

# AKARI Near-Infrared Asteroid Spectroscopic Survey



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# Existence of “water” in the solar system

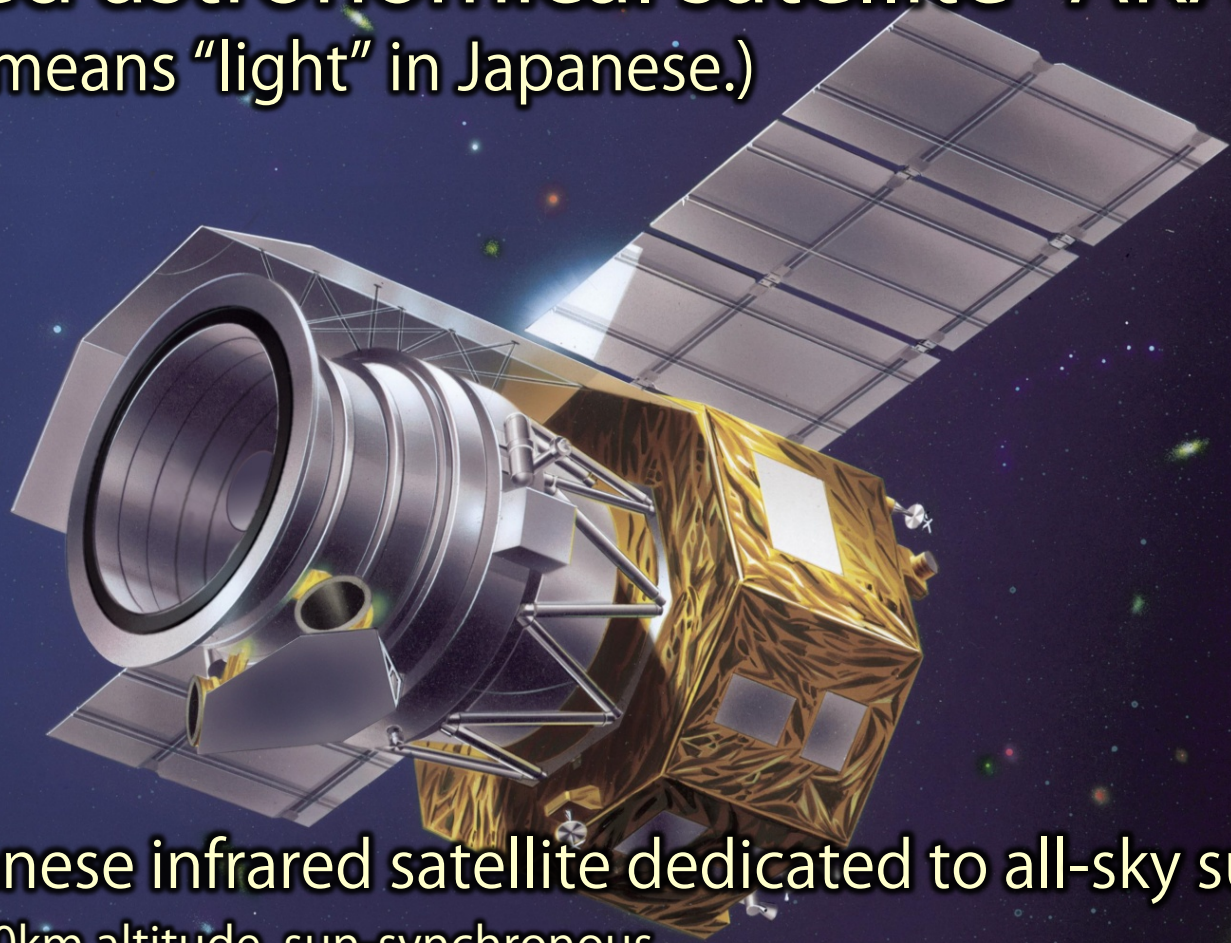
- Existence of “water” on asteroids
  - (1) Ceres : hydrated minerals (Rivkin+ 2002)、 water vapor (Küppers+2014)、 etc
  - (4) Vesta : hydrated minerals (Hasegawa+2003, Rivkin+2006, Russel+2015)
  - (24) Themis, (65) Cybele : water ice (Campins+ 2010; Rivkin+ 2010; Licandro+ 2011)
- Hydrated minerals :
  - Any minerals containing OH or H<sub>2</sub>O, which are formed in environments where **anhydrous rock** and **liquid water** are together (aqueous alteration).
  - They are found within chondrite matrix of meteorites.
  - Hydrated minerals are stable above the sublimation temperature of water ice.
  - Knowledge of the hydrated mineral is important for deducing the origin of Earth's water, and unraveling the processes in the earliest times of the solar system.
  - Diagnostic absorption features in 3 μm band (e.g., Takir & Emery 2012, Takir+2015, Rivkin+2015, etc, etc, …)
    - ✓ Hydroxyl associated with hydrated mineral (2.7--2.8 μm)
    - ✓ H<sub>2</sub>O ice (3.07 μm), etc

