Characterizing Volatiles and Organics on Asteroid (162173) Ryugu

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Outline

- Overview of Hayabusa2 mission and its target asteroid Ryugu
- Spectroscopic laboratory measurements under asteroid-like conditions of carbonaceous chondrites
- Recent ground-based observations of carbonaceous asteroids relevant to Ryugu
- Implications of meteorite spectroscopic measurements & asteroid observations for Hayabusa2's observations of Ryugu

Hayabusa2 Mission

- Ryugu characterization
- Sampling × 3 times
- Landing MASCOT
- Deploy an impactor
- Minervas

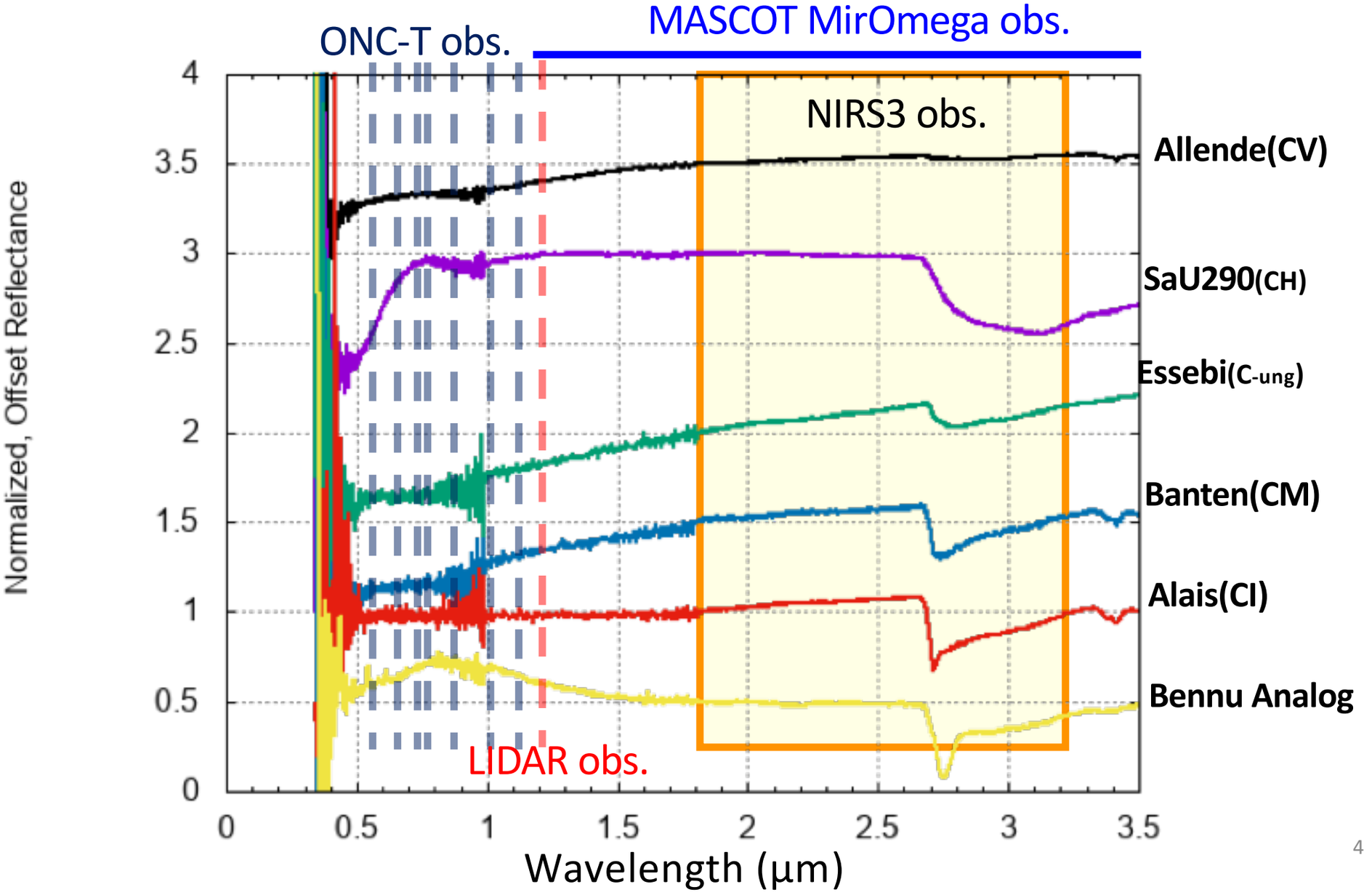
162173 Ryugu (1999JU$_3$)

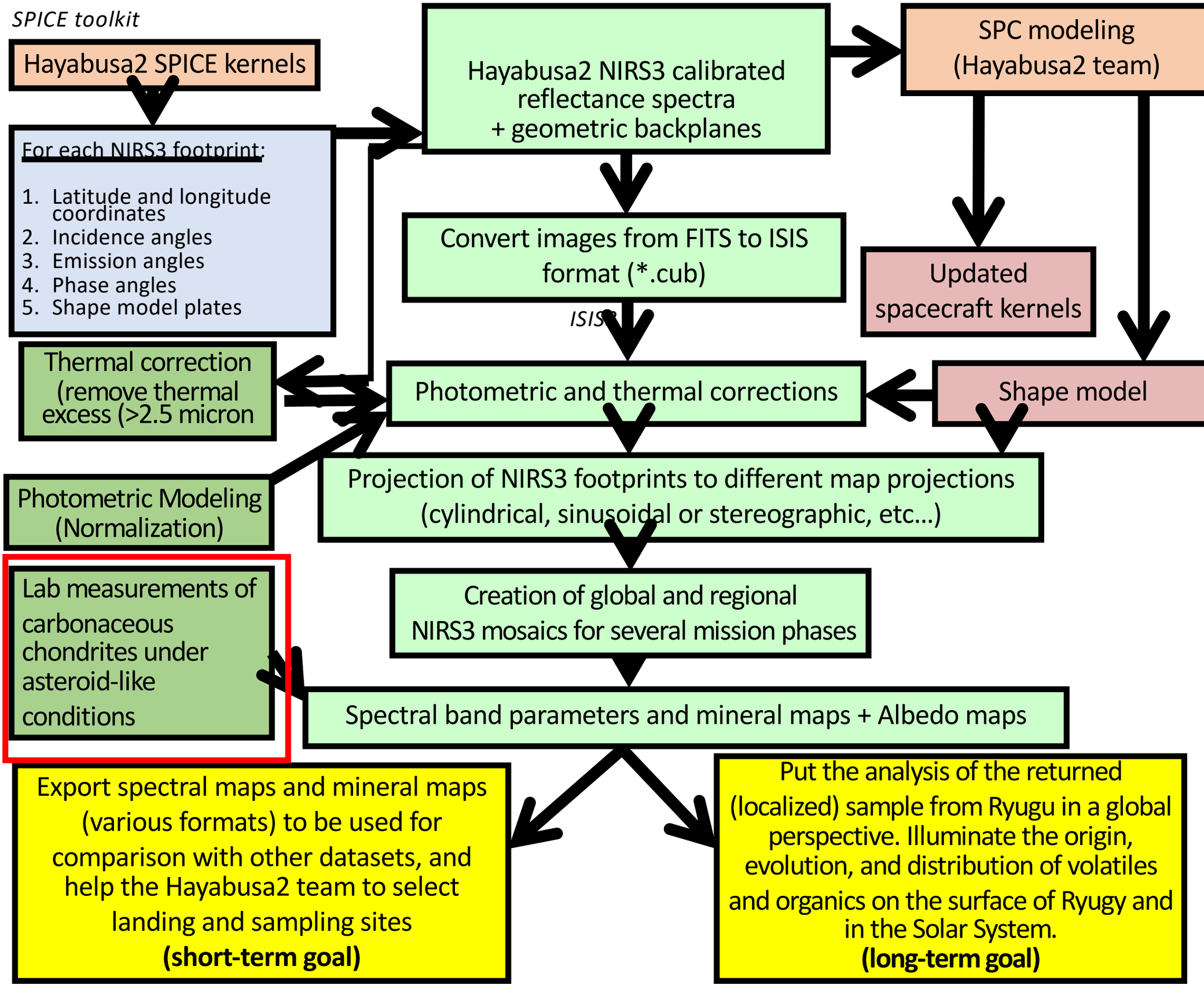
Rotation period	: 7 h 38 m
Shape	: almost spherical
Size	: 820 - 890 m
Geometric Albedo	: 0.05 – 0.06
Spectrum type	: Cg

