6th UC Irvine Center for Cosmology Workshop:
The View From 5AU, March 25-26th, 2010

JAXA Instrument Concept

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Collaborators for CIB science :
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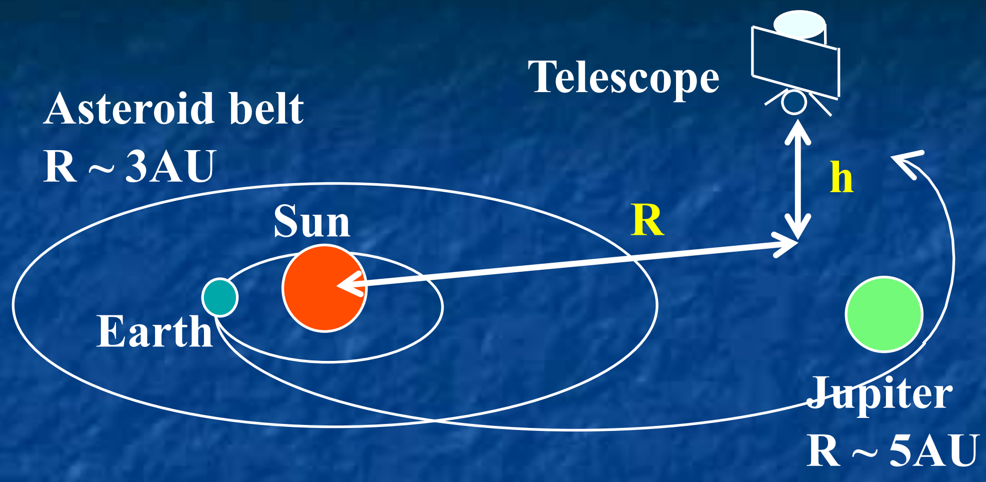
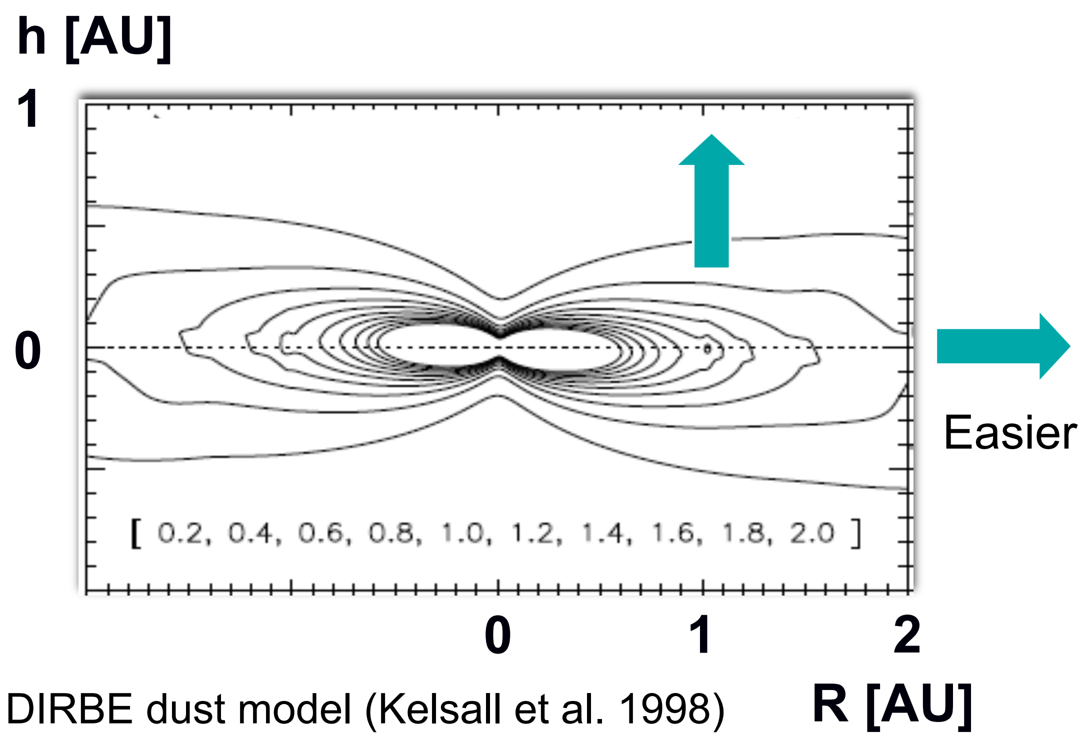
M. Kawada (Nagoya U.), S. Oyabu (SUBARU / UH),
J. Bock (JPL / Caltech)
and
Solar Sail Working Group, JAXA

Out of zodiacal cloud mission

- Two cases of zodi-free mission
  - Out-of-ecliptic orbit
  - In-ecliptic orbit but beyond the main asteroid belt (5AU mission)
- Both can be solution for accurate CIB measurement

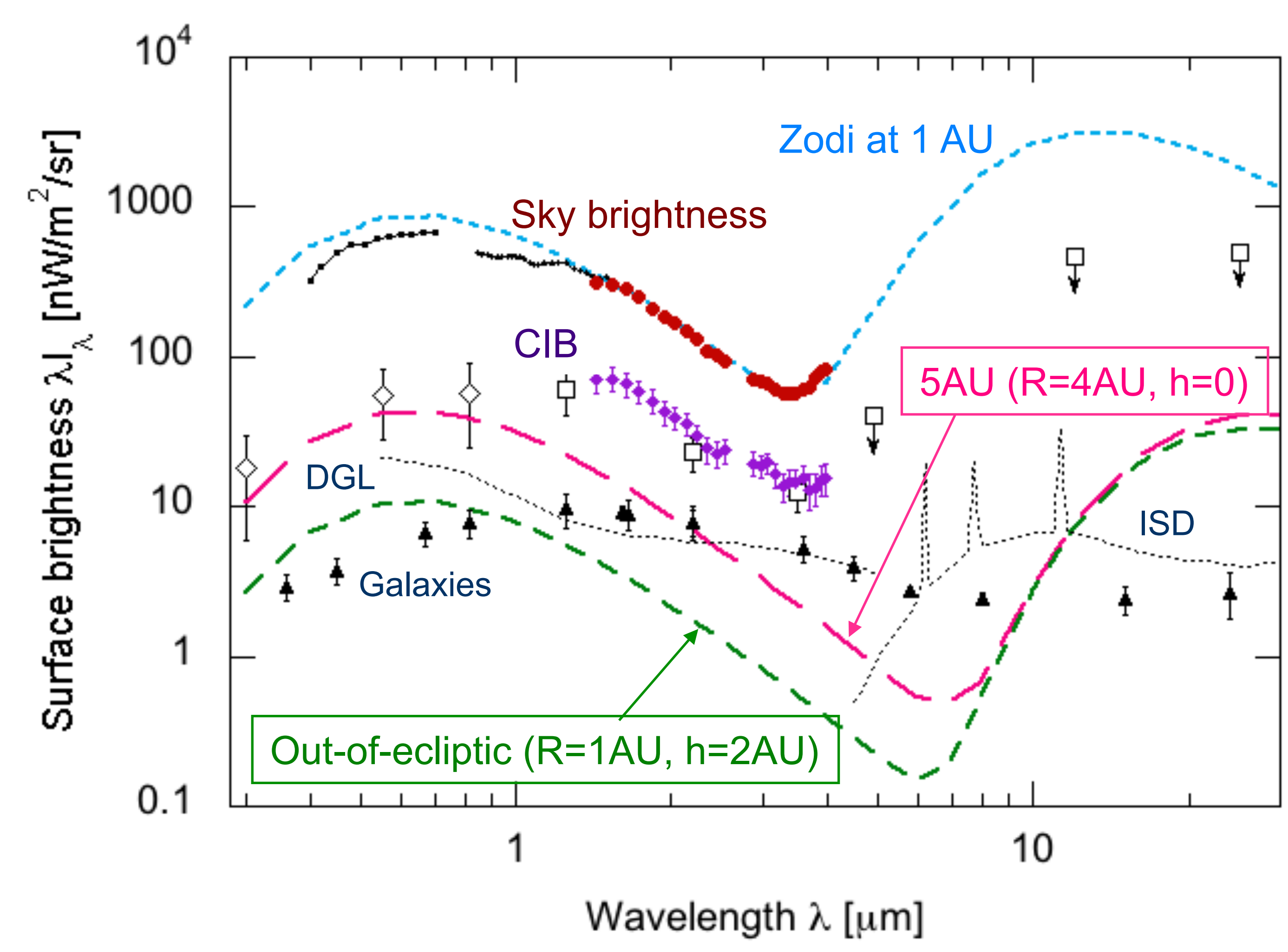




DIRBE dust model (Kelsall et al. 1998)