Infrared observations with ground-based telescopes are limited by atmospheric absorption. → Need to send telescopes into space!

# Infrared astronomical satellite "AKARI"

(AKARI means "light" in Japanese.)

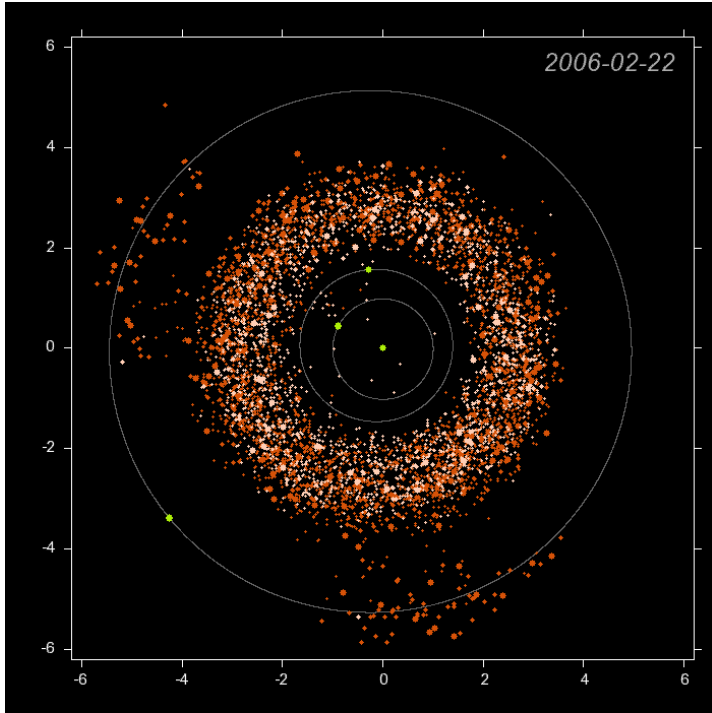
(c) JAXA



The first Japanese infrared satellite dedicated to all-sky survey

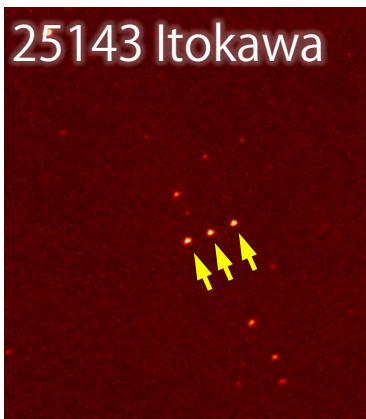
- Orbit : 700km altitude, sun-synchronous
- Size : 5.5 x 1.9 x 3.7 m (in orbit) / Mass : 952kg (at launch)
- Telescope : Ritchey-Chretien, 68.5cm SiC (f/6)
- Launched : 2006/02/22 06:28 JST (JAXA M-V-8 rocket)
- Terminated : 2011/11/24 17:23 JST

