COMPOSITION OF THE BINARY MAIN-BELT ASTEROID (22) KALLIOPE. F.. Marchis[1,2,3], P. S. Hardersen[4], J. Emery[1], P. Descamps[3], V. Reddy[5], L. Lim[6] [1]SETI Institute, Carl Sagan Center, 515 N. Whisman Road, Mountain view CA 94043, USA, fmarchis@seti.org; jemery@carlsagancenter.org. [2]UC-Berkeley, Dept of Astronomy, 601 Campbell Hall, Berkeley CA 94720, USA. [3]Institut de Mécanique Céleste et de Calcul des Éphémérides, Observatoire de Paris, 75014 Paris, France, descamps@imcce.fr. [4]Department of Space Studies, Box 9008, University of North Dakota, Grand Forks, North Dakota 58202, USA. Hardersen@space.edu, [5]Department of Earth System Science and Policy, Box 9011, University of North Dakota,Grand Forks, North Dakota 58202, USA. vishnu.kanupuru@und.nodak.edu. [6]NASA/GSFC, code 691, Greenbelt MD 20771, USA,

Introduction: (22) Kalliope is one of the first main belt binary asteroids discovered. The presence of its 28km-diameter companion, called Linus, was announced simultaneously by two teams [1] using Adaptive Optics (AO) observation at the W. M. Keck II telescope in 2001. The characteristics of its mutual orbit are well known due to an extensive study conducted by [2]. AO observations from medium (3m) and large (8-10m) aperture size ground-based telescopes are being collected since 2001. This orbital model allowed a large group of observers [3] to detect mutual events between Linus and the primary in March 2007. The main outcome of this extensive study [3] is a revised effective diameter for Kalliope (D_{eff} = 166 ± 4 km) leading to a bulk density of 3.45 ± 0.2 g/cm^3. This bulk density measurement is 40% larger than the one derived based on IRAS radiometric observations [4]. [3] showed that at the time of IRAS observations, the primary asteroid was seen pole-on, exhibiting a largest effective diameter.

Visible-NIR spectroscopy: (22) Kalliope was classified as an M-type asteroid by [5], corresponding to spectrally featureless object with a moderate albedo (p_V=0.07 to 0.30). Recent work focusing on this taxonomic classes has shown mineralogical diversities. [6] reported the presence of orthopyroxene weak band at 0.9 μm and ~2.0 μm for various M-type asteroids, including (22) Kalliope [7]. [8] identified 3-μm absorption feature that is presumably caused by phyllosilicate minerals. [9] showed that this absorption band could have a radiation origin due to solar wind protons trapped in OH groups. This absorption feature is anyway inconsistent with M-class class being primarily Fe-Ni metal.

A high SNR spectrum of this asteroid was recorded using the SpeX near-infrared spectrograph at the NASA Infrared Telescope Facility (IRTF) on Muana Kea Hawai'i on May 9 2004. The average spectrum shown in Fig. 1 is mostly featureless in contradiction with [7]. The detection of the 0.9 μm band is too marginal to be interpreted as due to the presence of low-Fe, low-Ca orthopyroxene on the surface of (22) Kalliope. This spectrum is an average of 5 spectroscopic observations with an incomplete coverage. The interpretation for a featureless spectrum is not well-constrained but remains consistent with Ni-Fe or enstatite chondrite meteorite analogs.

Thermal IR spectroscopy: (22) Kalliope was observed between 5 and 38 μm using the InfraRed Spectrometer (IRS) on the Spitzer telescope on 20 Nov 2005 as part of a large survey aiming to observe 27 class M asteroids [9]. The processed low resolution (R=64-128) thermal spectrum of (22) Kalliope displayed in Fig. 2, was analyzed using a slightly modified version of the asteroid Standard Thermal Model (STM)[10]. We confirm the approximate size and the medium albedo of (22) Kalliope. We also derived a beaming factor (η) of 0.96. The derived beaming factor is significantly higher than the 'canonical' STM value of 0.756, yet below unity, suggesting either lower roughness or higher thermal inertia than on large MBAs such as Ceres.

The emissivity spectrum created by dividing the measured SED by the best-fit STM displays a broad emission plateau centered at ~10 μm and a narrower peak at ~6.1 μm. Emission spectra in the thermal infrared are well suited to addressing silicate mineralogies. This spectral region contains the Si-O stretch and bend fundamental molecular vibration bands [16,17]. Initial analysis from comparisons with laboratory spectra of meteorites and minerals seem to preclude a significant abundance of enstatite and instead point toward a phyllosilicate-rich surface composition.

Emissivity spectrum of Kalliope calculated by dividing the thermal flux spectrum by the best fit thermal model, along with spectra of several meteorites and a phyllosilicate (lizardite) from the ASTER spectral library. The Kalliope spectrum exhibits a broad emissivity plateau centered near 10 μm and a narrower peak at ~6.1 μm. ALH84007 is an enstatite-rich aubrite meteorite. The Christiansen peak of enstatite is at a much shorter wavelength than is observed for the Kalliope spectrum. The Christiansen peak for the ordinary chondrite is also slightly shortward compared to Kalliope, and the peak at ~12 μm does not appear in Kalliope at all. Ivuna is a CI carbonaceous chondrite whose mineralogy is dominated by phyllosilicates. Allende is a CV carbonaceous condrite composed primarily of olivine, whose Christiansen feature and restrahlen bands are at longer wavelengths than observed for Kalliope. Lizardite is a phyllosilicate of the serpentine class, and its spectrum shows a Christiansen peak at the same wavelength as for Kalliope as well as a similar 6.1-μm feature. The 6.1-μm feature is an H-O-H bending mode of the bound water in the phyllosilicate – consistant with the 3-μm absorption feature found by [8].

