

Mid-Infrared Observations of asteroids for

**Establishment of asteroidal
calibrators
for far-IR and sub-mm
observations**

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& ASTRO-F Calibration team

outline

- # Calibration strategy of the *ASTRO-F/FIS*
 - Astronomical calibration - asteroids

 - # Asteroidal preparatory programme
 - Mid-IR observations of asteroids
 - Current activity / Future observations
-

ASTRO-F

The Japanese infrared survey mission

Onboard instruments

IRC: Infrared Camera
NIR, MIR-S, MIR-L

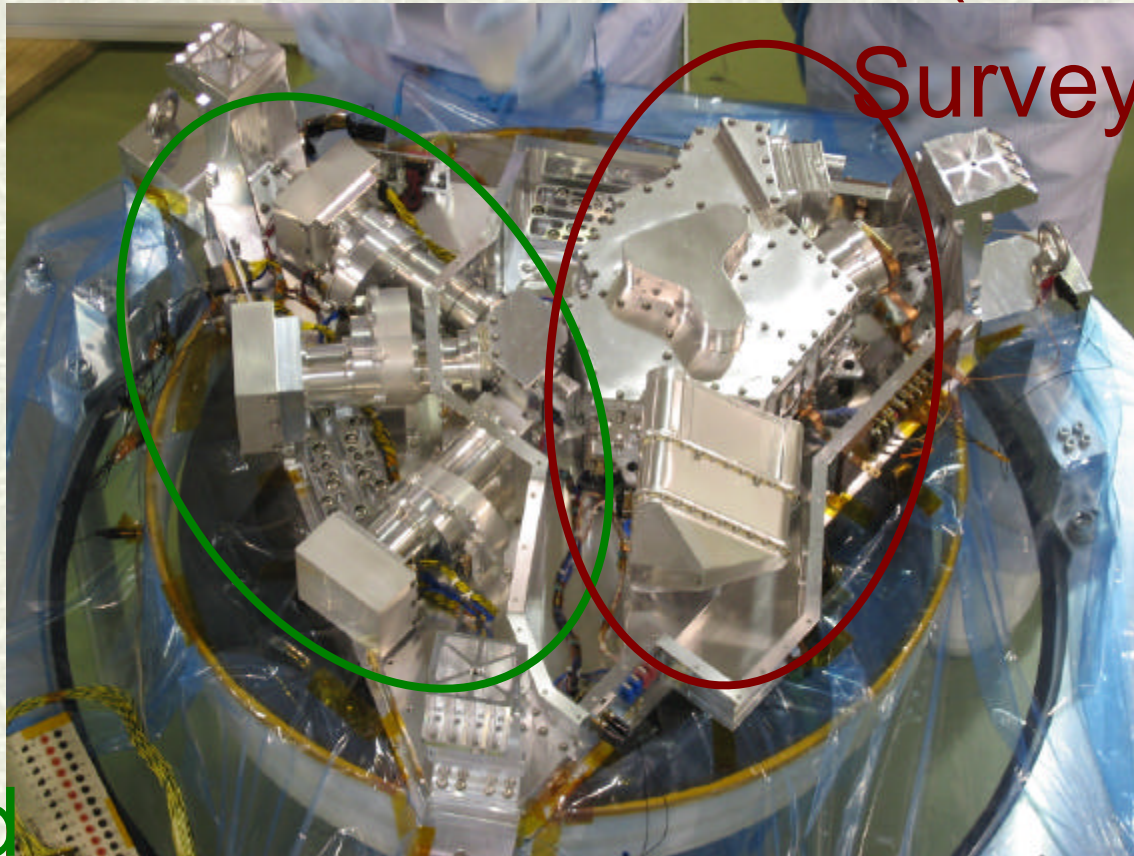
FIS: Far-Infrared Surveyor
simultaneous observation
in 4 FIR bands