# Asteroid observations with AKARI

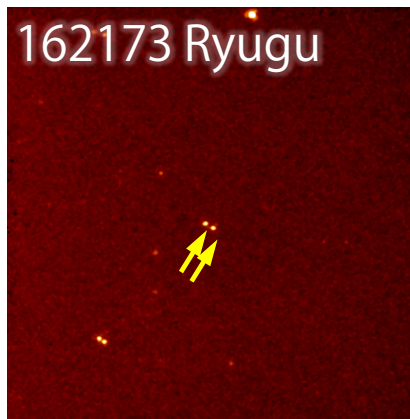


Distribution of AcuA asteroids

- All-sky survey data (9, 18  $\mu\text{m}$ )
  - Size and albedo catalog of 5120 asteroids: Asteroid catalog using AKARI (AcuA) (Usui+2011, 2013)
  - Larger asteroids are fully covered. (H < 9, >40 km in main belt; Usui+2014)
- Pointed observations (7-24  $\mu\text{m}$ )
  - Studying mission target asteroids (Hasegawa+2008, Müller+2014, 2017, etc)
  - Serendipitous survey (Hasegawa+2013, Deyama+ in prep.)



25143 Itokawa



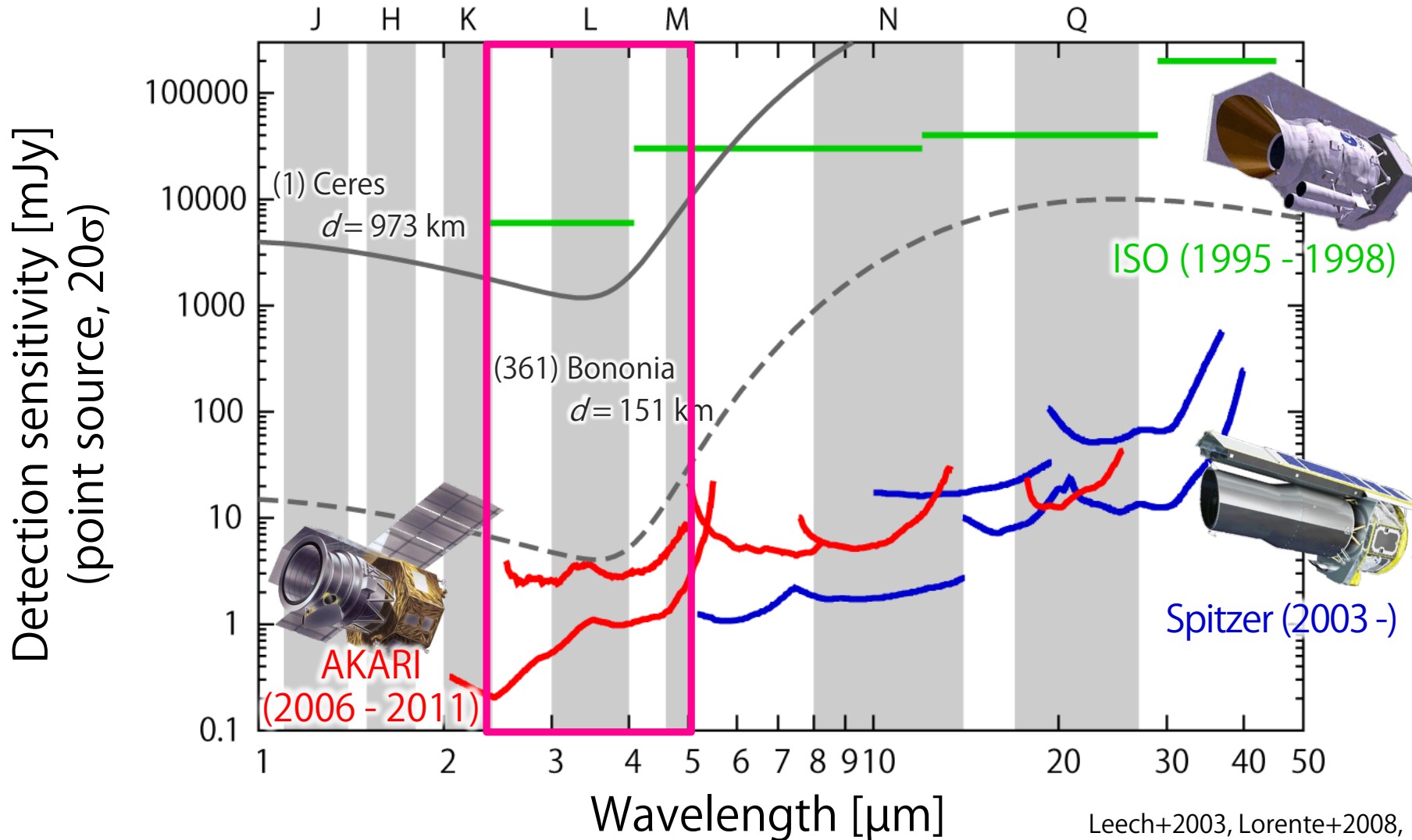
162173 Ryugu

Pointed observation data

- Archived photometric data of observed asteroids
  - Available at JAXA website: <http://www.ir.isas.jaxa.jp/AKARI/Archive/>