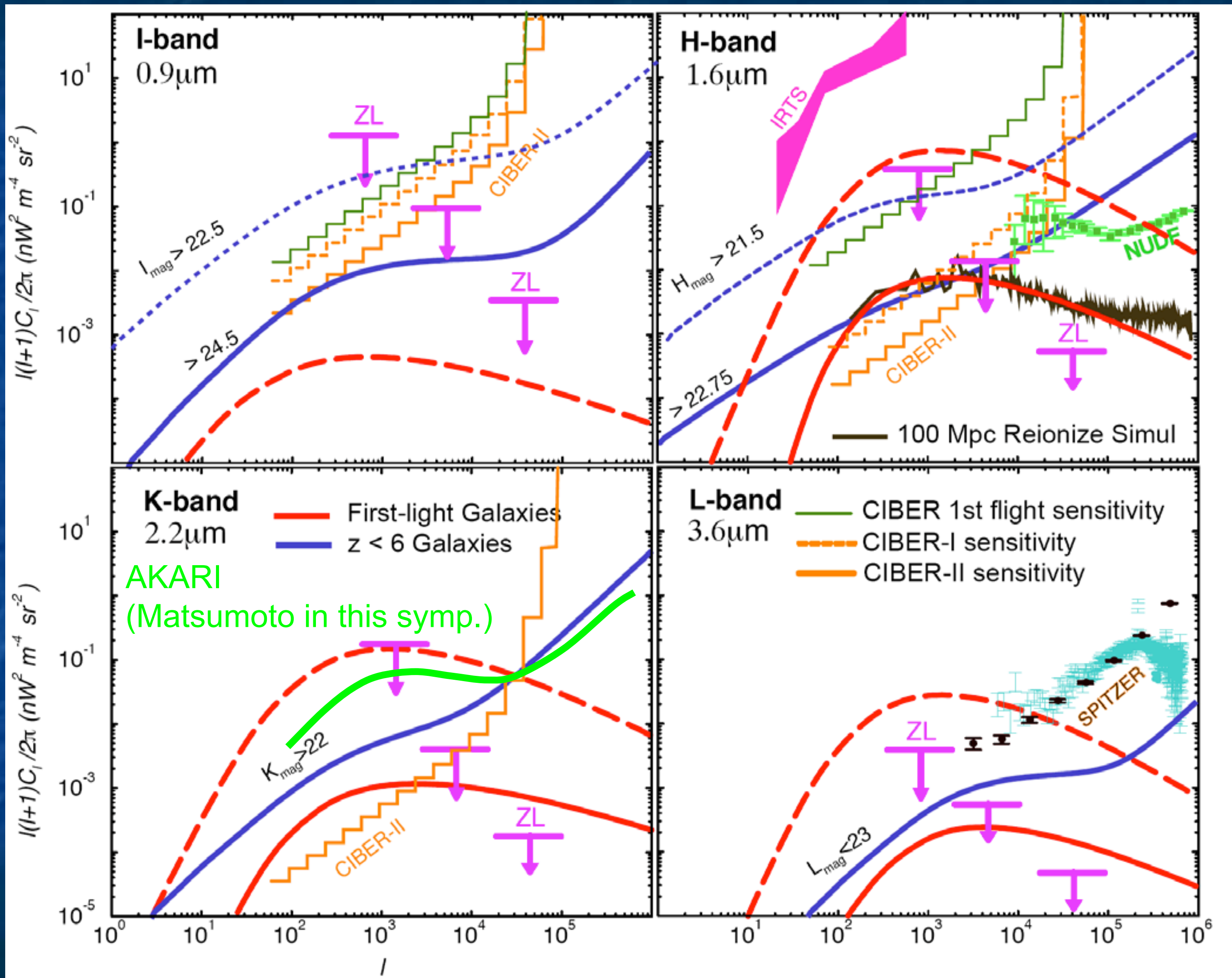
5AU site is not perfect for CIB measurement

- ZL in Optical-NIR remains at non-negligible level
- “Cosmological window” shifts from 3 um to > 6 um



Foreground subtraction (ZL, DGL, Gals) is still required. > How ?

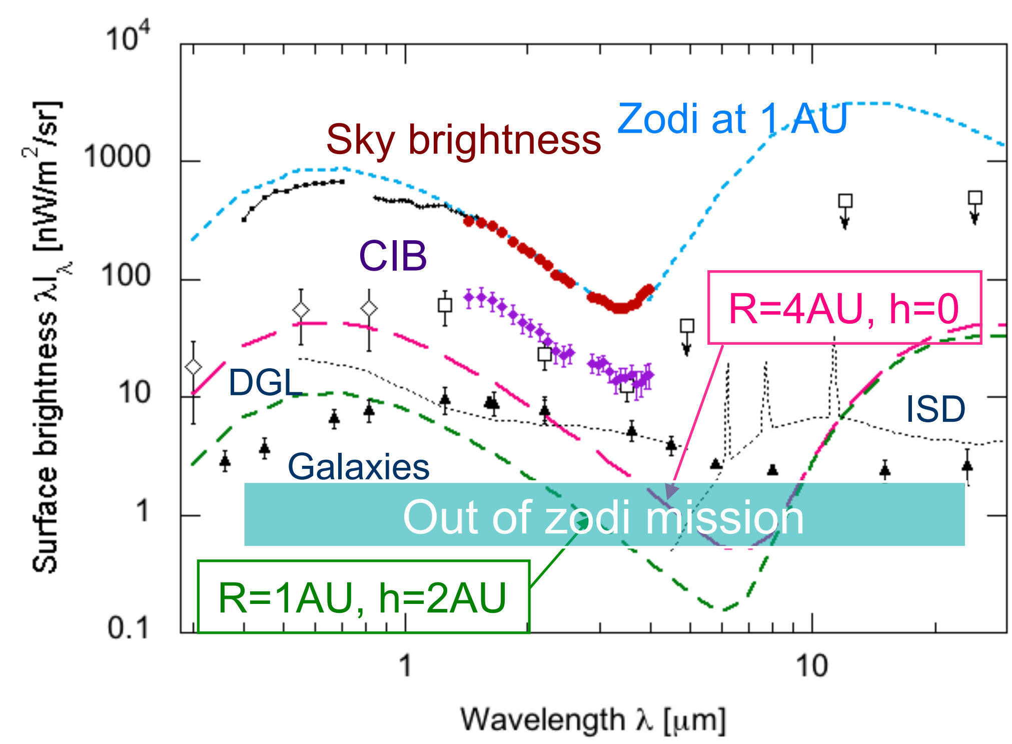
How to remove the residual foreground?
Fluctuation measurement : not so far from our goal



CIBER / CIBER-II (Bock et al.) would give a firm result.

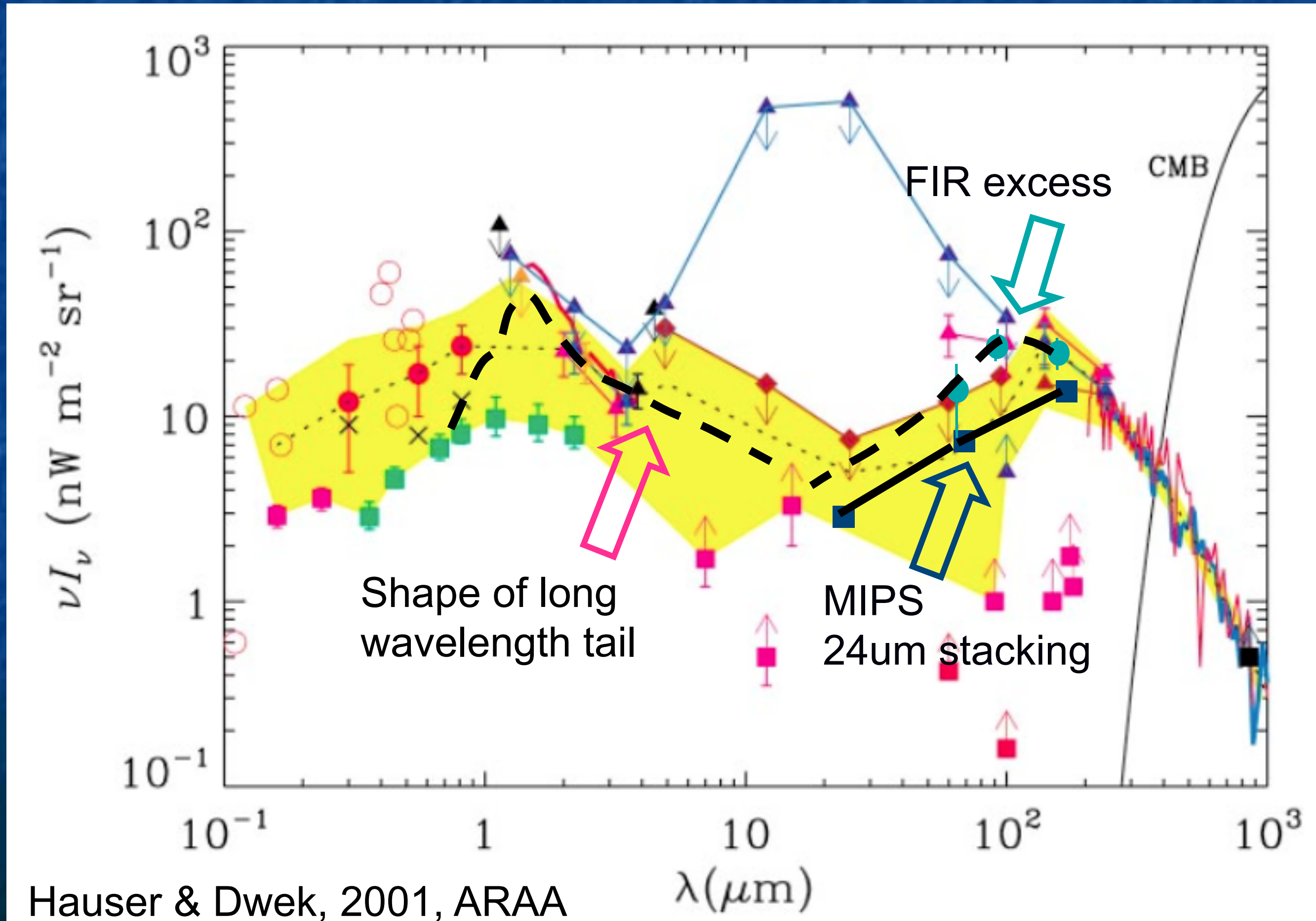
How to remove the foreground ?

