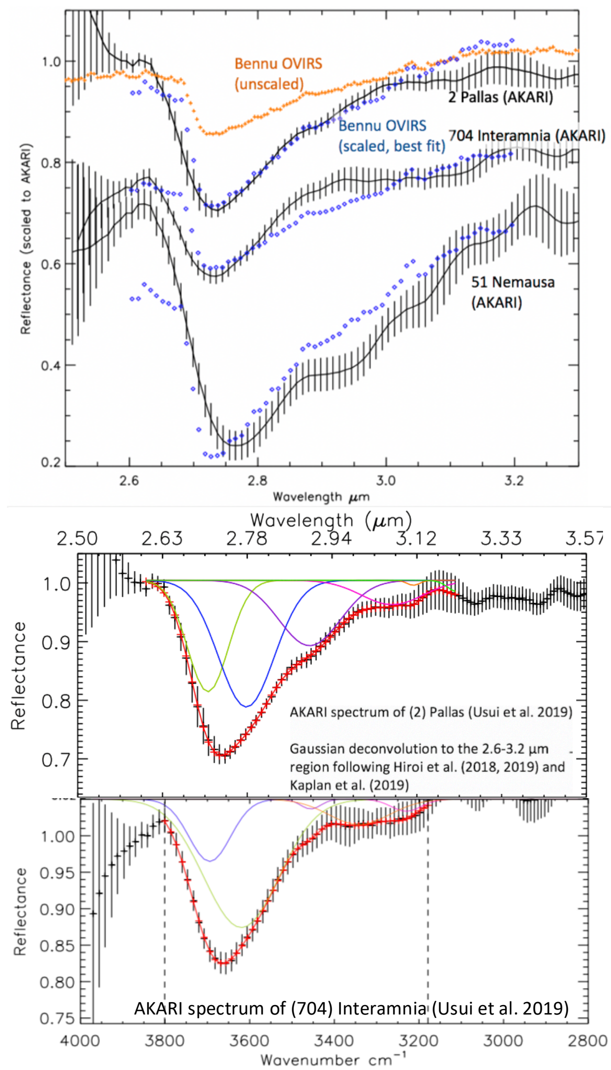

Figure 2 (a) OVIRS spectrum of Bennu vs. AKARI spectra of B-type asteroid (2) Pallas, B- or Cb-type asteroid (704) Interamnia, and inner-main-belt Cgh-type asteroid (51) Nemausa (b) Preliminary 5-Gaussian fit to the AKARI spectrum of 2 Pallas. The two deepest absorptions are the most similar in wavelength to the "Band 1" (2.72) and "Band 2" (2.76) identified in the Gaussian deconvolution of the NIRS3 spectrum of Ryugu [7].

In contrast, (24) Themis (Fig. 3) is a comparatively poor match to Bennu in this region and also contains a deep 3.1-µm band [9,10] not matched by corresponding structure in Bennu's spectrum. The preliminary Gaussian fit to this spectrum is shown in Fig. 3b.

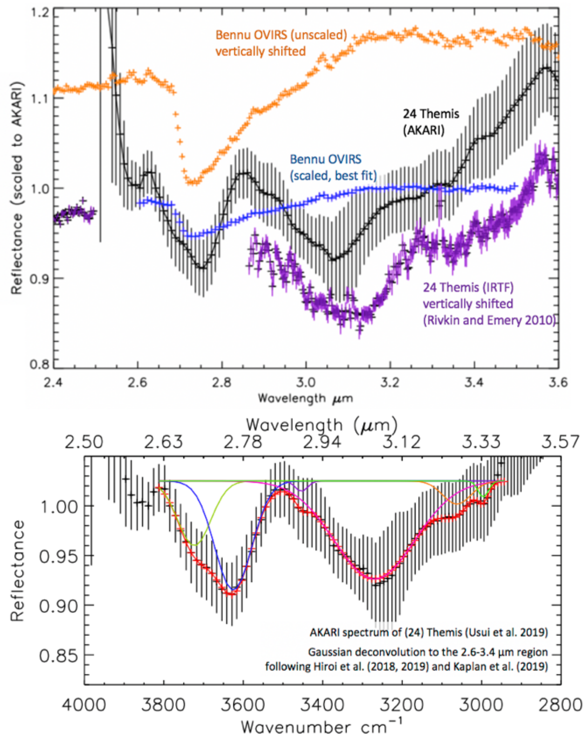

Fig. 3: (a) OVIRS spectrum of Bennu vs. AKARI and IRTF spectra of B- or C-type asteroid (24) Themis (b) Preliminary 6-Gaussian fit to the AKARI spectrum of (24) Themis.