  - Alí-Lagoa+2018
  - Szakáts+ talk (this morning)

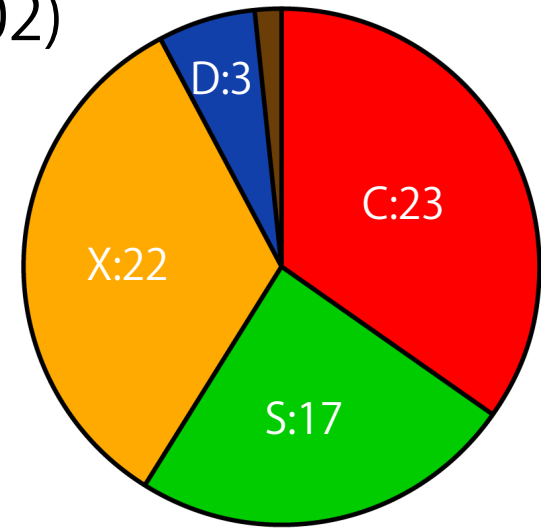
# AKARI/IRC spectroscopic observations

- AKARI provides valuable spectroscopic data because of its high sensitivity and unique wavelength coverage (2.5--5  $\mu\text{m}$ ).



# Near-infrared spectroscopy for asteroids with AKARI

- Spectroscopic observations at wavelengths from 2.5 to 5  $\mu\text{m}$ .
  - Spectral resolution :  $R=120@3.6 \mu\text{m}$
- Warm mission phase data (2008/05 - 2010/02)
- One pointed observation:  $\sim 10$  min.
  - Effective exposure time: 350-400 sec
- Targets : 66 asteroids
  - Main-belt to Hildas ( $d > 40$  km)
  - Classification : Bus-DeMeo taxonomy (compiled by Hasegawa+2017)