- Fluctuation measurement
  - Sensitive to the depth of point-source removal
  - Large-aperture telescope at 1AU, HST, Spitzer, AKARI and JWST, would do better
- CIB spectrum in wide wavelength range from optical to MIR
  - Optical : ZL, DGL
    - Polarization measurement
  - MIR: galaxies, ISD
    - PAH features
  - Possible with relatively small aperture & wide FOV



CIB measurement in MIR

- New cosmological window will be opened up in MIR.
  - Constraint on Balmer lines & Continuum emission components from First Stars, and redshift distribution (z >10) of star formation rate
  - We may see something new, e.g. new population causing the CIB excess in FIR



Hauser & Dwek, 2001, ARAA

Minimum instrument

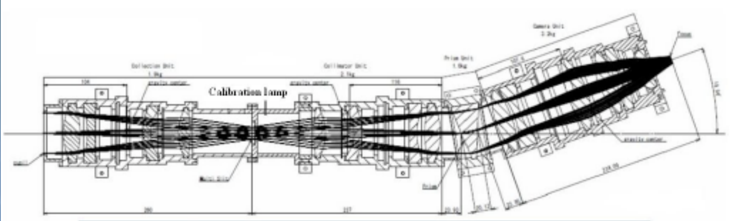
- Minimum instrument to measure the absolute spectrum of the first star background

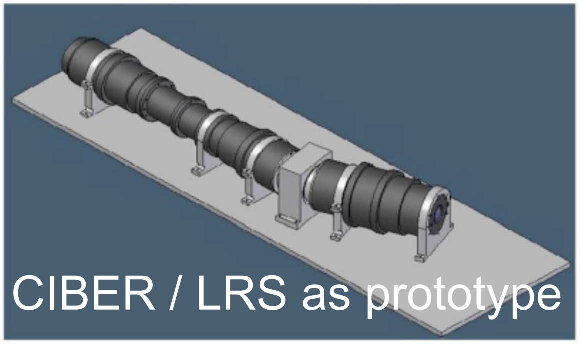
- Optical-NIR low-resolution spectrometer

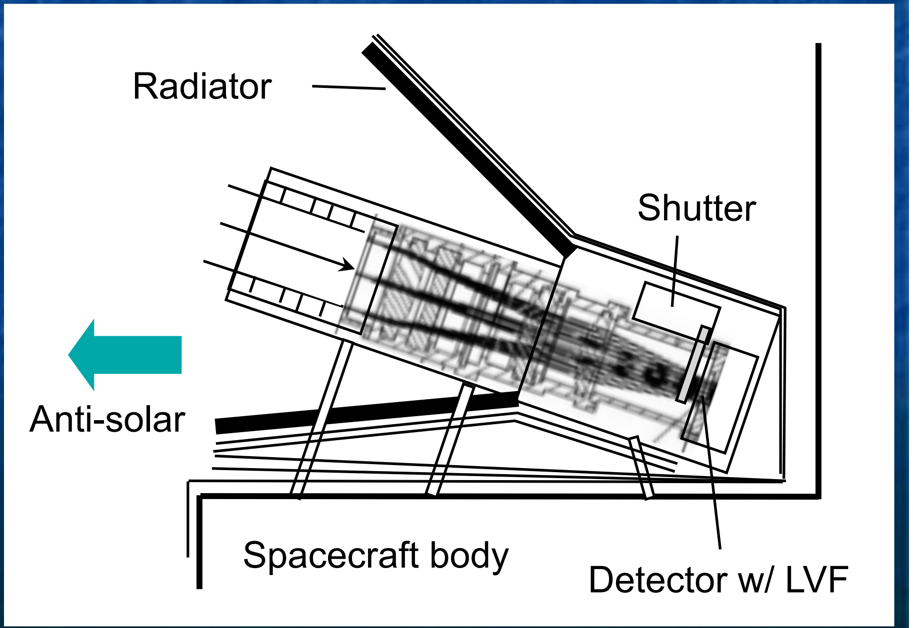
Telescope aperture： ~5cmΦ
Passive cooling: T<40K

Wavelength： λ=0.8-5μm
Resolution： $\lambda/\Delta\lambda$~20
(Linear Variable Filter)
FOV： 10 arcmin × 5 deg
Detector: 256^2 pix FPA
(HgCdTe + InSb)

Total mass: ~5kg







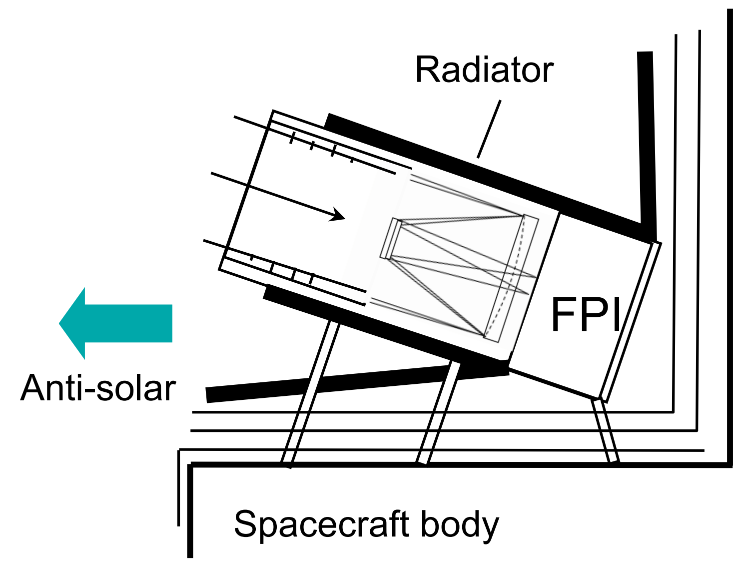
Full-spec version of the instrument

- Higher resolution and extended wavelength

Telescope aperture: 20cmΦ
Passive cooling + cooler

Medium resolution spectrometer
Wavelength: 0.4-1.7μm (HgCdTe or InGaAs)
1.6-5.1μm (InSb)
5.0-25μm (Si:As)
Resolution: $\lambda/\Delta\lambda \sim 100$
Multi-channel FTS (large throughput)
Polarization measurement capability
residual ZL, DGL
CIB pol ?
Detector format: 1k^2 / 512^2
FOV: 30 arcmin × 3 deg

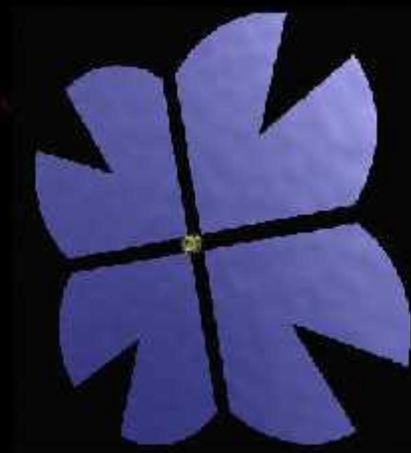
Total mass >30kg



How to bring it to >5AU?

Solar Power Sail mission

- JAXA's future spacecraft
  for outer planetary exploration

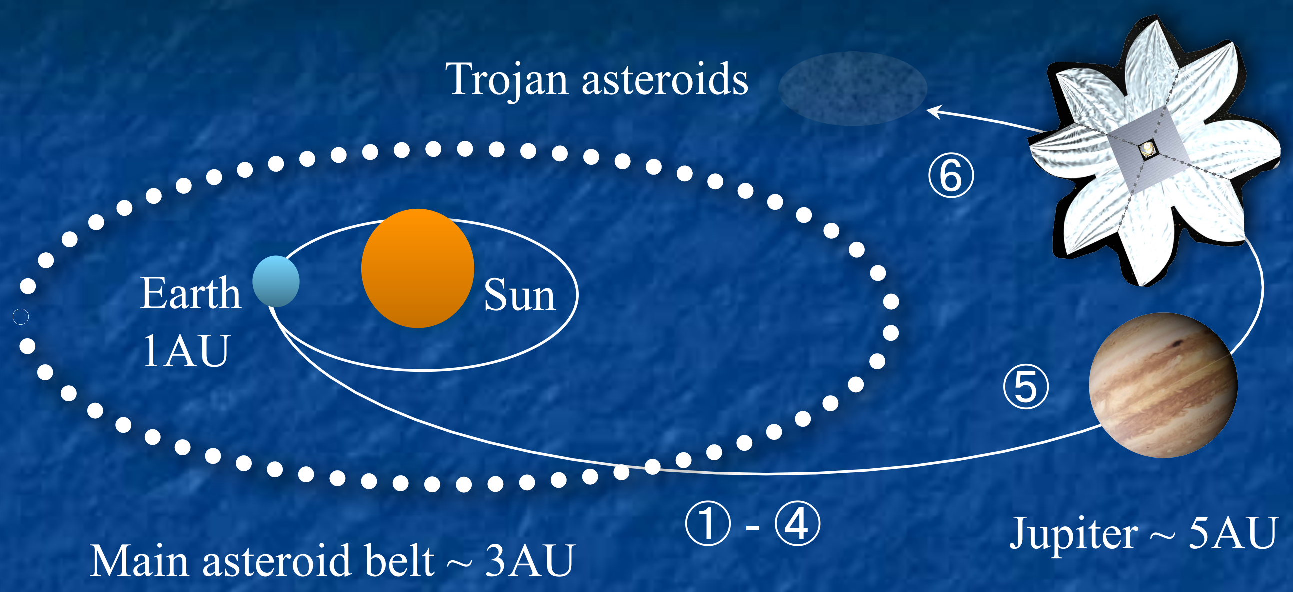


- Objectives for planetary science
  - Jupiter magnetosphere observation as JMO of EJSM (PI: T. Takashima)
  - Trojan asteroids exploration (PI: H. Yano)

http://www.muses-c.isas.jaxa.jp/kawalab/

- Science in Cruising phase
  - CIB / ZL observation (PI: S. Matsuura)
  - In-situ measurement of dusts (PI: H. Yano)
  - Gamma-ray burst monitor (PI: D. Yonetoku)