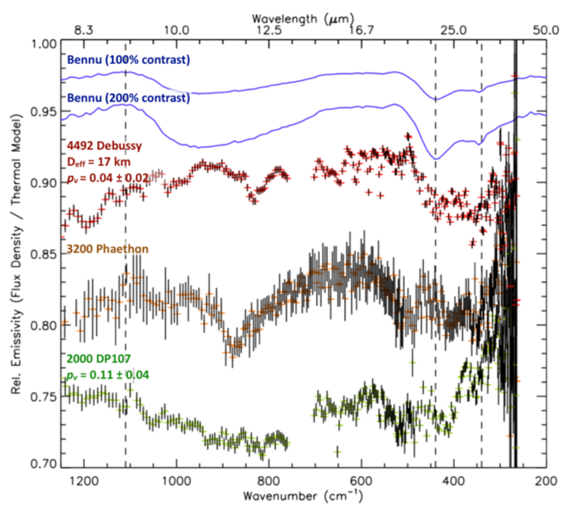

Fig. 4: OTES spectrum of Bennu with spectra of (4492) Debussy (a = 2.77 AU; D_{eff} = 17 km), B-type NEO 3200 Phaethon (D ≈ 5 km) and the sub-kilometer top-shaped asteroid NEO 2000 DP107 [12]

Spitzer IRS asteroid spectra: Emissivity spectra for several low-albedo binary asteroids have been published [12]. Among these, the spectrum of (4492) Debussy (Fig. 4) is the closest match to that of Bennu in the 20–30 µm region but is dissimilar in the 8–14 µm region, with a narrow emissivity minimum at 12 µm that is absent from the spectrum of Bennu. Debussy was classified as a C-type in [13]. A low Bennu-like density was reported for Debussy ($\rho = 0.9 \pm 0.1$ g/cm^3) [12].

Summary and Conclusions: Although dynamically distant from the most likely Bennu source regions in the main belt, (2) Pallas is a close spectral analogue to Bennu in the 2.6–3.2 µm region. There are no Spitzer IRS spectra of Pallas or its family members.

Bennu's thermal IR spectrum is unlike those of "10-µm plateau" main-belt and Trojan low-albedo objects, including the B-type asteroid (24) Themis and its large family members. Thus, the low-thermal-inertia boulders that dominate the surface of Bennu are not producing the same spectral emissivity behavior that has been attributed to underdense fairy-castle surface structure in these larger objects (e.g. [11]). We note that the main-belt "plateau" asteroids have thermal inertias in the range 5–85 J s$^{-1/2}$ K^{-1} m^{-2} (5–85 for (45) Eugenia, 5–65 for (130) Electra; [12]) whereas the average thermal inertia for Bennu is ~300 in the same units, with values as low as ~200 observed in some of the larger boulders [14]. (24) Themis is also not a close spectral match in the 2.5–3.5 µm region.

Small B-type family members in the main belt have not yet been spectrally characterized in the thermal IR. Measurements of small Polana/Eulalia family members in the main belt would be the most directly relevant to understanding the origin of Bennu.

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References: [1] Reuter, D. C. et al. (2018) *Space Science Reviews*, 214, 54. [2] Christensen, P. R. et al. (2018) *Space Science Reviews*, 214, 87. [3] Hamilton, V. E. et al. (2019) *Nature Astronomy*, 3, 332-340. [4] Usui, F. et al. (2019) *Publ. Astron. Soc. Japan* 71, 1 (1–41). [5] Houck, J. R., et al. (2004) *ApJS* 154, 18. [6] Bottke, W. F., et al. (2015) *Icarus* 247, 191. [7] Hiroi, T. et al. (2019) *LPSC* 50, #1129. [8] Kaplan, H. H., et al. (2019) *M&PS*, 54: 1051-1068. [9] Rivkin, A.S. and Emery, J.P. (2010) Nature 464, 1322. [10] Campins, H. et al. (2010) Nature 464, 1320. [11] Emery, J. P., et al. (2006) *Icarus* 182, 496. [12] Marchis, F. et al. (2012) *Icarus* 221, 1130. [13] Dandy, C. L. et al. (2003) *Icarus* 163, 363. [14] Rozitis, B. et al. (2019) this meeting.