Focal Plane Instruments

(Far-Infrared
Surveyor) FIS

50–180
 μm



1.8–26 μm

IRC

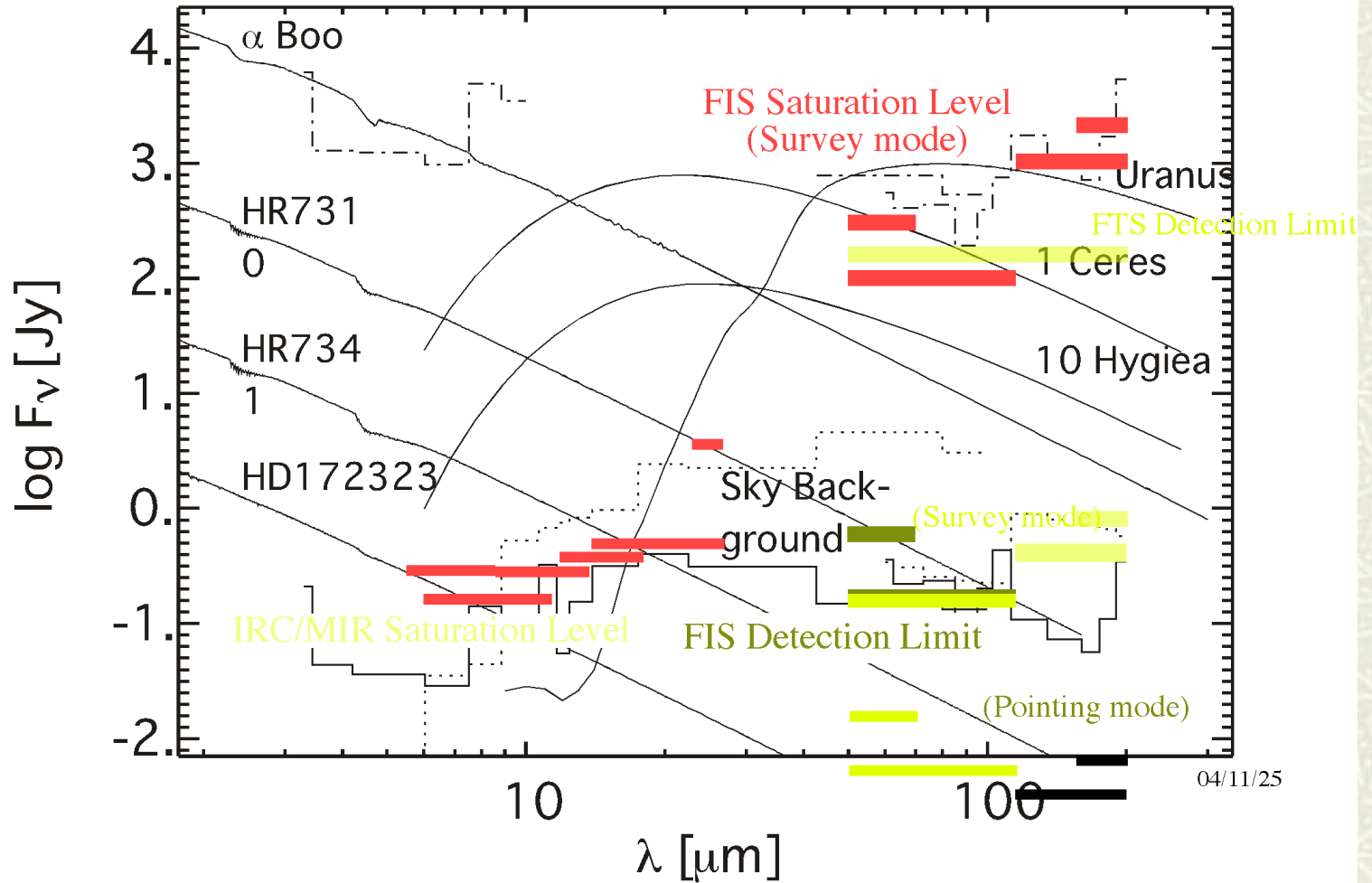
(Infrared
Camera)

ASTRO-F

The goal of FIS flux calibration (for survey)

- Absolute
 - **10 % for point sources**
 - 20 % for diffuse emission
 - Relative
 - 5 % for point sources
 - 10 % for diffuse emission
-

ASTRO-F/FIS Calibrators



Calibration for ASTRO-F/FIS

Astronomical flux calibration sources
FIS - mainly **asteroids** (& stars)

ASTRO-F is an all-sky survey mission

- Scanning the sky along ecliptic meridian
- Large constraint of visibility

Only ± 1 deg in cross-scan direction is visible at a time

A pointing observation is limited up to 10 min exposure

(cf. Yamamura-san's talk for more detail)

--> effort to increase the number of asteroidal calibrator
is essential !! (ISO ~10 asteroids)