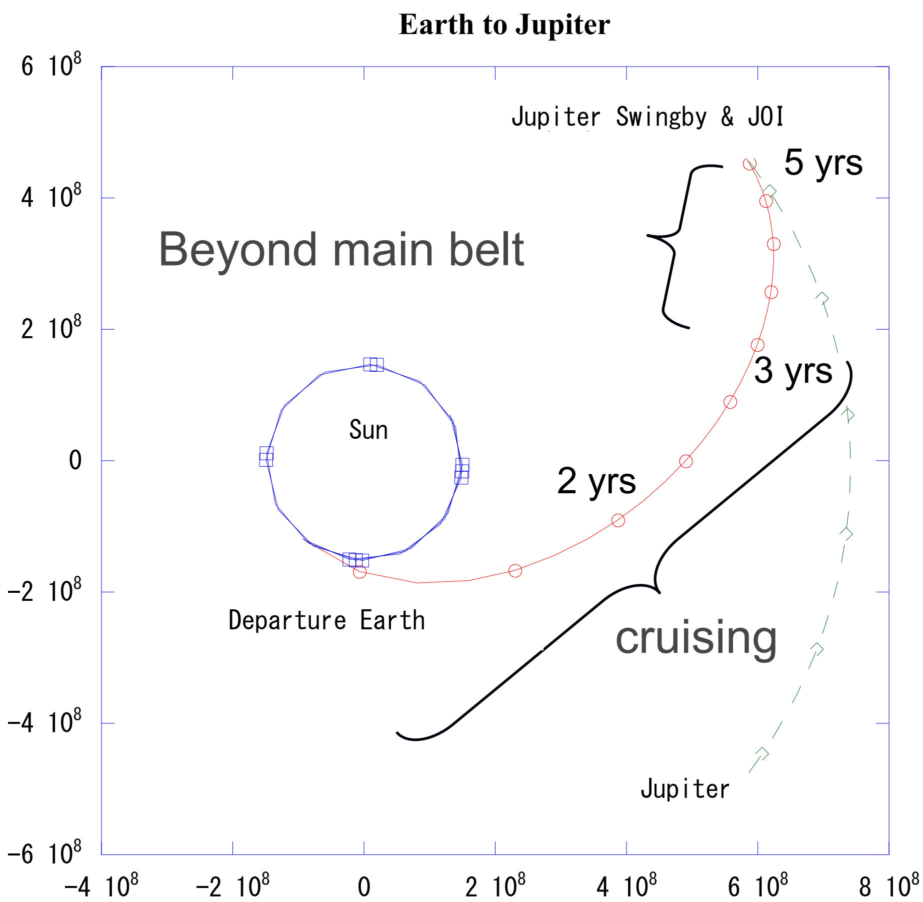
Operation plan

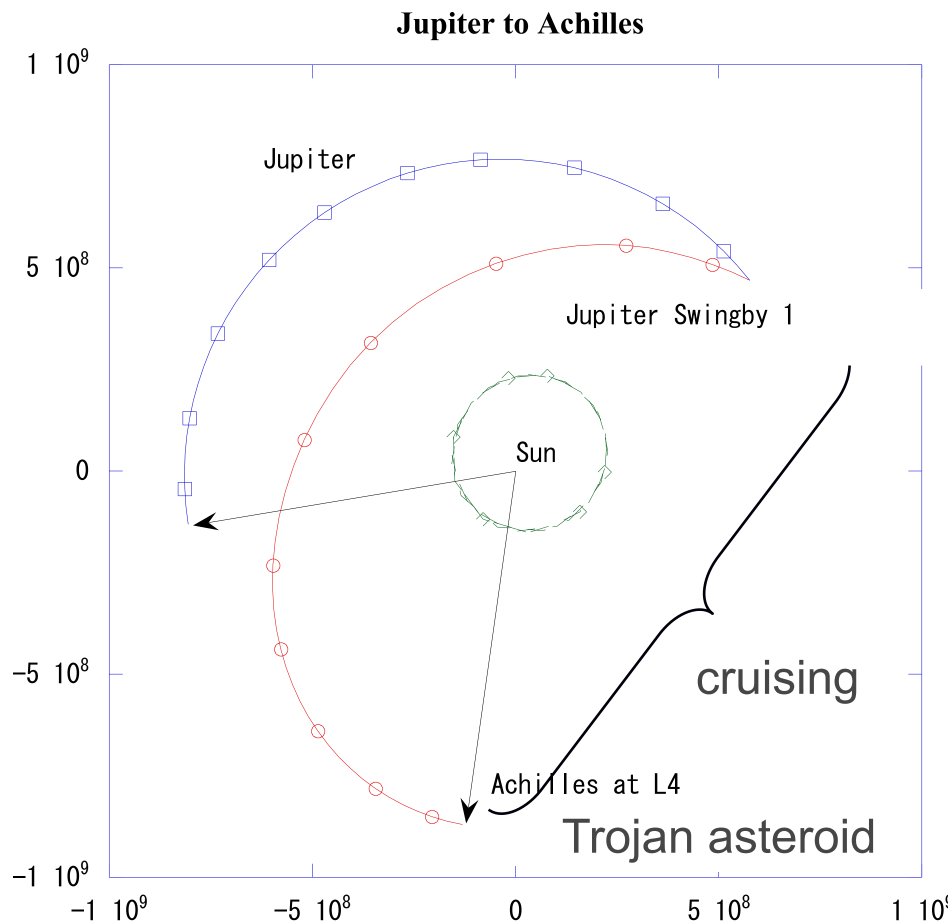


Ⅰ. Cruising
① CIB measurement
② ZL measurement
③ In-situ measurement of dusts
④ Gamma-ray burst monitoring

Ⅱ. Jupiter exploration
⑤ Jupiter magnetosphere observation
⑥ Trojan asteroid exploration

An example of spacecraft trajectory





Launch→Single EDVEGA→Jupiter Swingby

Jupiter→Trojan asteroid rendezvous

Main belt Y + 3 yrs
Jupiter arrival Y + 5 yrs
Trojan asteroids Y + 11 yrs Be patient !

Mass budget

Current maximum payload is 203kg.

Science payload after accounting for Jovian orbiter is 46kg.

Mother ship（for cruising science and Trojan asteroids exploration）

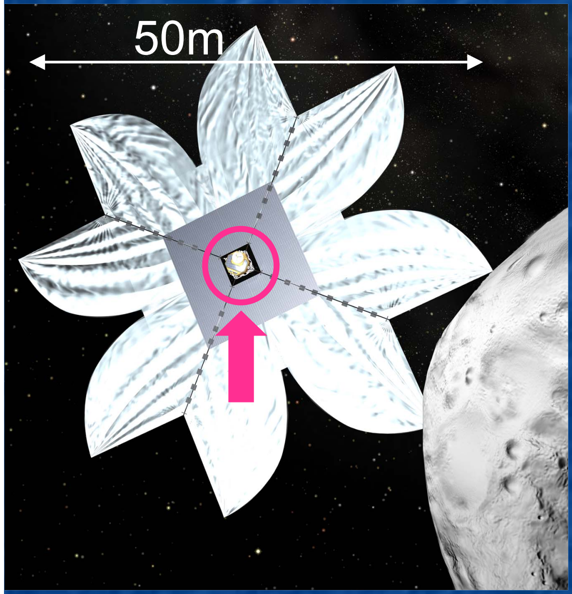
Mother Spacecraft		Wet@Launch (kg)	Flight Time (year)	Payload (kg)	Xe for EP (kg)	Fuel for BP (kg)	Membrane Area (kg) [m^2]	ThinFilm Cell (kg) [m^2]	Net Bus (kg)
Double EDVEGA	H-IIA 204 4S *1	3600	11	116.4	756.0	499.0	166.2	590.8	211.8
Single EDVEGA	H-IIA 204 4S *1	2150	9.5	202.7	344.0	227.0	99.2	352.8	163.7
Direct	H-IIA 204 4S *1	1040	7.5	112.4	124.8	82.4	48.0	170.7	113.8

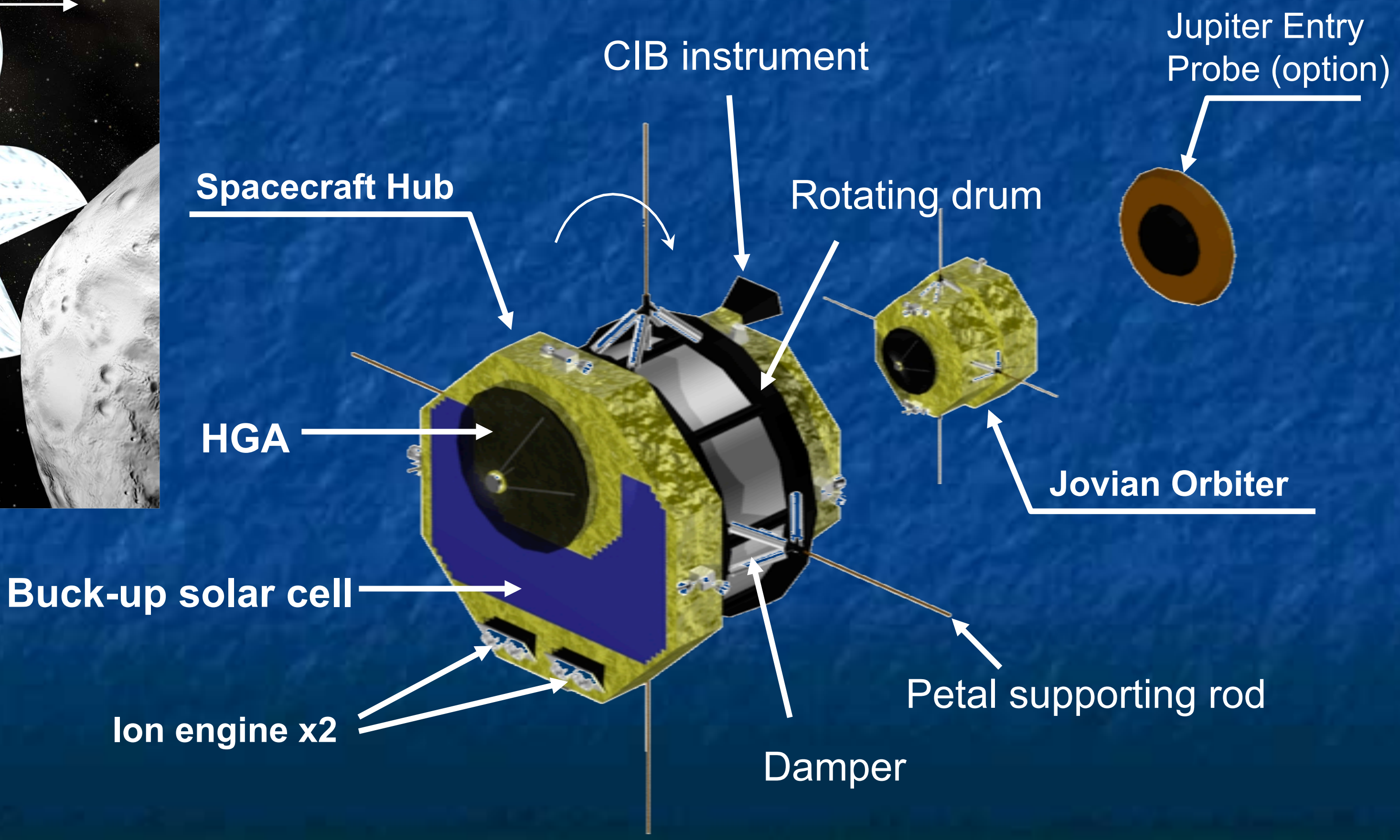
Jovian orbiter（magnetosphere observation）