Tsuda & Yoshikawa(SBAG)

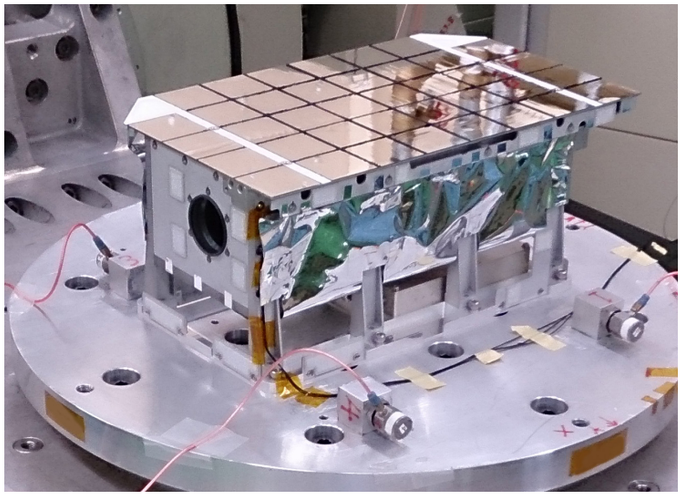
Relevance to Hayabusa2 Instruments

Reflectance Spectra of Carbonaceous Chondrites
normalized at 1.8 μm (measured under asteroid-like conditions)




SPICE toolkit
Hayabusa2 SPICE kernels
Hayabusa2 NIRS3 calibrated reflectance spectra + geometric backplanes
SPC modeling (Hayabusa2 team)
For each NIRS3 footprint:
1. Latitude and longitude coordinates
2. Incidence angles
3. Emission angles
4. Phase angles
5. Shape model plates
Convert images from FITS to ISIS format (*.cub)
ISIS3
Updated spacecraft kernels
Thermal correction (remove thermal excess (>2.5 micron
Photometric and thermal corrections
Shape model
Photometric Modeling (Normalization)
Projection of NIRS3 footprints to different map projections (cylindrical, sinusoidal or stereographic, etc…)
Lab measurements of carbonaceous chondrites under asteroid-like conditions
Creation of global and regional NIRS3 mosaics for several mission phases
Spectral band parameters and mineral maps + Albedo maps
Export spectral maps and mineral maps (various formats) to be used for comparison with other datasets, and help the Hayabusa2 team to select landing and sampling sites
(short-term goal)
Put the analysis of the returned (localized) sample from Ryugu in a global perspective. Illuminate the origin, evolution, and distribution of volatiles and organics on the surface of Ryugy and in the Solar System.
(long-term goal)

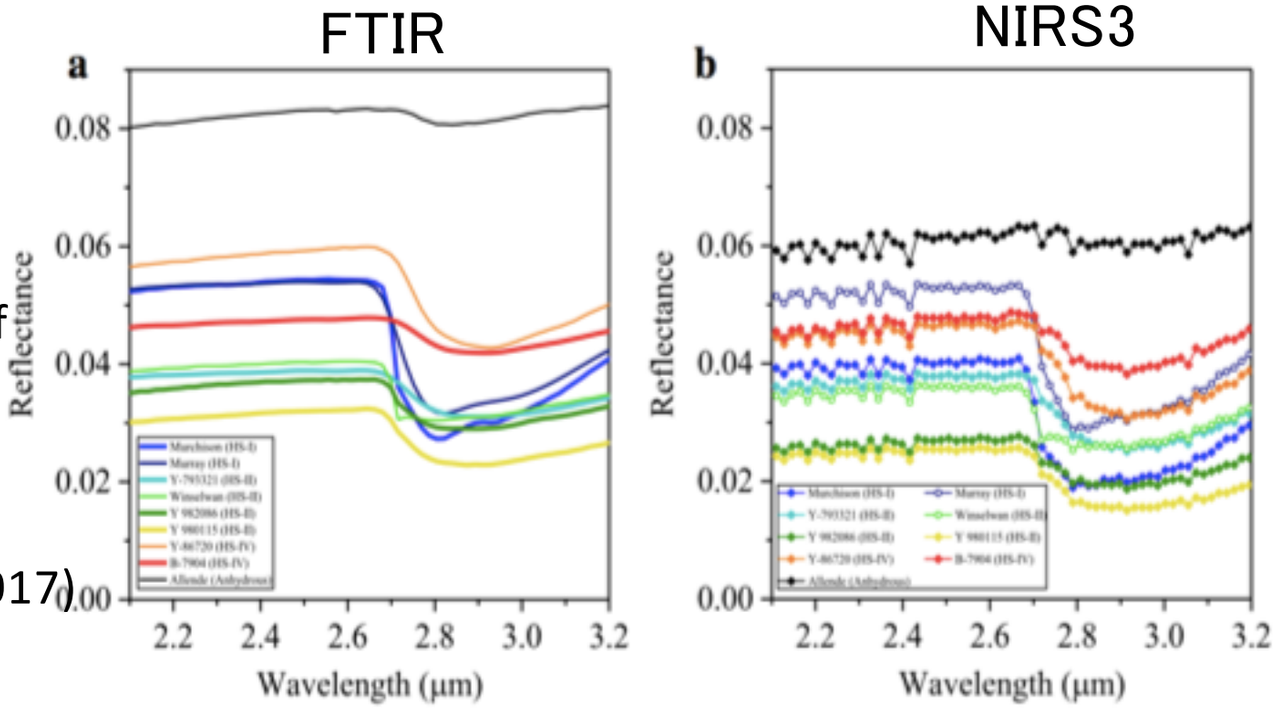
NIRS3 Instrument



Iwata et al. (2017)

Spectral range : 1.8μm – 3.2μm
Spectral sampling : 18 nm/pixel
Field of View (FOV) : 0.11° × 0.11°
Spatial resolution at one-shot :
40 m/spectrum at 20 km in altitude
Signal-to-noise ratio (SNR) at 2.6 μm :
> 300 at 20 km

We measured the reflectance spectra of carbonaceous chondrites using a flight model of NIRS3.