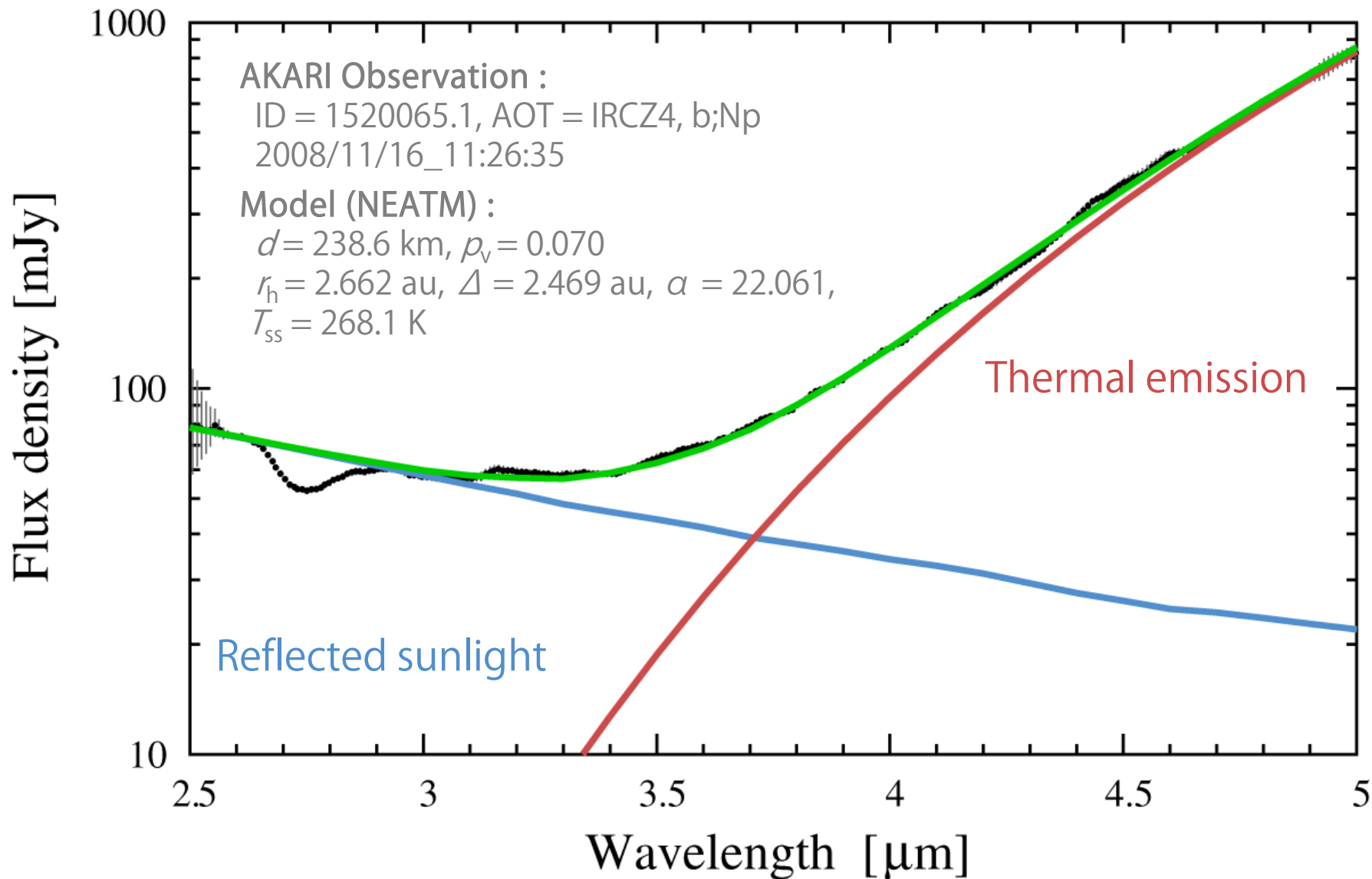


Taxonomy of observed asteroids

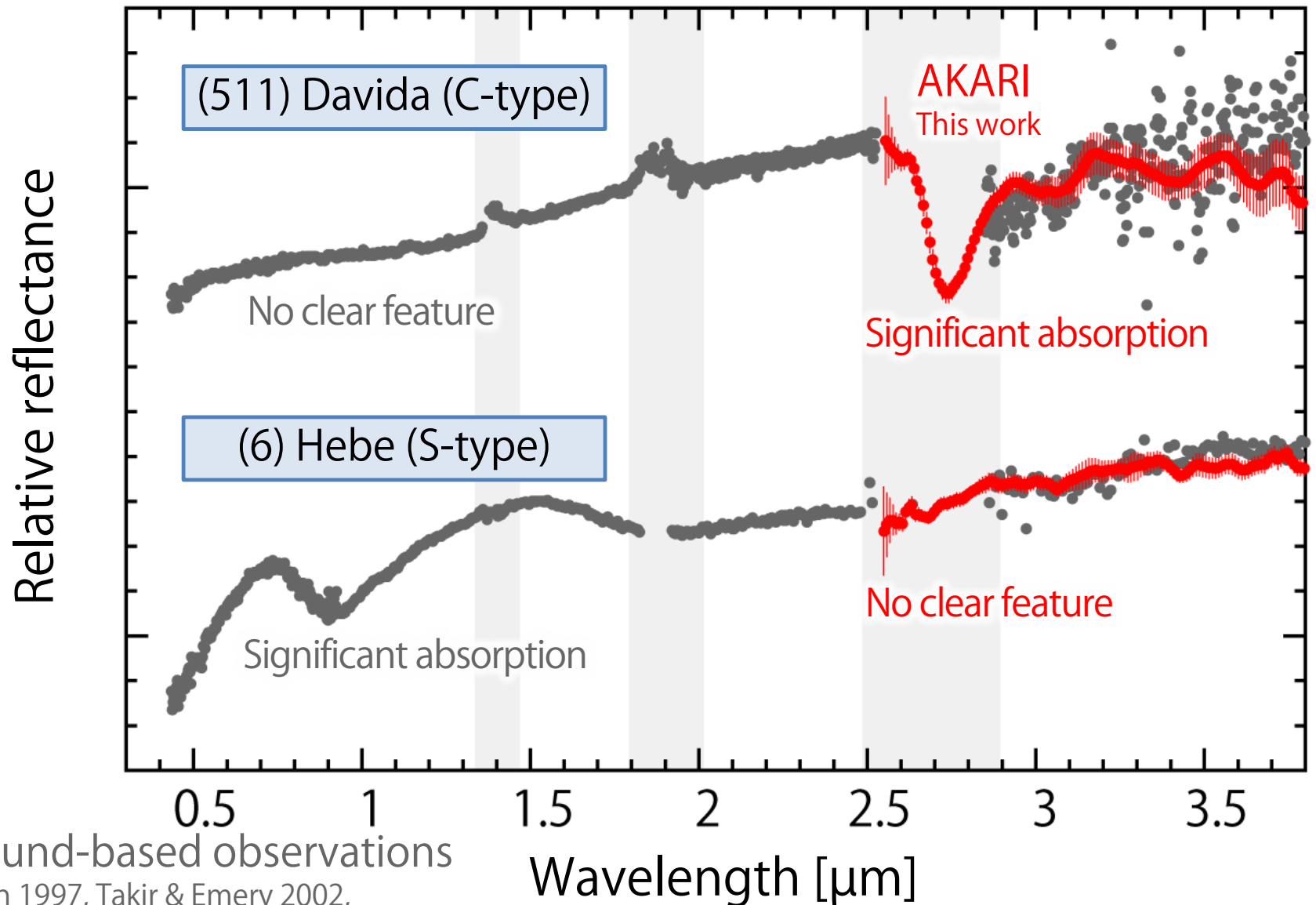
- Data reduction
  - IRC Spectroscopy Toolkit for Phase 3 Version 20170225RC (IDL-based package)
  - Frame shift-and-add for moving objects (Ootsubo+2012)
  - Object positions : obtained from JPL/Horizons
  - Computed solar spectrum : corrected Kurucz model (Berk+1999)