Jovian Orbiter		Payload (kg)	BP Fuel *3 (kg)	Film Cell *4 (kg)	Net Bus (kg)	Science Payload (kg)
Double EDVEGA	H-IIA 204 4S *1	116.4	48.9	10	8.6	17.4
Single EDVEGA	H-IIA 204 4S *1	202.7	85.1	10	11.3	45.9
Direct	H-IIA 204 4S *1	112.4	47.2	10	8.4	16.1

Solar Power Sail spacecraft

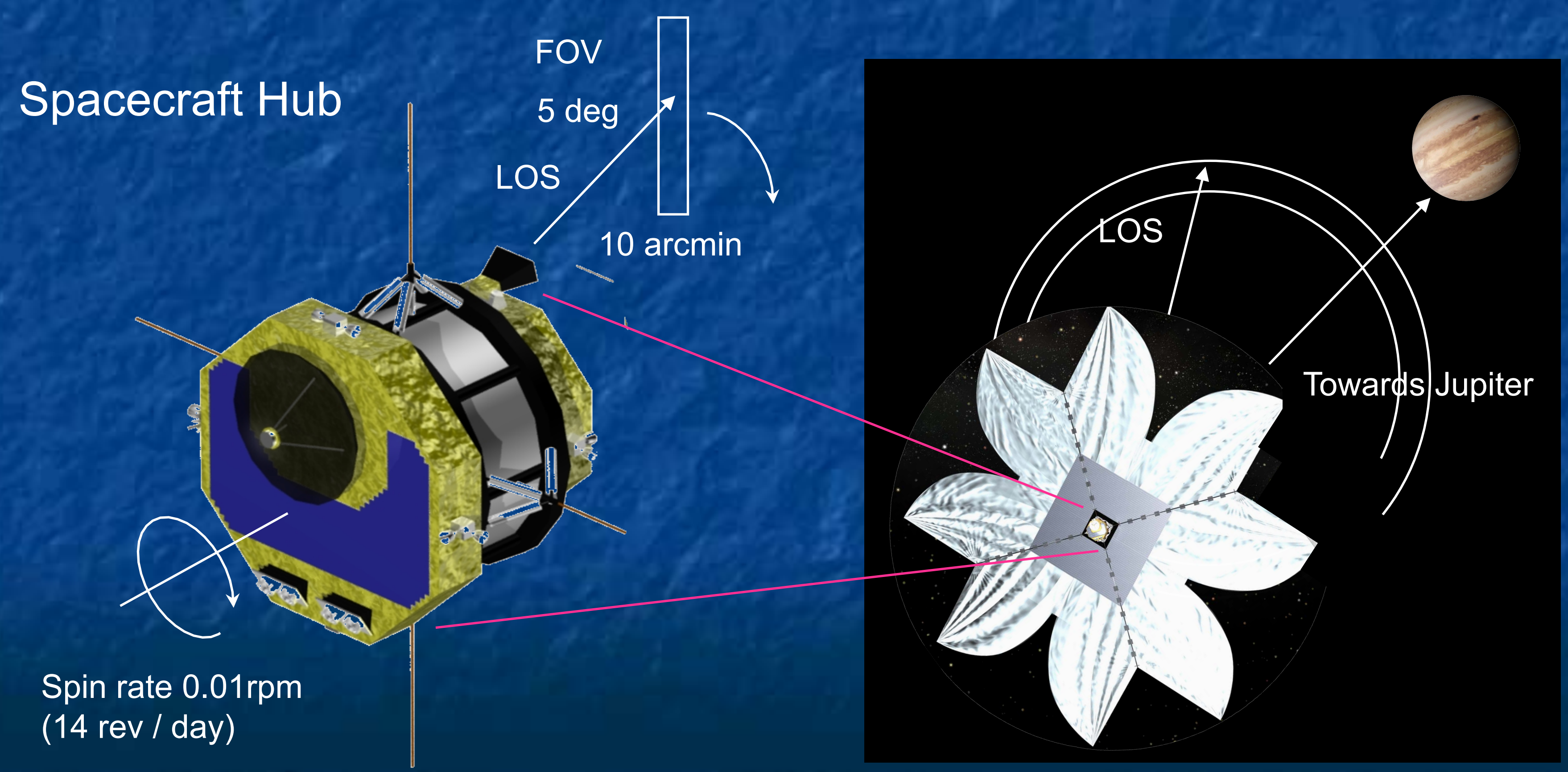
- Solar sail made of membrane solar power cell, Sail size ~50m
- Spin stabilization (Spacecraft Hub and Sail can rotate independently)
- Hybrid propulsion system: Radiation pressure + Electrical propulsion



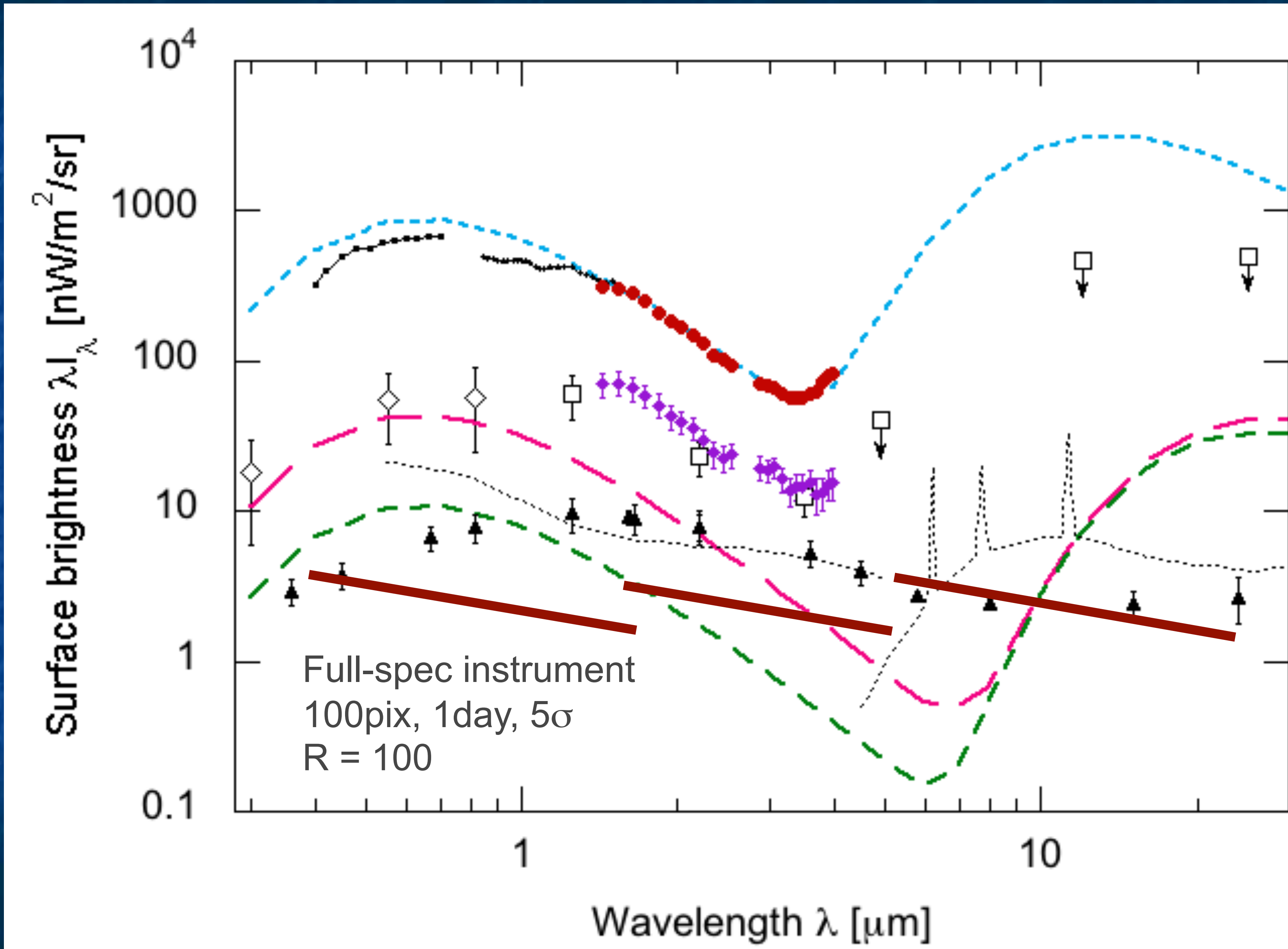


Observation mode

- Observation in cruising phase and even after arrival at Jupiter
- Mapping over ring sky by telescope scan with spacecraft spin
- Continuous monitoring of ZL decrease with time
- Direct CIB detection after passing through the main belt



Sensitivity of this mission



Mission schedule

Now～2011： concept study is being by SS working group

- System design
  - Design according to science requirement
  - Study to keep much more science payload
- R&D of technical elements including the science instruments

- Schedule
  - Pre-project：2011～2013
  - PM design and manufacture, TTM / MTM：2013~2015
  - FM manufacture：2016~2017
  - FM test：2018~2019

  - Launch：2019~2020
  - Cruising to Jupiter：2020～（beyond main belt：2023～）
  - Jovian Orbiter in orbit：2026~28
  - Trojan asteroid rendezvous：2030

Technical issues to be cleared

- Data rate
  - Data generation rate ~1Mbps
  - Average down link rate with JAXA ground station ~1kbps
  - Need on-board processing
  - NASA DSN, Ka-band