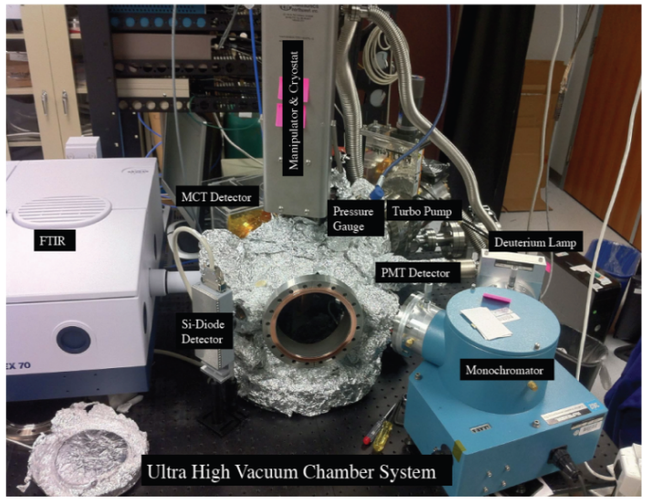
Matsuoka et al. (2017)

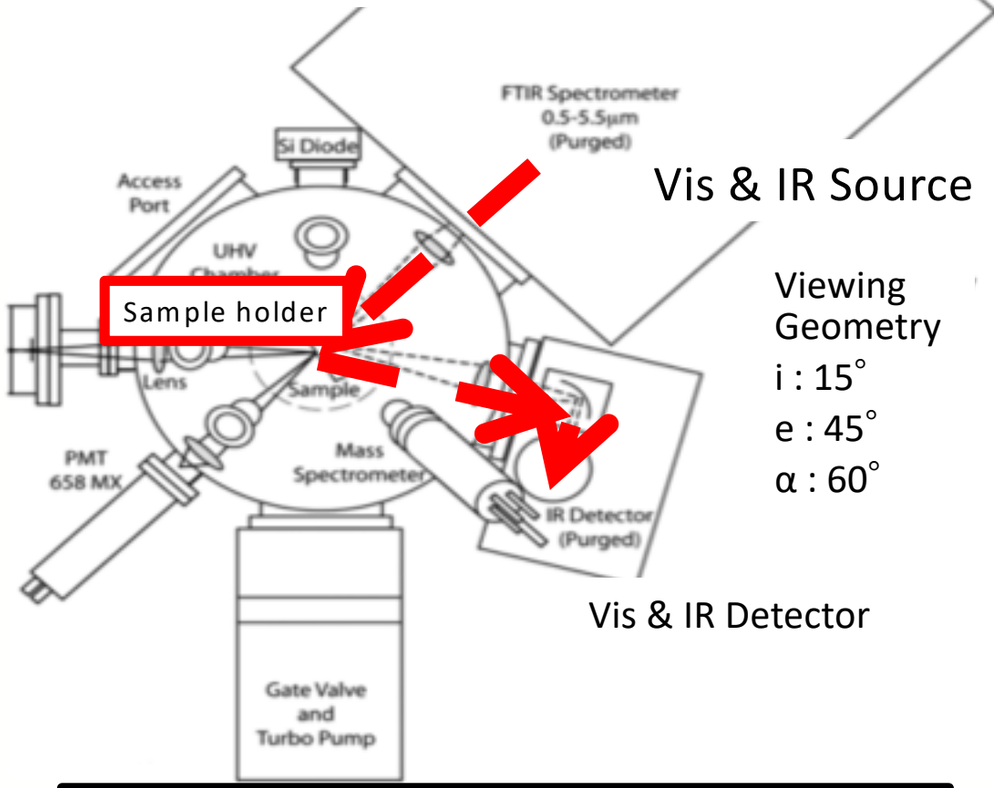
Lab Experiments @ JHU APL

Meteorite (number of samples)	
CV (1)	Allende
CO (1)	Felix
CR (1)	Al Rais, MIL 15328
CM (11)	Murray, Banten, Crescent, QUE97990, QUE99038, MIL00770, LAP03786, Cold Bokkeveld, MET00639, MAC02606, LAP02777
CI (2)	Alais, Ivuna
C-ung. (3)	Essebi, EET83226, Bells

Blue: New vacuum spectra

Red: Takir et al. (2013)