# Example of data reduction : (511) Davida

## Near-infrared spectrum



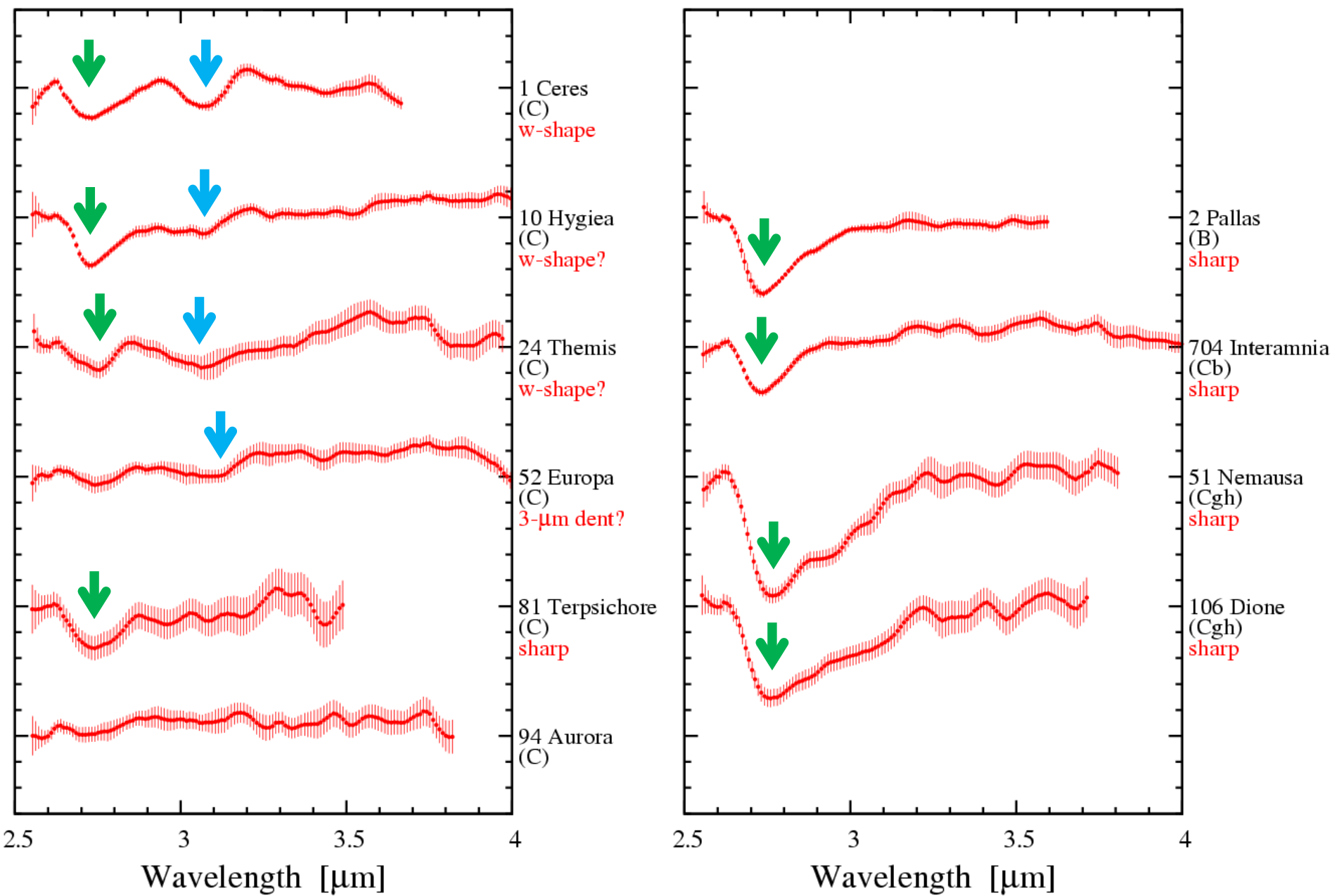
# Reflectance spectra of asteroids (vis - near IR)



Ground-based observations  
Rivkin 1997, Takir & Emery 2002,  
Bus & Binzel 2002, Vernazza et al. 2014