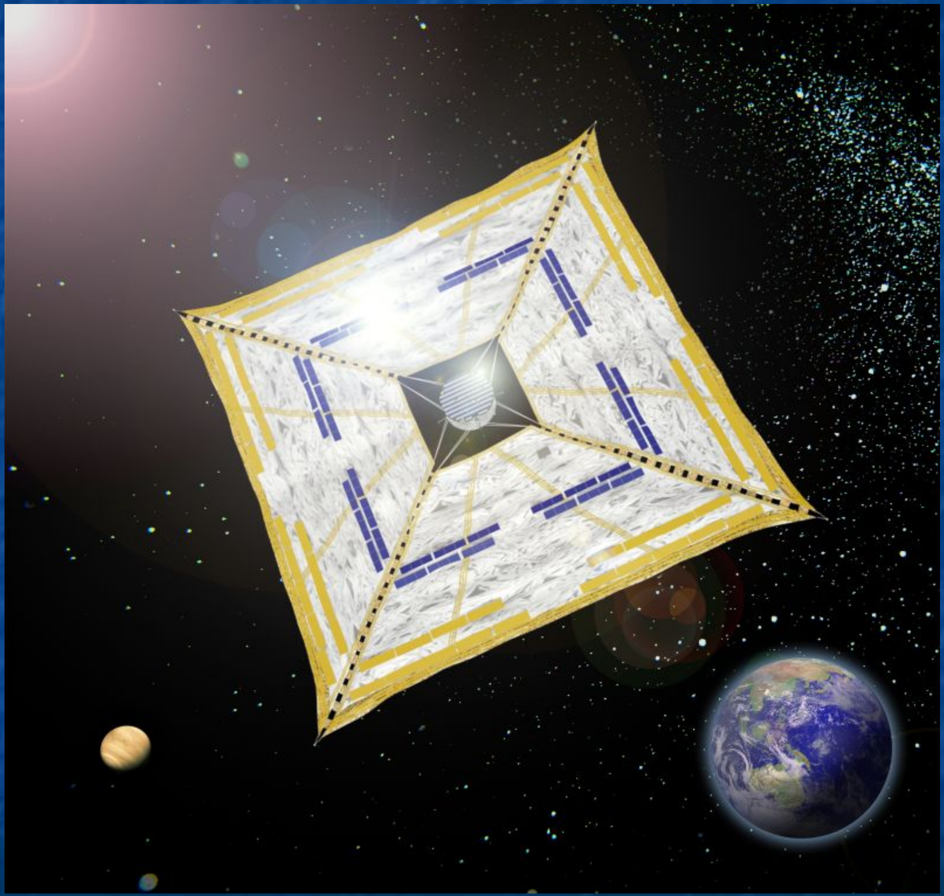
- Pointing accuracy
  - Not easy to predict and control dynamical property of large membrane
  - Difficult to achieve telescope pointing accuracy better than 1 arcmin.
  - Pix FOV has to be >1 arcmin, which limits the point source sensitivity.

- Thermal
  - Near the earth orbit, not very easy to cool the MIR detector to 10K by radiation cooling only.
  - Utilizing cooler give an impact to the mass of science payload.

Mission for the proof

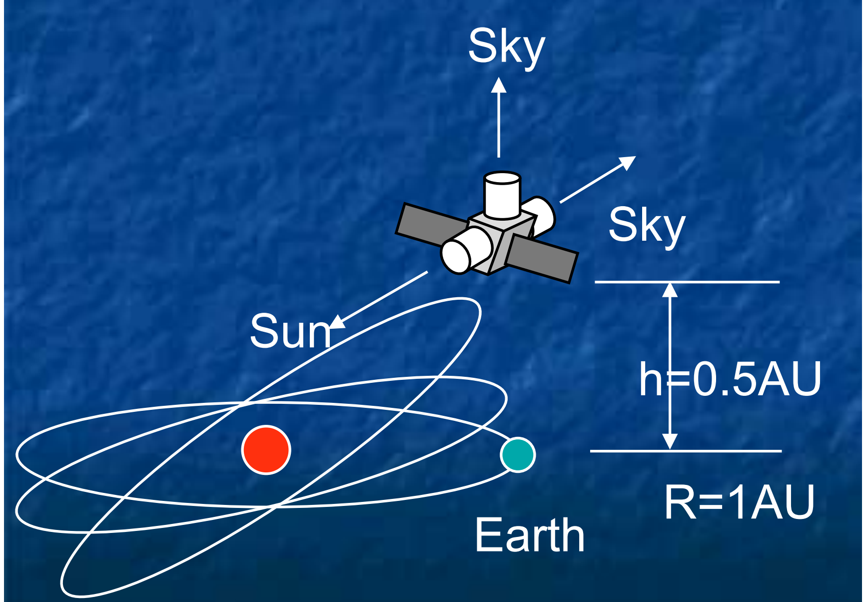
- Engineering model of Solar Power Sail,
  named IKAROS
  - 10-m small sail

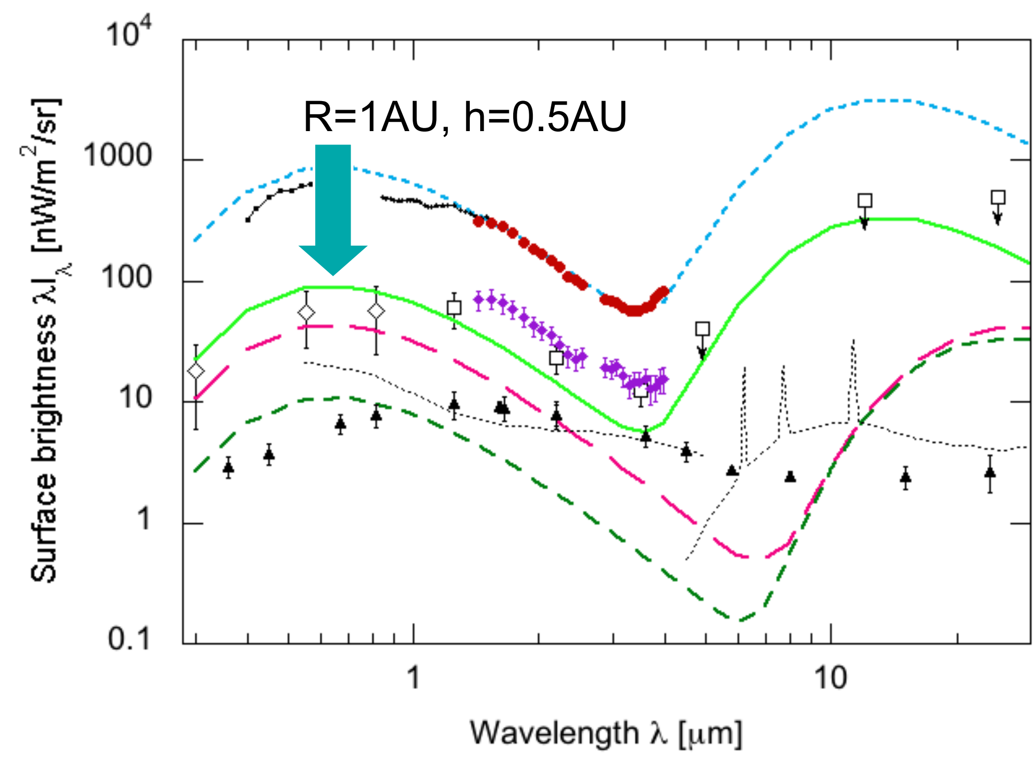
- It sails to Venus, rather dense region
- Useful to understand basic properties of the sail
- Launch
  May 18th, 2010,
  together with Venus mission, AKATSUKI



Out-of-ecliptic mission

- Another mission for CIB measurement in Zodi-free environment
- Solar science community in Japan plans to go out-of-ecliptic orbit for the next Solar mission, Solar-C. Target launch date : ~2020
- Highly inclined orbit at 1AU can be realized by the Earth swing-by technique
- At h=0.5 AU, ZL becomes comparable to or lower than the current CIB limits
- We are proposing to install our minimum instrument on this satellite.





EXZIT (Exo-Zodiacal Infrared Telescope) powered by Solar Sail

~ New generation astronomy from interplanetary space

We are happy if we can contribute to NASA’s 5AU mission.

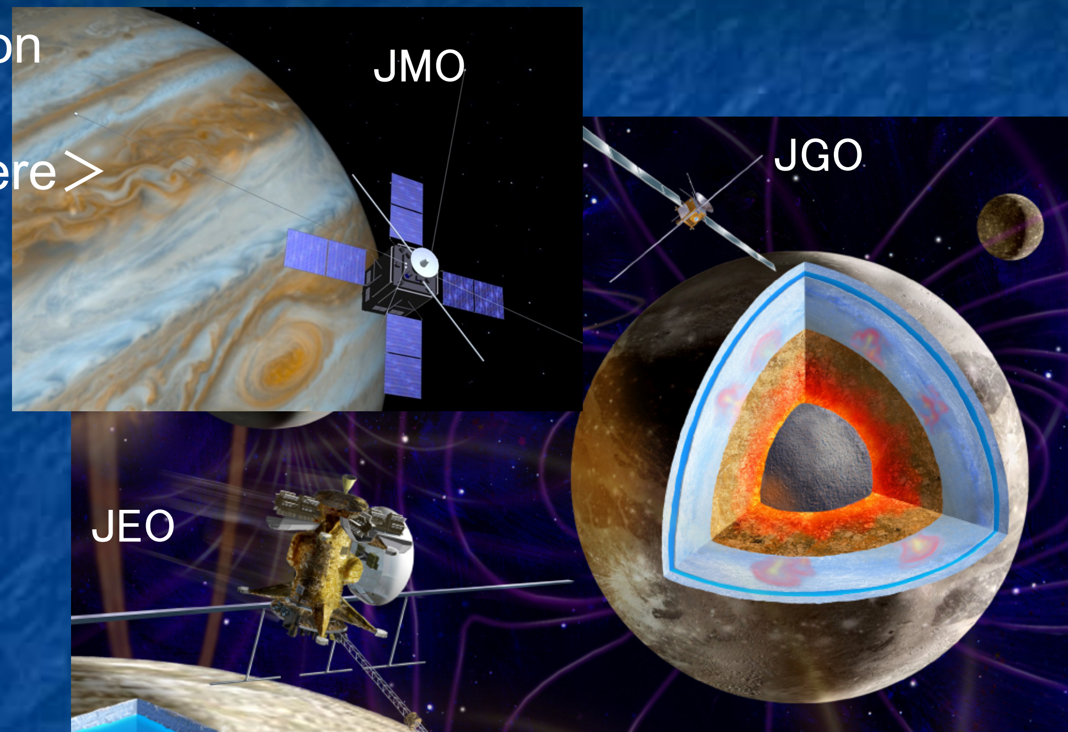
http://www.muses-c.isas.jaxa.jp/kawalab/