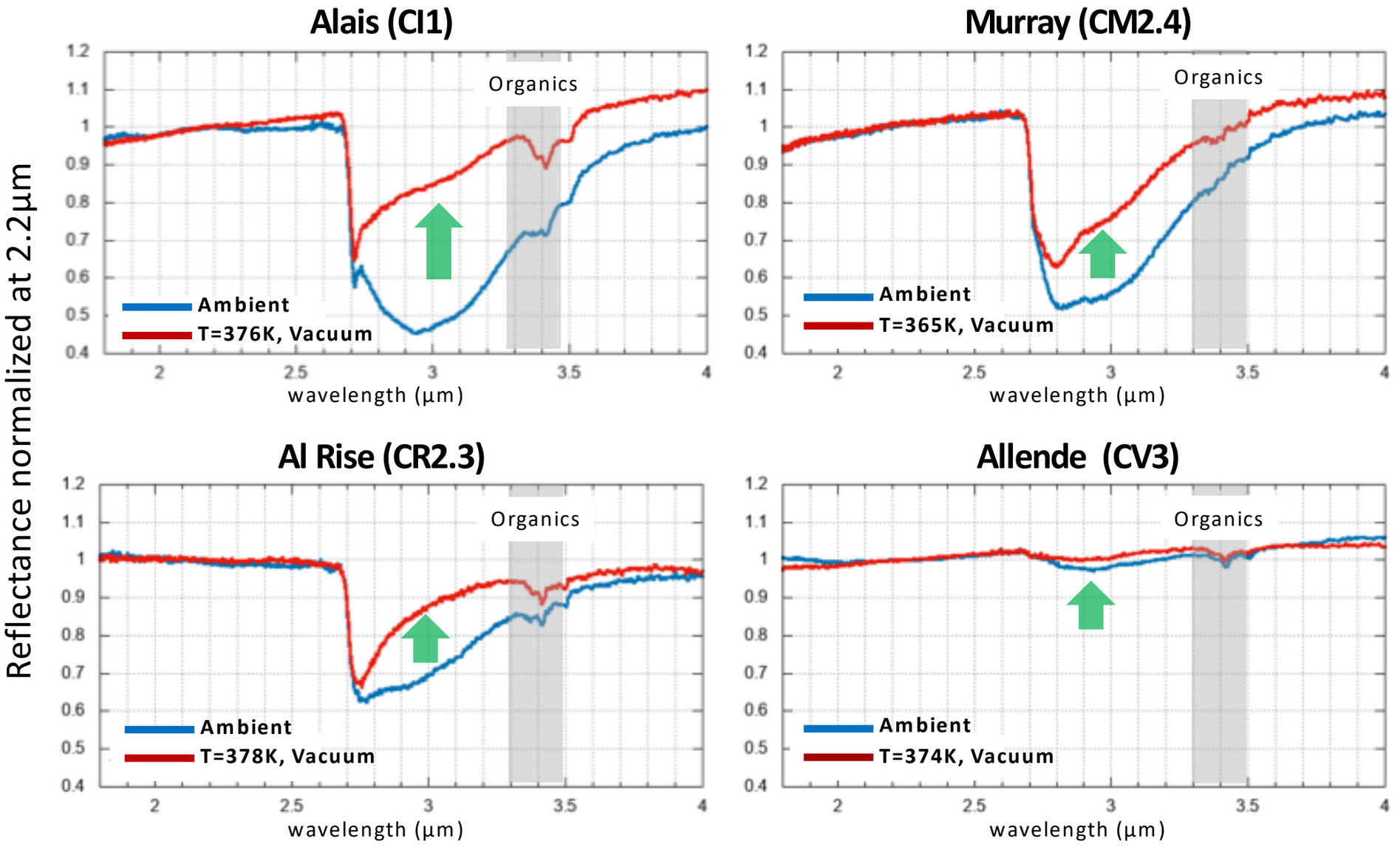


Sample Temperature : 150K ~ 475K

Chamber Pressure : ~10^{-6}-10^{-9} Torr

Spectral range: 0.5 - 8 μm

CIs have more Adsorptive Surfaces



- Average CO2 adsorption bands throughout the duration of the experiment while maintaining 150 K. Ivuna (CI) displays the greatest CO2 adsorption

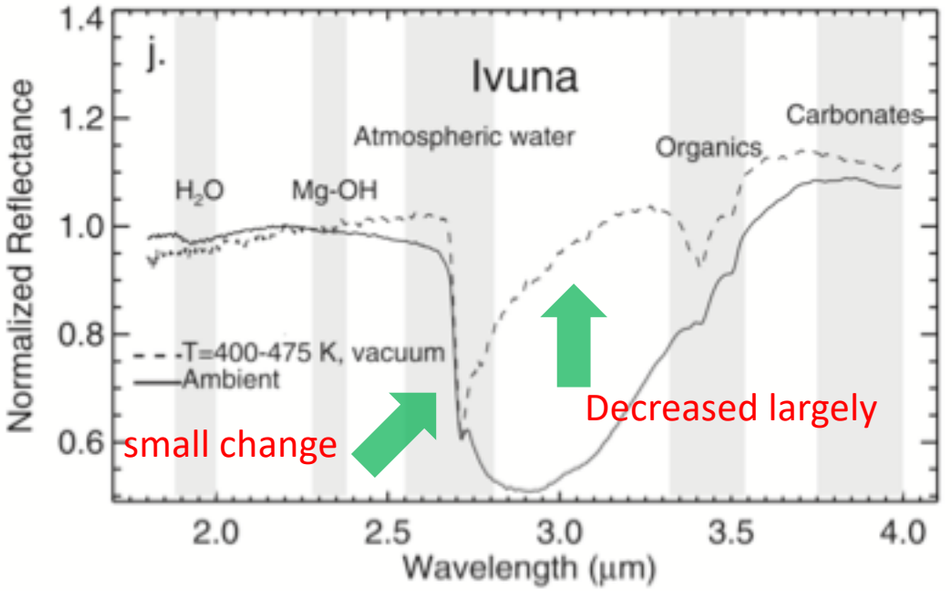
Reflectance spectra in Asteroid-like Condition

Takir et al.(2013)
The reflectance spectra of carbonaceous chondrites are affected by terrestrial water

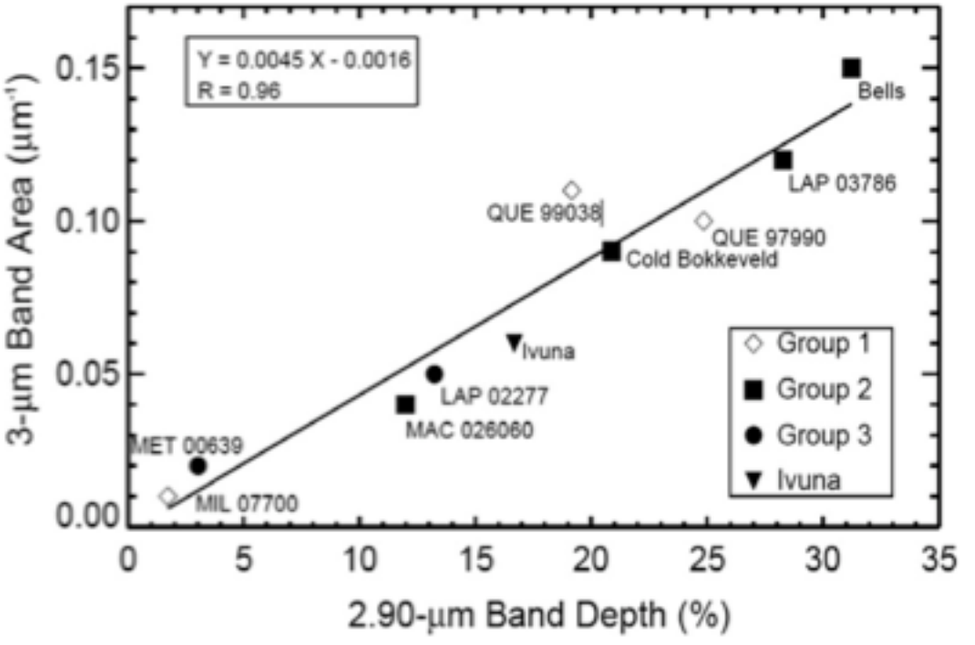
[Measurement condition]