Conclusion: More detailed analysis are underway and will be presented in this poster.

[1] Margot, J.-L. et al., (2001) *IAU circular 7703*. [2] Marchis. F. et al. (2008) *Icarus, in press*. [3] Descamps, P. et al. (2007) *Icarus submitted*. [4] Marchis, F. et al.. (2003) *Icarus, 165, 1,112-120*. [5] Tholen D. J., et al. (1989), *Asteroid II*, 806-825. [6] Hardersen, P. S., et al., (2005) *Icarus* 175, 141-158. [7] Hardersen, P. S., et al., (2006) *LPSC XXXVII*, 1106. [8] Rivkin A.S., et al. (2000) *Icarus 145*, 351-368. [9] Starukhina, L. (2001) *JGR 106*, E7, 14701-14710 [10] Lim, L.F., and Emery, J. P., *AAS-DSP #38*, #71.04, [11] Emery J.P., et al., (2006) *Icarus 182*, 2, 496-512. [12] Britt, D.T. and Consolmagno, G.J., (2004) *LPSC XXXV*, 2108 [13] Marchis F., et al., (2005) *Nature 436*, 7052, 822-824. [14] Descamps, P., et al. (2006) *Icarus 187*, 2, 482-499 [15] Lebofsky, LA., & Spencer, J.R. (1989) in *Asteroids II* (UofA Press), pp128-147. [16] Salisbury, J.W., et al. (1991), *Icarus* 92, 121-128. [17] Salisbury, J.W. et al. (1992) *Mid-infrared (2.1 – 25 μm) Spectra of Minerals* (JHU Press), 346pp.

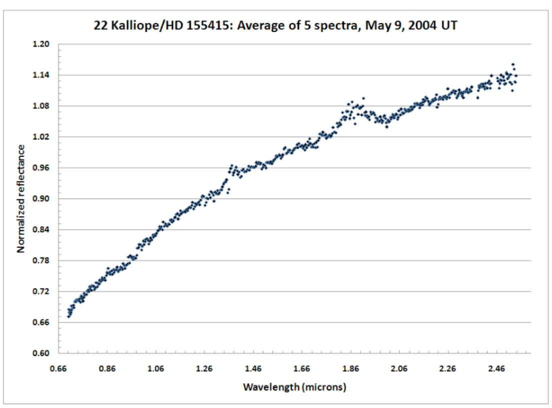

Fig. 1. Visible and NIR spectrum of (22) Kalliope

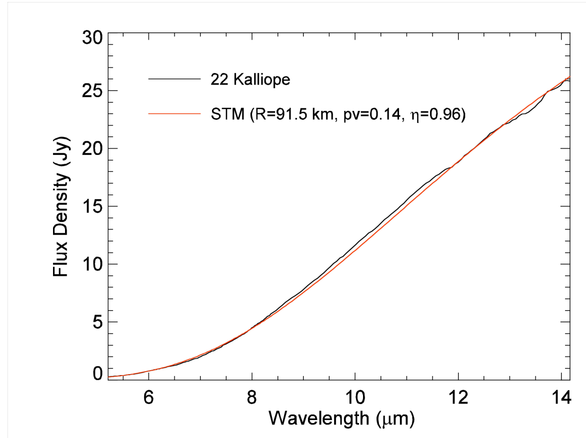

Fig 2. Thermal flux of Kalliope measured with the Spitzer space telescope. The best fit thermal model (modified STM [15,10]) is overplotted.

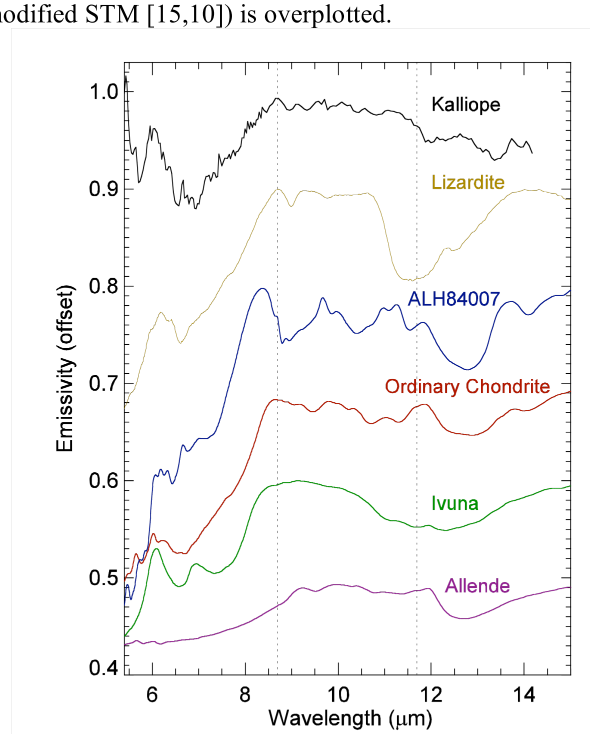

Fig 3. Emissivity spectrum of Kalliope. Comparison with several meteorites and a phyllosilicate (lizardite) from the ASTER spectral library. See text for details.