NEAR-INFRARED SPECTROSCOPY OF 3:1 KIRKWOOD GAP ASTEROIDS: A BATTALION OF BASALTS

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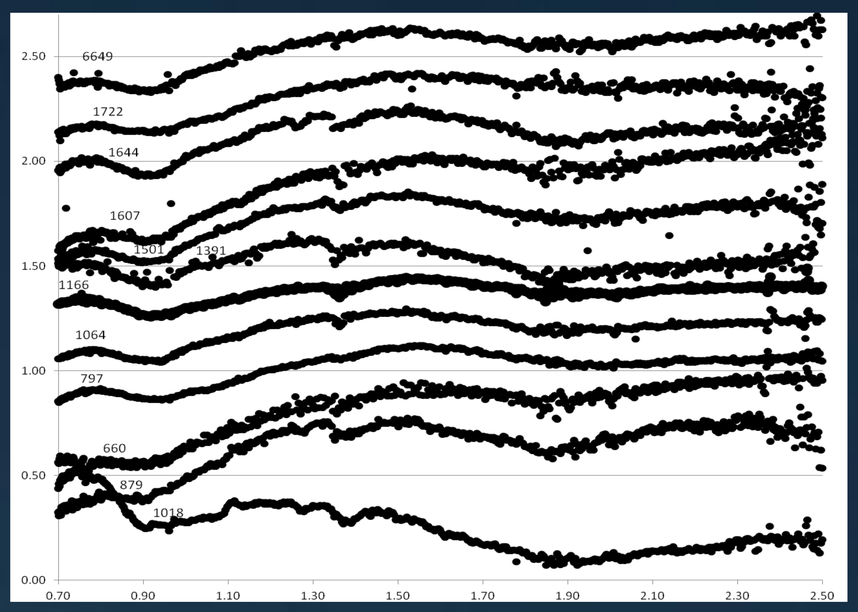
Introduction:

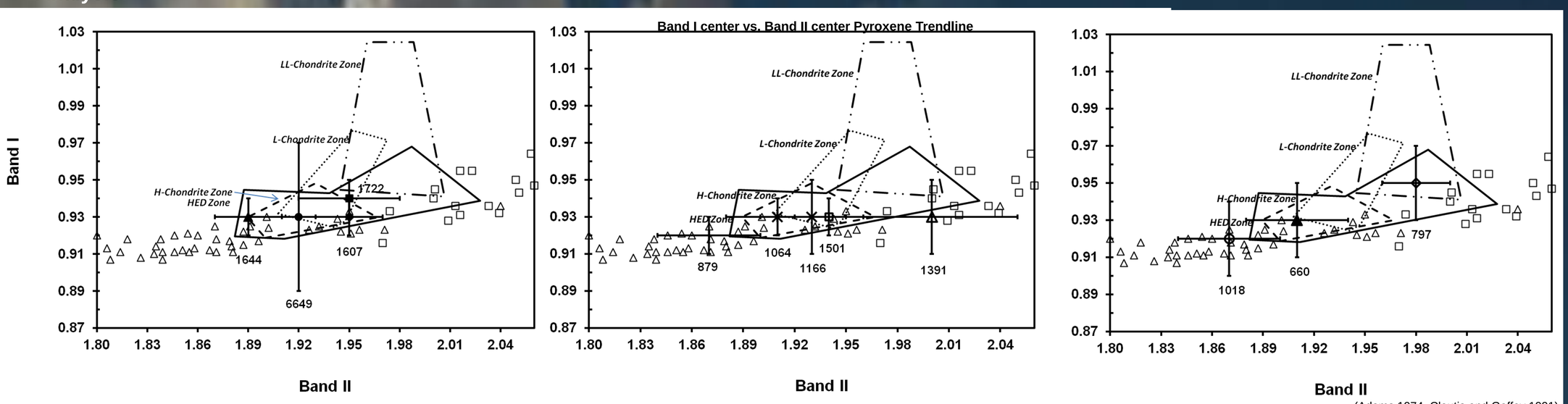
The mineralogy, petrology, isotope chemistry, and cosmic ray exposure history revealed by laboratory study of the meteorites provides detailed insights into the relative and absolute timing of major processes operating and conditions present in the early inner solar system. However, the source regions of the individual meteorite types are poorly constrained because their specific parent bodies and hence their early solar system locations have generally not yet been identified. Mineralogical characterizations of the asteroids provide a "geologic map" of conditions and processes in the early solar system. The chronological studies of the meteorite types provide a "clock" for the relative timing of those events and processes. By identifying the source asteroids of particular meteorite types, the "map" and "clock" can be combined to provide a much more sophisticated understanding of the history and evolution of the early solar system.