Temperature: 400 – 475K

Pressure : 10^{-5} - 10^{-6} Torr

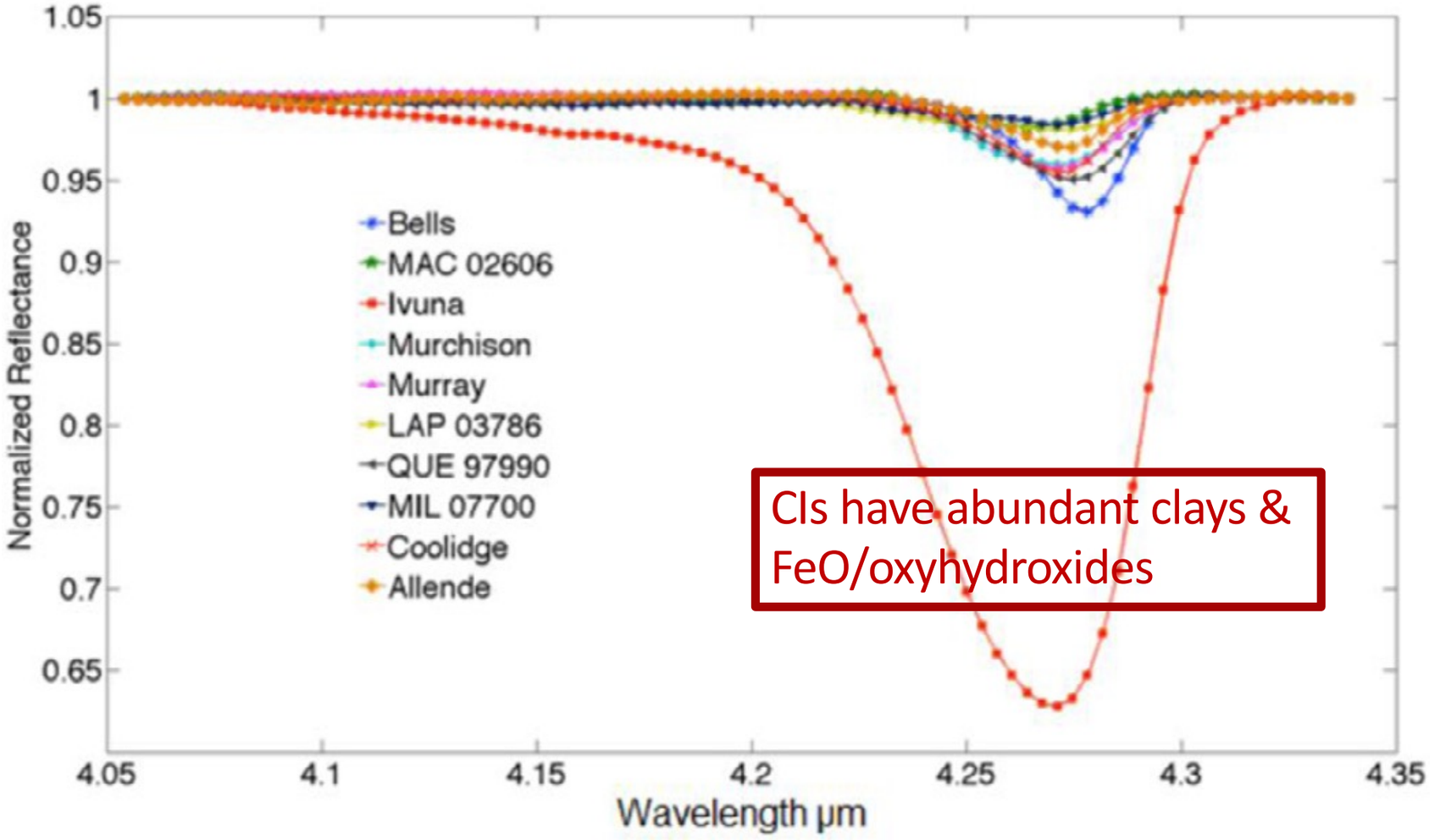


Takir et al. (2015)
There is a linear correlation between 2.9μm band depth and 3μm band area (Samples : CI and CMs)



CO_2 Gas Adsorption Experiments

CO_2 gas adsorption experiments on carbonaceous chondrites:



Berlanga et al. (2016), Icarus

Average CO2 adsorption bands throughout the duration of the experiment while maintaining 150 K. Ivuna (CI) displays the greatest CO2 adsorption

Spectral Analysis

Takir et al. (2015)