Preparation of asteroidal calibrators

- How do we obtain the accurate flux of the asteroids which ASTRO-F/FIS will observe ?
 - > Thermophysical model (cf. Müller-san's talk)
 - TPM requires the following individual object parameters
 - H-G values
 - Geometrical albedo: p_v
 - Effective diameter: $D_{\text{eff}} = 2(abc)^{1/3}$
 - Shape values: a/b , b/c
 - Spin vector orientation: λ_{pole} , β_{pole}
 - Absolute rotational phase: γ_0 at the time JD_0
 - Rotational period: P_{sid}
-

Asteroid Selection Process

- High quality, smooth, low amplitude visible lightcurves
- Good quality of spin vector and shape
- Large main-belt asteroids with diameters > 100 km
- Independent diameter and albedo information
- **Thermal observations available**
- binaries, M-types, poor spin vectors, elongated objects ×

starting list: 150 asteroids

→ current list: 49 asteroids (cf. Müller-san's talk)

No.	SV qual.	shape	occ.	LC qual.	IRAS	ISO	MSX	other therm. obs.	Remarks
1	I	y	5	3	y	y	n	nq/NQ/submm mm	primary calibrator, HST, adaptive optics, extensive thermal observations, ...
2	I	y	5	4	y	y	n	nq/NQ/mm	ISOPHOT calibrator
3	I	y	5	4	y	y	n	nq/NQ	ISOPHOT calibrator
4	I	y	4	4	y	y	n	nq/NQ/submm/ mm/radar	ISOPHOT calibrator; optical shape model by HST; adaptive optics; thermal LC
5	I	h	-	4	y	n	n	nq/radar	
6	I	h	3	4	y	y	n	submm/radar	
7	I	y	1	4	y	n	n	nq/submm/radar	
9	I	y	4	4	y	y	y	nq/radar	
10	I	h	1	4	y	y	n	nq/NQ/mm	ISOPHOT calibrator, HST, speckle
12	II	y	1	4	y	n	n	nq/radar	
17	I	y	-	4	y	n	n	nq	IRAS diam. 90.04 km
18	I	h	5	4	y	n	n	nq/submm/radar	
19	I	y	4	4	y	n	n	nq/radar	
20	I	h	-	4	y	y	n	nq/radar	
21	I	h	1	4	y	n	n	nq/radar	IRAS diam. 95.76 km; M-type, radar size/shape/SV
23	I	h	-	4	y	n	y	nq	
24	I	h	-	3	y	n	n	●	
28	I	h	-	4	y	n	y	nq	
29	I	y	-	4	y	n	n	nq	
31	I	h	-	4	y	n	n	●	
37	I	h	2	4	y	n	n	nq	
40	I	y	-	4	y	n	n	nq	
41	I	y	1	4	y	n	n	nq/radar	
42	I	n	1	3	y	n	n	nq	

● No data

No.	SV qual.	shape	occ.	LC qual.	IRAS	ISO	MSX	other therm. obs.	Remarks
47	I	y	4	4	y	n	n	nq	
48	I	n	2	3	y	n	n	●	
51	I	n	5	4	y	n	n	nq	
52	I	y	2	4	y	y	n	nq	
54	II	n	-	4	y	y	n	nq/NQ	ISOPHOT calibrator
56	II	h	-	2	y	y	n	nq	
65	II	y	4	4	y	y	n	NQ	ISOPHOT calibrator
69	I	y	-	4	y	n	n	●	
85	I	h	4	4	y	n	n	nq	
88	I	y	5	4	y	n	n	●	
93	II	y	4	4	y	n	y	●	
94	I	y	-	3	y	n	n	nq	
196	II	y	-	4	y	n	n	nq	
241	I	y	-	3	y	n	n	nq	
313	II	y	1	2	y	y	n	nq/NQ/mm	IRAS diam. 96.34 km; ISOPHOT calibrator
354	I	y	-	4	y	n	n	nq	
360	I	y	-	4	y	n	n	nq	
423	I	h	1	2	y	n	n	●	
451	II	y	-	4	y	n	n	nq	
471	II	h	4	3	y	n	n	nq	
505	I	v	-	3	y	n	n	●	
511	I	y	1	4	y	y	n	nq	
532	I	y	3	4	y	y	n	nq/NQ/mm/radar	ISOPHOT calibrator
704	I	y	4	4	y	n	n	nq	
776	I	y	-	2	y	n	n	●	

Some asteroids need good quality thermal observations

Observational Programmes

To determine **the size** and thermal inertia of an asteroid
we need **an accurate measurement of thermal radiation flux**

in multiple wavelength bands

--> infrared wavelength range beyond $\sim 5 \mu\text{m}$

N and Q bands are accessible from the ground in MIR

SUBARU/COMICS at Mauna Kea

stable mid-IR instruments available for open use

(SUBARU/COMICS, UKIRT/Michelle, TIMMI2, ...???)