The Kirkwood Gaps are zones in the asteroid belt located at proper motion resonances with Jupiter. According to several theoretical models, the bulk of meteoroids and near-Earth objects delivered to the inner solar system originate from the 3:1 and ν_6 resonances [1-4]. The current spectroscopic investigation of the 3:1 Kirkwood Gap asteroids assumes each of the targeted asteroids is individually a potential parent body of one of a variety of meteorite types.



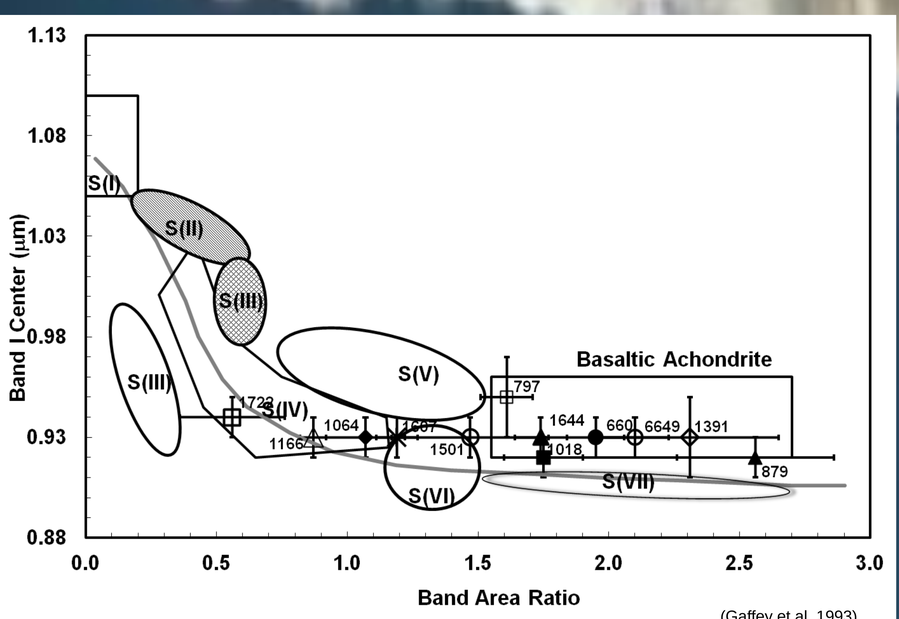
- Near-IR spectra of 12 asteroids located in/near the 3:1 Kirkwood Gap were obtained at the NASA IRTF using the SpeX instrument [5] in the low-res spectrographic mode:
  - June 12 /13, 2010
  - June 3 /4, 2011
  - July 19-21, 2011
- Asteroid & standard star observations were interspersed within the same airmass range to allow modeling of atmospheric extinction.
- Data reduction was done using previously outlined procedures [6,7].
- All twelve asteroids exhibit two absorption features near 1 and 2 µm, with varying spectral redness, which are typical of anhydrous mafic assemblages.

Analysis:



(Adams 1974, Cloutis and Gaffey 1991)

- Assemblages in which pyx is the sole/predominant spectral contributor fall along a trend with Fe^{2+} and Ca^{2+} content increasing from the lower L to the upper R.
- If olivine is present in opx-bearing assemblages, the Band I center is displaced toward longer wavelength while the Band II center is unchanged.
- The mafic-dominated meteorites occupy discrete zones on the Band-Band plot as shown.
- To be identified as a possible meteorite assemblage, an asteroid must plot within the appropriate zone.



(Gaffey et al. 1993)

- The BAR value for olivine-orthopyroxene assemblages is proportional to the abundance of opx in the mixture.
- The Band I position is affected by both the relative abundances of the olivine and pyroxene phases and by the composition of the pyroxene phase.
- The resulting parameter space is subdivided into mineralogically distinct regions