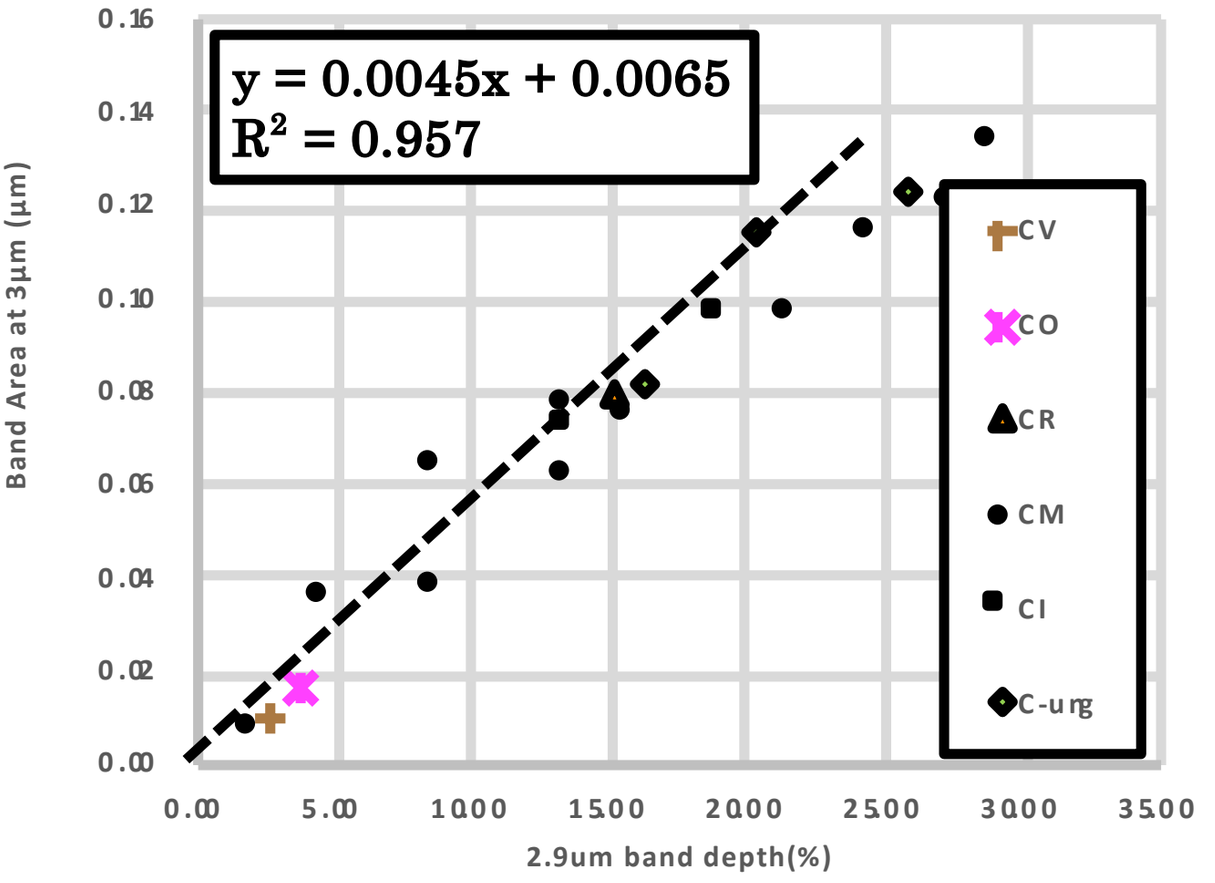
Band depth

$$BD(\lambda) = 1 - \frac{R(\lambda)}{R_C(\lambda)}$$

Band area

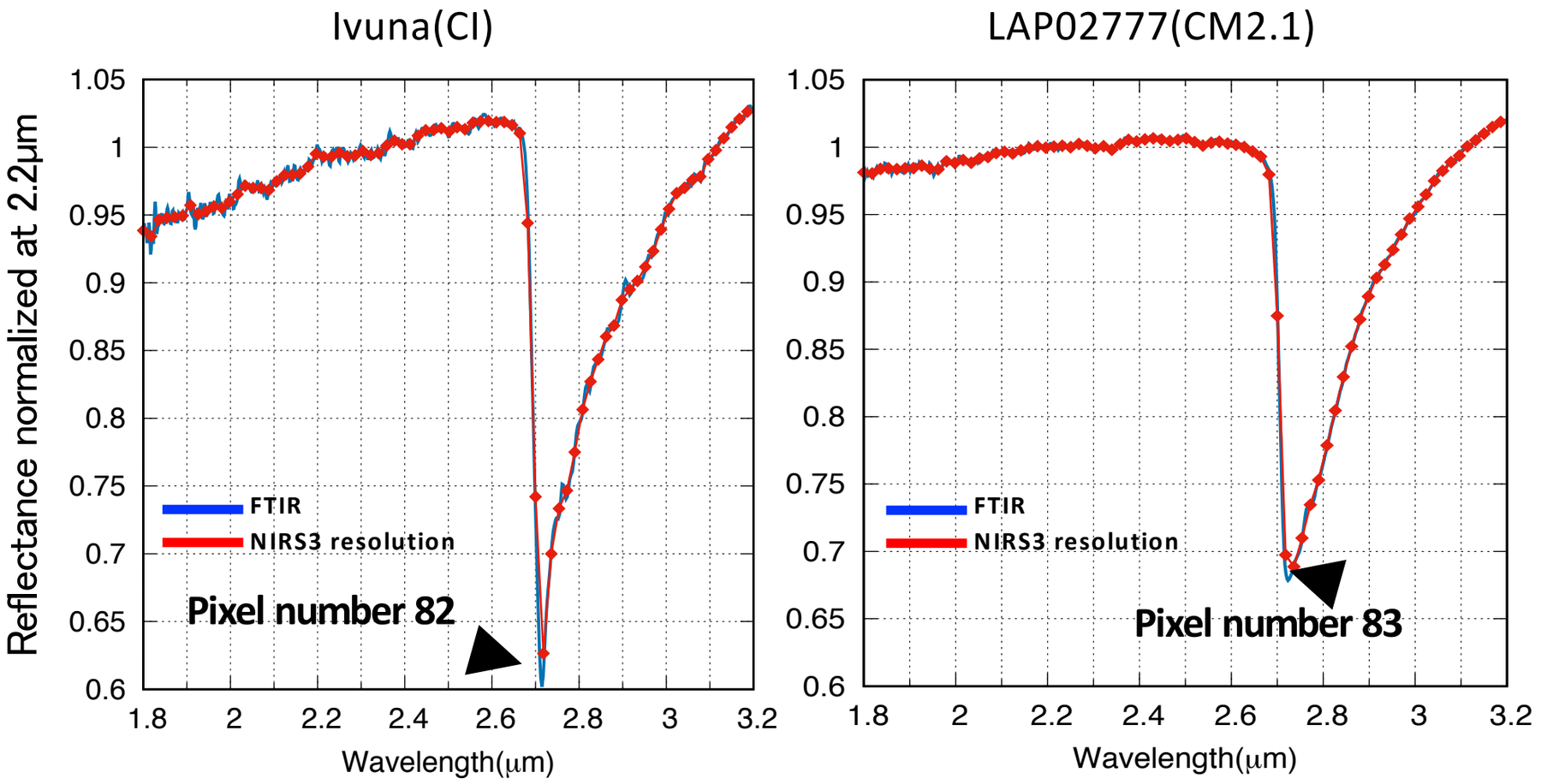
$$BA = \oint \frac{R(\lambda)}{R_C(\lambda)} d\lambda$$

Rc is linear continuum.



There is a good correlation between the new results and the results of Takir et al. (2015), however, meteorite types could not be separated.

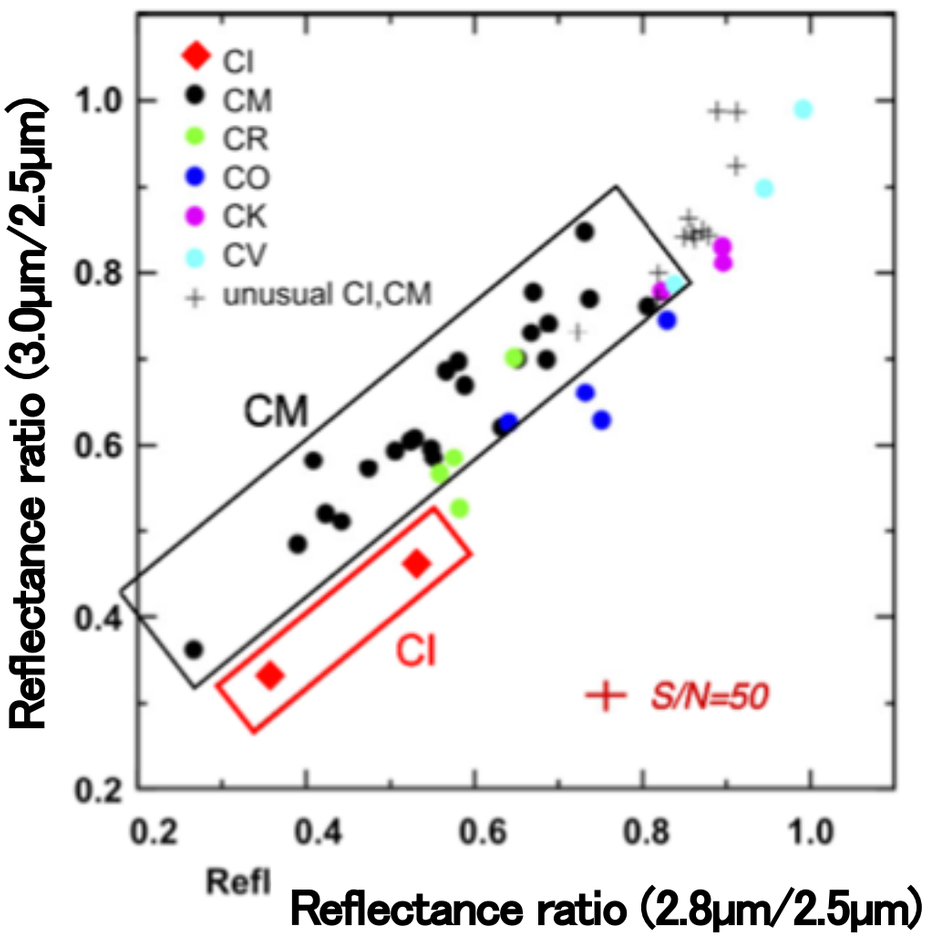
Resampled Spectra (NIRS3 Resolution)