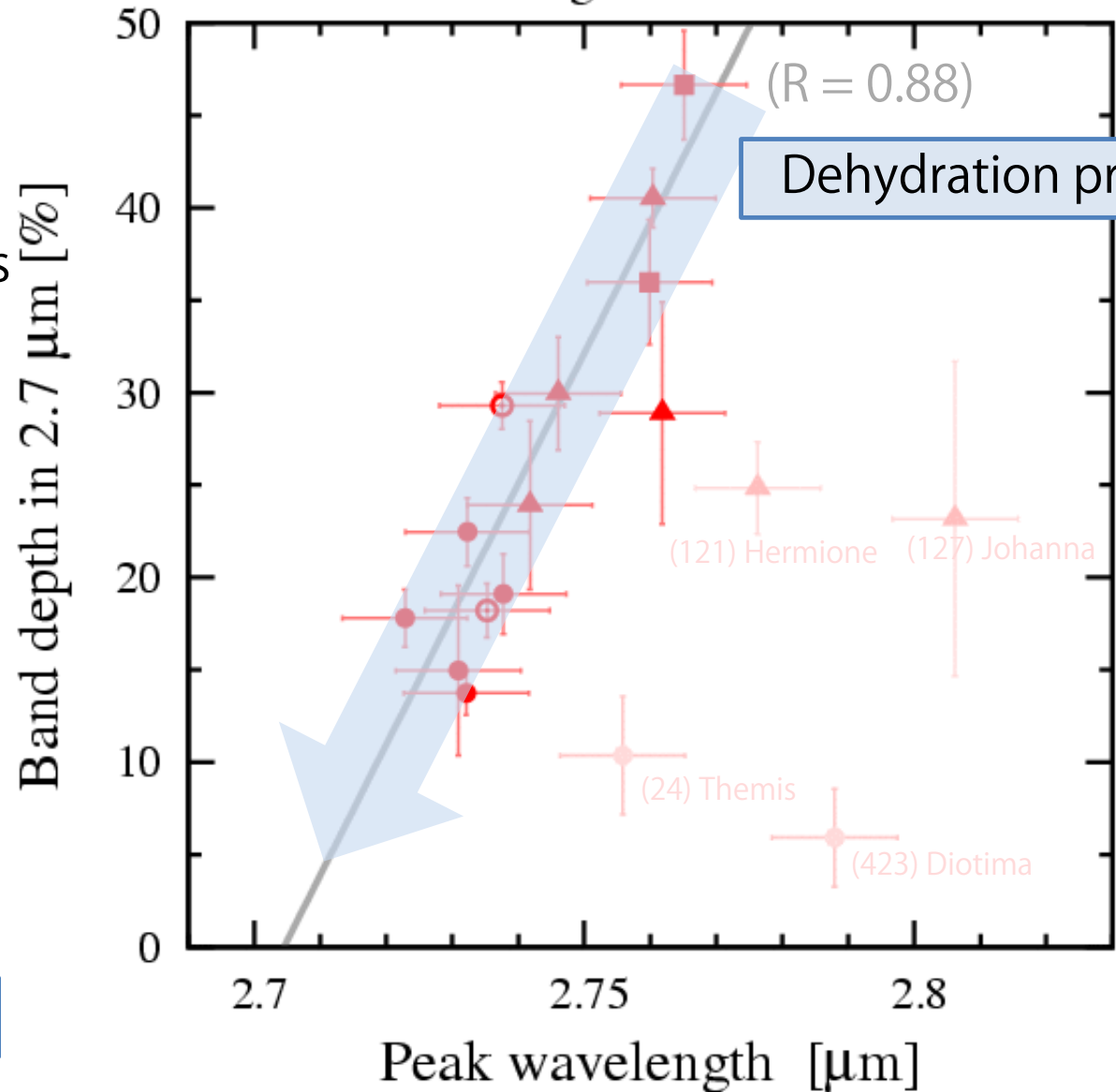


# Near-infrared spectra of C-complex asteroids



# Band depth at 2.7 $\mu\text{m}$ vs peak wavelength (C-complex)

▲ Ch    ■ Cgh    ○ B/Cb    ● C



Laboratory experiments  
(Yamashita+ in prep)

Heating experiments  
of meteorites



Abundance of  
phyllosilicate  
decreases



Mg/Fe ratio increases

# Summary

## Near-infrared Asteroid Spectroscopic Survey with AKARI

Usui, F., et al. 2019, PASJ, 71, 1

- Spectroscopic observations for 66 asteroids (total 147 times) with IRC/NIR in the warm mission phase of AKARI
  - Wavelength coverage : 2.5--5  $\mu\text{m}$ , spectral resolution :  $R \sim 100$
  - Time variation of the spectra is not examined at present.  
(two or three spectra are averaged for each object)
- From the reduced spectra (in 2.5-3.5  $\mu\text{m}$  range),
  - Most C-complex (17/22) have clear absorption feature at around 2.75  $\mu\text{m}$ .  
(which is associated with hydrated minerals).
  - Correlation between peak wavelength and band depth of 2.7  $\mu\text{m}$  feature can be understood as dehydration process of C-complex asteroids.
  - Combination of the absorption features at 0.7  $\mu\text{m}$  and 2.7  $\mu\text{m}$  can be diagnostic of aqueous alteration / dehydration history of C-complex asteroids.



Usui et al. 2019, PASJ, 71, 1

<https://doi.org/10.1093/pasj/psy125>

<http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=J/PASJ/71/1>



*Publ. Astron. Soc. Japan* (2019) 71 (1), 1 (1–41)

doi: 10.1093/pasj/psy125

Advance Access Publication Date: 2018 December 17



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## AKARI/IRC near-infrared asteroid spectroscopic survey: AcuA-spec

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Received 2018 August 2; Accepted 2018 October 9

### Abstract

Knowledge of water in the solar system is important for the understanding of a wide