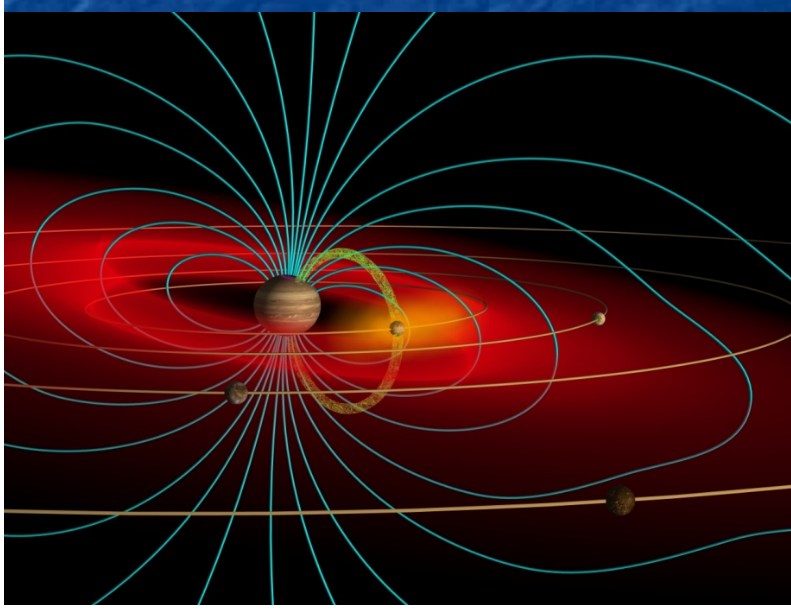
The END

Jovian Magnetosphere Orbiter : JMO

JAXA has a roll for the joint mission

＜Physics of Jovian magnetosphere＞
- particle acceleration
- rapidly rotating magnetosphere
- interaction with satellites

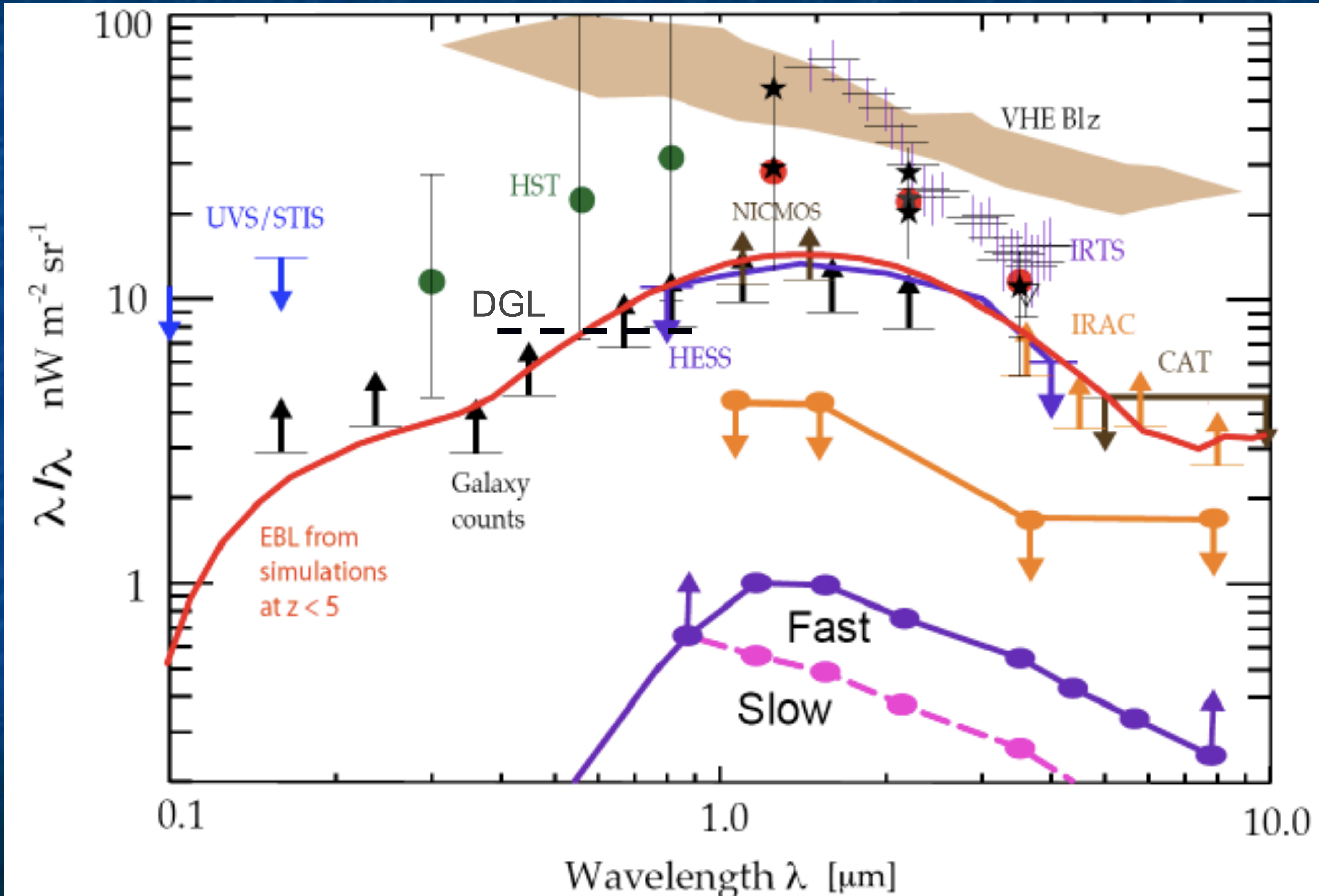




＊ Simultaneous observations with Europa Orbiter（NASA） and Ganymede Orbiter（ESA）are powerful for understanding “icy satellite”

＊ Motivation from Astrobiology

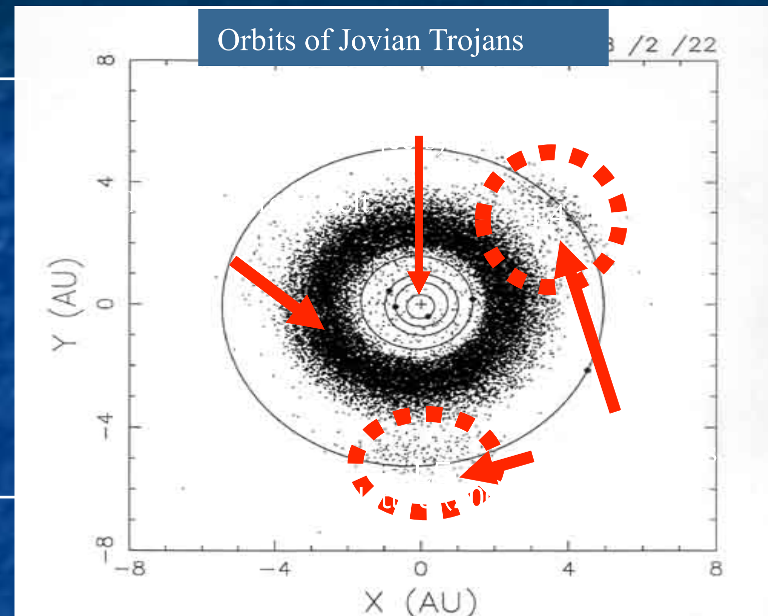
Ultimate CIB measurement



木星トロヤ群：未踏領域、D型、連星小惑星の科学～「木星系の形成条件を知る」ことに貢献

[基本性質]

* 存在領域：木星公転軌道前後60度（L4, L5点）
* 既発見数：L4=1264, L5=1178（2008年6月現在）
* 全数見積もり(>1 km)：~1.6 x 10^5
  （cf. メインベルト= 6.7 x 10^5）
* バルク密度： <1 g.ccあるいは~2 g/ccが主流
* 多色測光：0.35<(V, R) <~0.6
* 幾何アルベド：0.04~.09
* スペクトル型： D、P



[科学課題1]トロヤ群の起源の二つの学説

（1）古典的モデル

＝「トロヤ群は木星系形成時の微惑星の残滓である」

➔木星系の原材料の解明

（2）ニースモデル

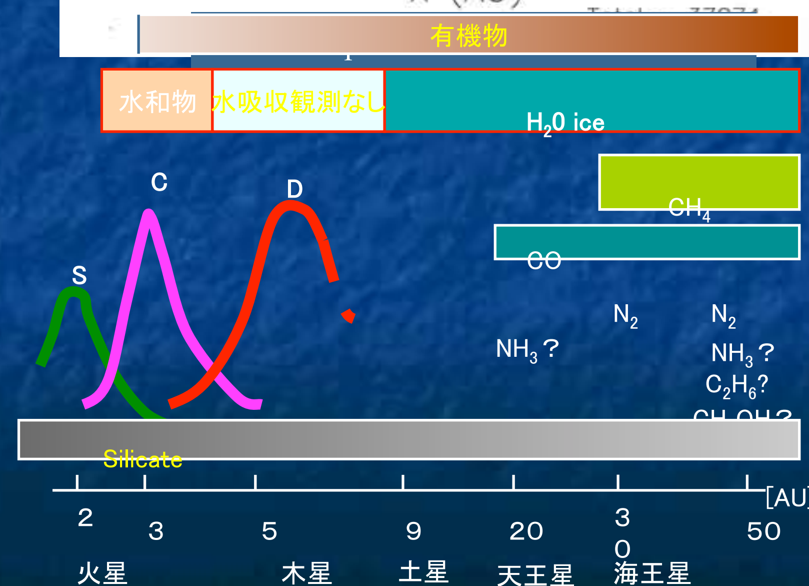
＝「現在のトロヤ群は、ガス惑星大移動の過程で第一世代が拡散された後に捕獲された、EKBO天体である」