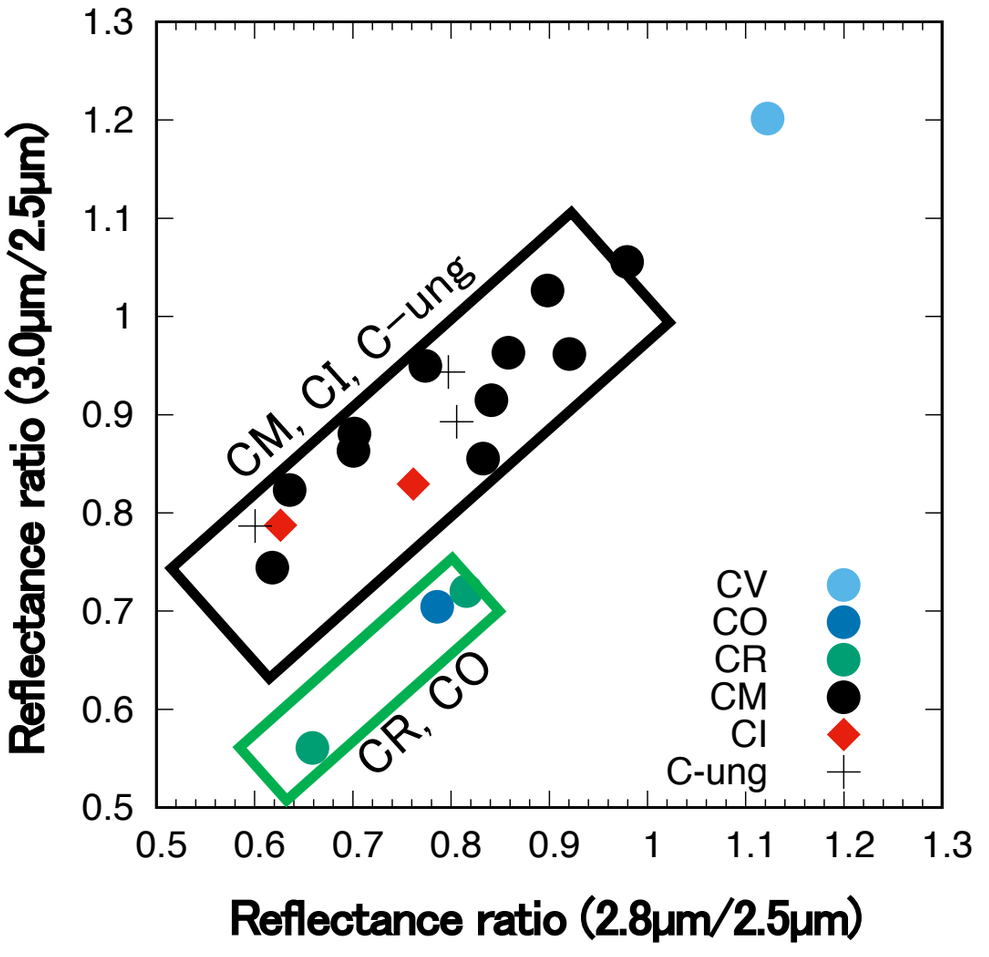
Reflectance spectra was changed by resampling. In particular, **the 3μm absorption center was shifted**.

Meteorite Type Spectral Separation

Iwata et al. (2017) using RELAB data



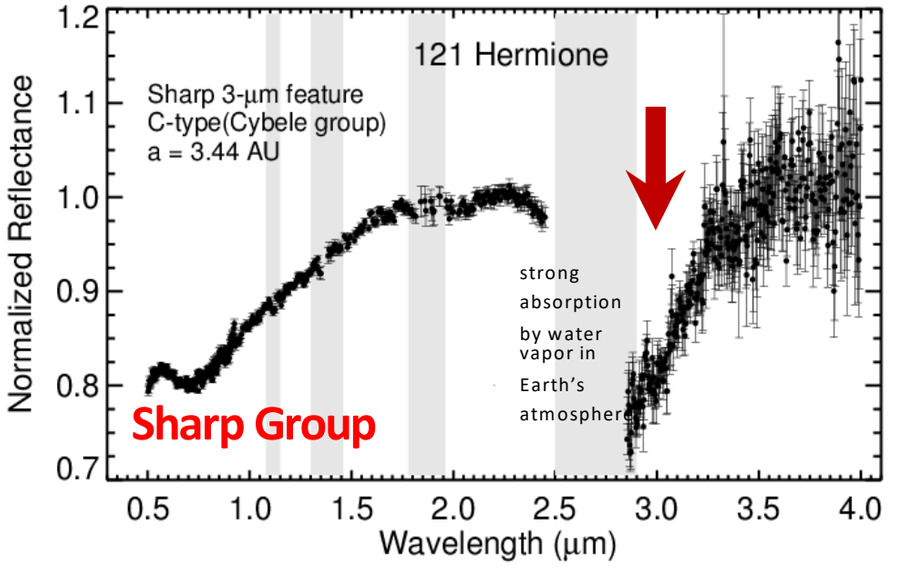
New plot using data of this study

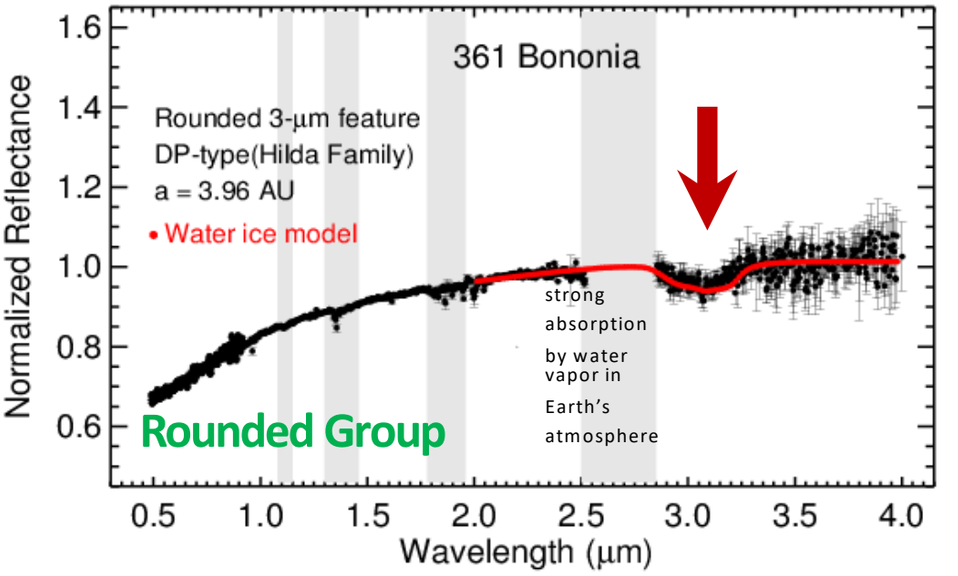


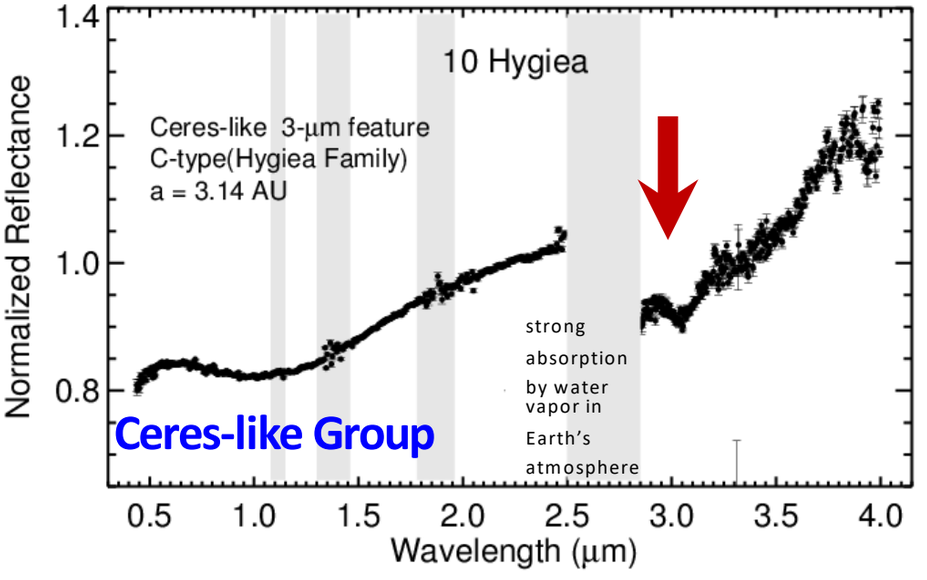
Scatterplots of reflectance ratio at 2.5μm, 2.8μm and 3.0μm. The black diagonal quadrangle cover the area of CM, CI, and C-ung chondrites. The green diagonal quadrangle covers the area of CR and CO chondrites.