observations of several wavelengths in N- and Q-band

--> the **physical size** and thermal inertia of the ~~asteroids~~

Observational Programmes

Submitted proposals to SUBARU (and UKIRT)

- Establishment of calibration sources from MIR to sub-mm
 - Hasegawa et al. (S03A) - partly observed (5 asteroids) ←
- Thermophysical study of asteroids with mid-infrared photometry by COMICS - Ootsubo et al. (S03B) ×
- Establishment of calibration stars for far-infrared and sub-mm observatories using Michelle/UKIRT - Sekiguchi et al. (2004A) ×
- Establishment of new calibration stars from MIR to submm
 - Ootsubo et al. (S04A) - partly observed (3 asteroids)

Observation

SUBARU/COMICS at Mauna Kea

June 20 & July 16, 2003

Imaging with 3 filters

8.6, 11.7, 18.7 μm (N-, Q-band)

24 Themis, 505 Cava,
624 Hektor, 675 Ludmilla,
852 Wladilena

Standard star:

HD108985, HD123139, HD169916

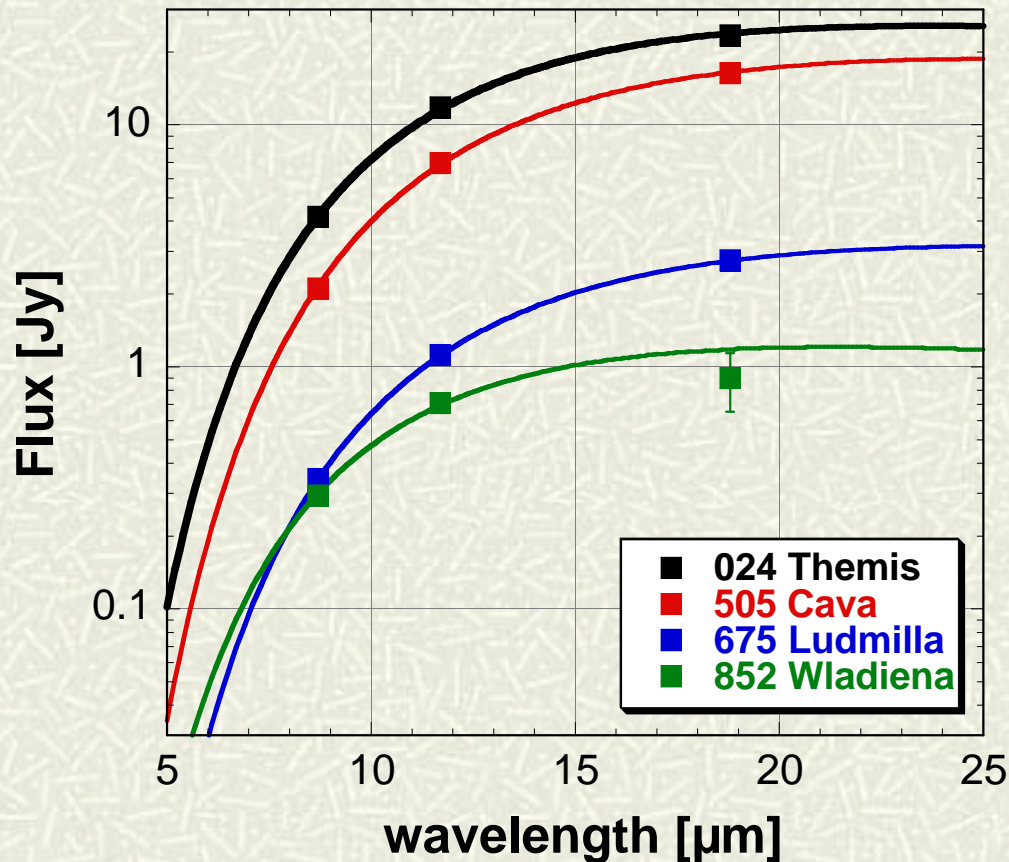
4 Vesta

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Results

COMICS/Subaru Observations



- Fit with Thermal model (STM) for asteroids (Hasegawa & Abe 2001)
- Flux [Jy] @ 3 bands
--> Diameter: D [km]
Geometric albedo: p
Beaming parameter:?