➔逆行外縁衛星と同じ起源を持つ可能性

[科学課題2]トロヤ群の構成物質と内部構造

(1) スノーラインを超えた遠方に存在するのに、なぜD型小惑星には「水吸収」の分光特徴が見えないのか？

(2) 1~2g/ccと低いバルク密度はどんな内部構造（集積プロセス、原材料）によって実現されているのか？

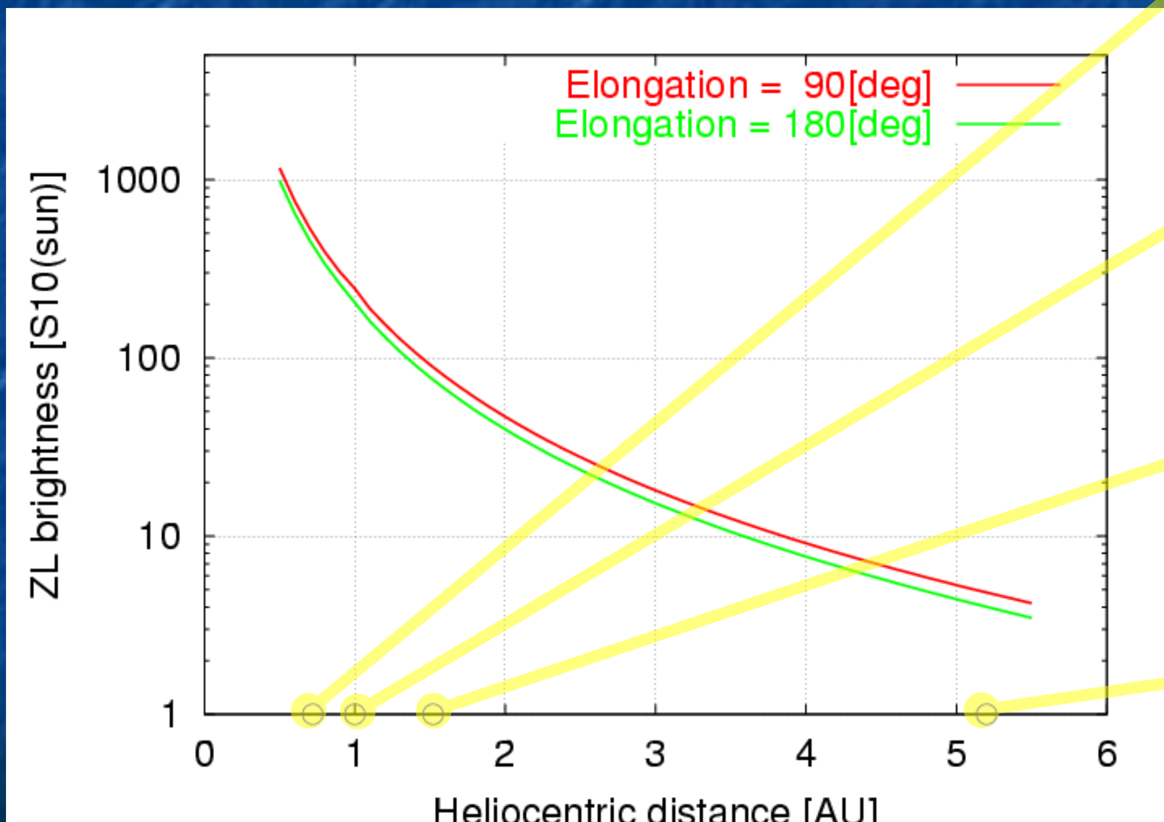


（作成：高遠徳尚氏（NAOJ））

Estimate of ZL brightness

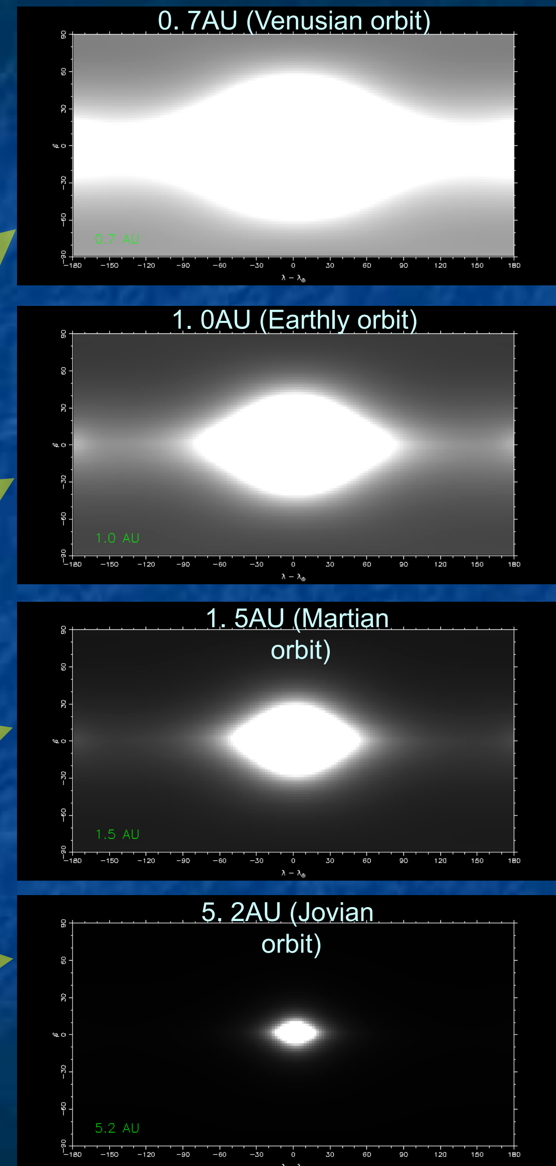
- Estimate of ZL brightness viewed from the in-ecliptic orbit as a function of heliocentric distance

Model calculation of ZL



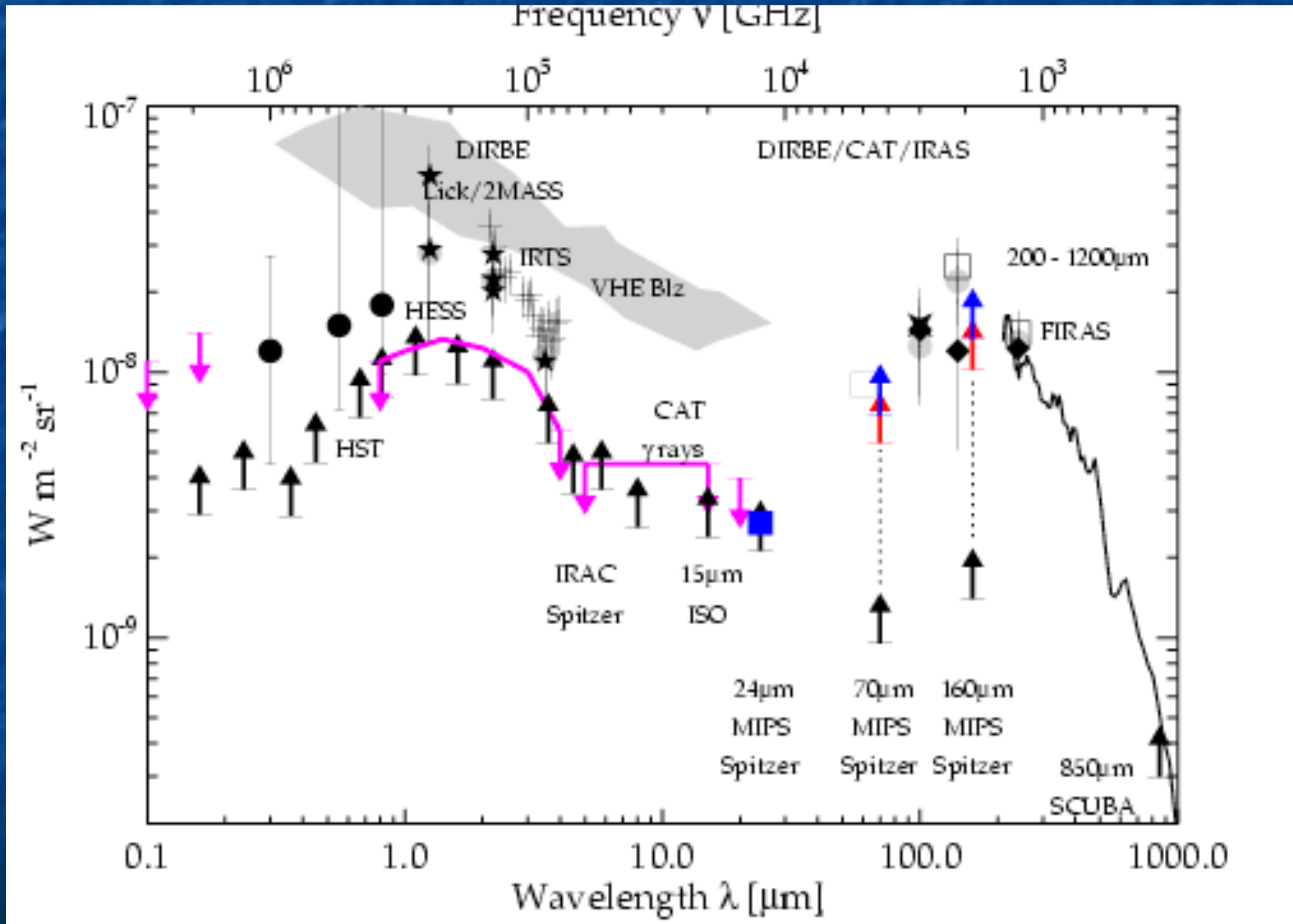
•3D distribution of dust：COBE/DIRBE model（Kelsall et al. 1998）

•Scattering phase function：Hong 1985



Sky maps of ZL brightness in (λ-λ☉, β) coordinate.

Current CIB limits



Dole et al. 2006

Slit size

- Current CIB limits