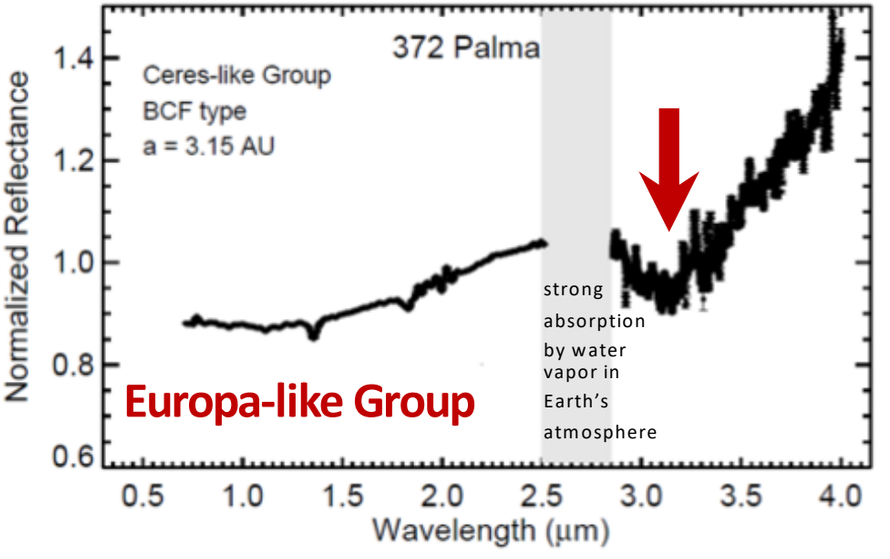
Spectral Survey of Carbonaceous Asteroids

- Identification and distribution of four 3-µm spectral groups in primitive asteroids (Takir & Emery 2012; Takir et al. 2018):

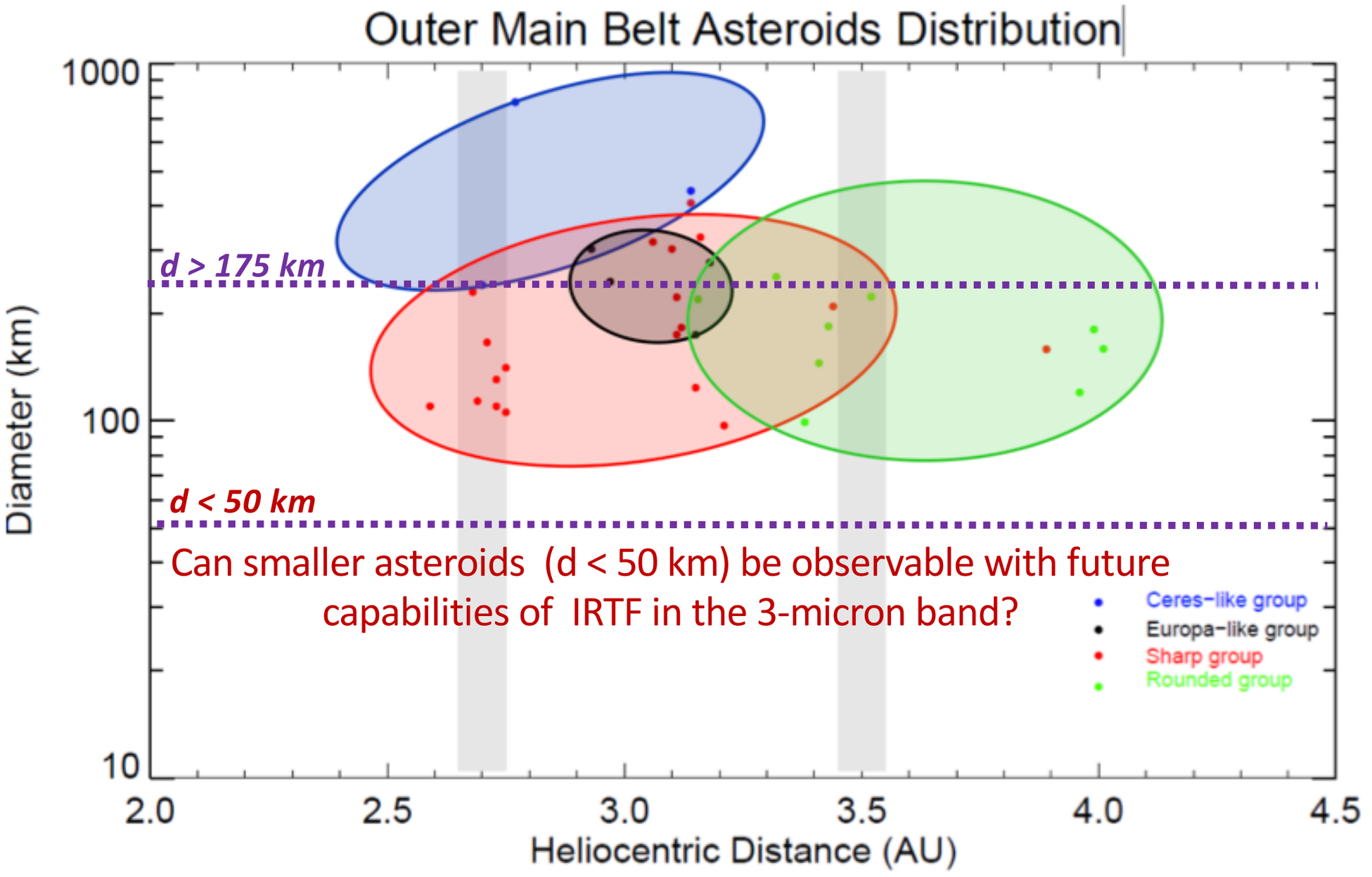








Orbital Distribution of Carbonaceous Asteroids



(Takir et al. 2018,Elsiever book chapter)

Summary

- New CIs, CMs, COs, CRs, CVs and C-ungrouped were measured under vacuum and while heated to minimize adsorbed water. The shape of the absorption band around 3 µm changed under vacuum and elevated temperatures in all carbonaceous chondrites.
- Using these spectra, we found a good correlation between the 3-µm band area and the 2.9-µm band depth. Although these parameters maybe used to estimate water abundance in primitive asteroids, the meteorite types cannot be separated. On the other hand, the scatterplots of new reflectance ratio at 2.5 µm, 2.8 µm and 3.0 µm can be used to separate primitive carbonaceous chondrites and other meteorites.