Asteroid	Band I µm	Band II µm	BAR	Pyx Chemistry*	Ol**	Meteorite Affinity
660	0.93 ± .01	1.91± .03	1.59 ± .11	$Fs_{28.5(\pm5)}Wo_{7.4(\pm4)}$ $Fs_{33.4(\pm3)}Wo_{6.1(\pm1)}$	28%	Mesosiderite (opx-diogenite w/metal)
797	0.95 ± .02	1.98 ± .02	1.61 ± .10	$Fs_{41.1(\pm5)}Wo_{15.5(\pm4)}$ $Fs_{50.8(\pm3)}Wo_{12.8(\pm1)}$	27%	Non-cumulate Eucrite- metal? Space weathered?
879	0.92 ± .01	1.87 ± .03	2.56 ± .30	$Fs_{17.8(\pm5)}Wo_{2.8(\pm3)}$ $Fs_{24.1(\pm3)}Wo_{2.5(\pm1)}$	0%	Mesosiderite (diogenite-like)
1018	0.92 ± .02	1.87± .03	1.75 ± .15	$Fs_{17.8(\pm5)}Wo_{1.3(\pm3)}$ $Fs_{24.1(\pm3)}Wo_{2.5(\pm1)}$	22%	Diogenite-like w metal Space weathered?
1064	0.93 ± .01	1.91 ± .05	1.07 ± .15	$Fs_{25.4(\pm5)}Wo_{3.8(\pm4)}$ $Fs_{16.9}Fa_{15.1}$	50%	H-Ordinary Chondrite Ureilite?
1166	0.93 ± .01	1.93 ± .03	0.87 ± .03	$Fs_{16.5(\pm5)}Wo_{0(\pm4)}$ $Fs_{16.9}Fa_{15.1}$	59%	H/L-Ordinary Chondrite?
1391	0.93 ± .02	2.00 ± .05	2.31 ± .34	$Fs_{52.7(\pm5)}Wo_{8.7(\pm4)}$ $Fs_{42.6(\pm3)}Wo_{9.7(\pm1)}$	0%	Euc poss rich in feldspar need albedo-not rep
1501	0.93 ± .01	1.94 ± .02	1.47 ± .30	$Fs_{36.6(\pm5)}Wo_{6.2(\pm4)}$ $Fs_{36.5(\pm3)}Wo_{7.3(\pm1)}$	33%	TBD
1607	0.93 ± .01	1.95 ± .04	1.19 ± .08	$Fs_{22(\pm5)}Wo_{3(\pm3)}$ $Fs_{16.9}Fa_{15.1}$	45%	H-Ordinary Chondrite
1644	0.93 ± .01	1.89 ± .02	1.74 ± .10	$Fs_{23.2(\pm5)}Wo_{5.8(\pm3)}$ $Fs_{31.4(\pm3)}Wo_{5.3(\pm1)}$	22%	basaltic assemblage
1722	0.94 ± .01	1.95 ± .03	0.56 ± .20	$Fs_{22.6(\pm5)}Wo_{2.8(\pm3)}$ $Fs_{16.9}Fa_{19.5}$	71%	L-OC
6649	0.93 ± .01	1.92 ± .04	2.10 ± .13	$Fs_{31.2(\pm5)}Wo_{8.7(\pm4)}$ $Fs_{34.4(\pm3)}Wo_{6.5(\pm1)}$	7%	TBD

- Pyroxene chemistries (Fs and Wo contents) were determined using formulas derived by [6] and tested against HED formulas by [8] and tested against ordinary chondrite formulas derived by [9].
- The derived pyroxene compositions represent the average pyroxene mineralogies of the object being analyzed.
- In order to be considered an ordinary chondrite analog, the object under investigation must have
  - ordinary chondrite pyroxene mineralogy,
  - plot within the S(IV) sub-type region of the S-asteroid plot,
  - and fall within an ordinary chondrite zone of the Band I vs. Band II pyroxene trendline.
- Failure to meet all three criteria automatically excludes the ordinary chondrite analog possibility. Thus, other meteorite analogs must be explored.

Points to consider:

- Each are derived from partial melt residues, cumulates, or complete differentiation.
- The iron/stony-iron meteorite groups indicate a minimum of 70 discrete parent bodies.
- The crustal and mantle portions of these disrupted bodies are grossly under represented in the meteorite collection.
- Understanding the compositional and dynamical nature of asteroids is necessary to address:
  - attainment and exploitation of space resources,
  - impact hazards to society,
  - impact mitigation strategies,
  - biological consequences on Earth due to impact.

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References: [1] P. Farinella et al. (1993) *Icarus* 101, 174-187. [2] A. Morbidelli et al. (1995) *Icarus* 114, 33-50. [3] A. Morbidelli et al. (1995) *Icarus* 115,60-65. [4] J.H. Ji et al. (2007) *Chin. J. Astron. Astrophys* **7**, 148-54. [5] J.T. Rayner et al. (2003) *Pubs. of the Astronomical Society of the Pacific* 115, 362-82. [6] M.J. Gaffey et al. (2002), *Asteroids III*, 183-204. [7] P.S. Hardersen et al. (2005) *Icarus* 175, 141-58. [8] T.H. Burbine et al. (2009) *MAPS.* 44, 1331–41. [9] T.L. Dunn et al. (2010) *Icarus 208, 789–97*.