Results

#	name	D [km]	p	?	errors in photometry
					@8.7, 11.7, 18.8 μ m
24	Themis	183.1 km	0.077	0.80	(4.4, 4.0, 7.2 %)
505	Cava	141.0 km	0.032	0.93	(6.2, 2.6, 4.2 %)
675	Ludmilla	75.5 km	0.212	0.82	(7.3, 4.2, 11.4 %)
852	Wladilena	27.2 km	0.263	0.74	(8.9, 5.7, 26.9 %)

624 Hektor - not obtained because of bad S/N

505 Cava, 675 Ludmilla - size & albedo obtained for the first time

Results

24 Themis

No data of IR observation or occultation so far

compare with previous result

from the model -- $D = 205 \text{ km}$, $p = 0.061$

from the observation -- $D = 183.1 \text{ km}$, $p = 0.077$

COMICS observations of 24 & 505

--> meet the requirement of 10 % photometric accuracy

all standard candidates have the IR observation data!

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current list: 49 asteroids

No.	SVC	SMC	LCC	OCC	IRAS	ISO	MSX	Other	thern.	Remarks
001	I	y	3	5	n	y	n	na/NQ/submm/rm		ISO-col, HST, AO (949km)
002	I	y	4	5	y	y	n	na/NQ/rm		ISO-col, Speckle (524km)
003	I	y	4	5	y	y	n	na/NQ		ISO-col, AO (234km)
004	I	y	4	4	y	y	n	na/NQ/submm/rm/radar		ISO-col, HST, AO, Spe. (506km)
005	I	n	4	-	y	n	n	na/radar/NQ(2004/Sに観測)		(119km)
006	I	n	4	3	y	y	n	submm/radar		(185km)
007	I	y	4	1	y	n	n	na/submm/radar		(200km)
009	I	y	4	4	n	y	y	na/radar		(155km)
010	I	n	4	1	y	y	n	na/NQ/rm		ISO-col, HST (407km)
012	II	y	4	1	y	n	n	na/radar		(113km)
017	I	y	4	-	y	n	n	na		(90km)
018	I	n	4	5	y	n	n	na/submm/radar		(141km)
019	I	y	4	4	y	n	n	na/radar		(225km)
020	I	n	4	-	y	y	n	na/radar/NQ(2004/Sに観測)		(146km)
021	I	n	4	1	y	n	n	na/radar		not M-type but W-type (96km)
023	I	n	4	-	y	n	y	na		(108km)
024	I	n	3	-	n	n	n	NO		(183km)
028	I	n	4	-	y	n	y	na		(121km)

029	I	y	4	-	y	n	n	na	Speckle (212)
081	I	n	4	-	y	n	n		(256km)
087	I	n	4	2	y	n	n	na	(188km)
090	I	y	4	-	y	n	n	na	(188km)
041	I	y	4	1	y	n	n	na/radar	(174km)
042	I	n	3	1	y	n	n	na	(180km)
047	I	y	4	4	y	n	n	na	(127km)
048	I	n	3	2	y	n	n		(222km)
051	I	n	4	5	y	n	n	na	(148km)
052	I	y	4	2	y	y	n	na	(303km)
054	II	n	4	-	y	y	n	na/NQ	ISO-col(166km)
056	II	n	2	-	y	y	n	na	(113km)
065	II	y	4	4	y	y	n	NQ	ISO-col(237km)
069	I	y	4	-	y	n	n		(138km)
085	I	n	4	4	y	n	n	na	(188km)
088	I	y	4	5	y	n	n		(155km)
093	II	y	4	4	y	n	y		(188km)
094	I	y	3	-	y	n	n	na	(142km)

No.	SVC	SMC	LCC	OCC	IRAS	ISO	MSX	Other	therr.	Remarks
798	11	y	4	-	y	n	n	na		(136km)
241	1	y	4	-	y	n	n	na		(169km)
313	11	y	2	1	y	y	n	na/NQ/mm		ISO-col(96km)
354	1	y	4	-	y	n	n	na		(155km)
360	11	y	4	-	y	n	n	na		(116km)
423	1	n	2	1	y	n	n			(209km)
451	11	y	4	-	y	n	n	na		(225km)
471	11	n	3	4	y	n	n	na		(134km)
505	1	y	3	-	n	n	n	NQ		(141km)
511	1	y	4	3	y	y	n	na/NQ	(2004/SIC1001)	Speckle (344km)
532	1	y	4	3	y	y	n	na/NQ/mm/roder		ISO-col., HST, AO, Spec.(231km)
704	1	y	4	6	y	n	n	na		(317km)
776	1	y	2	-	y	n	n			(151km)

Results

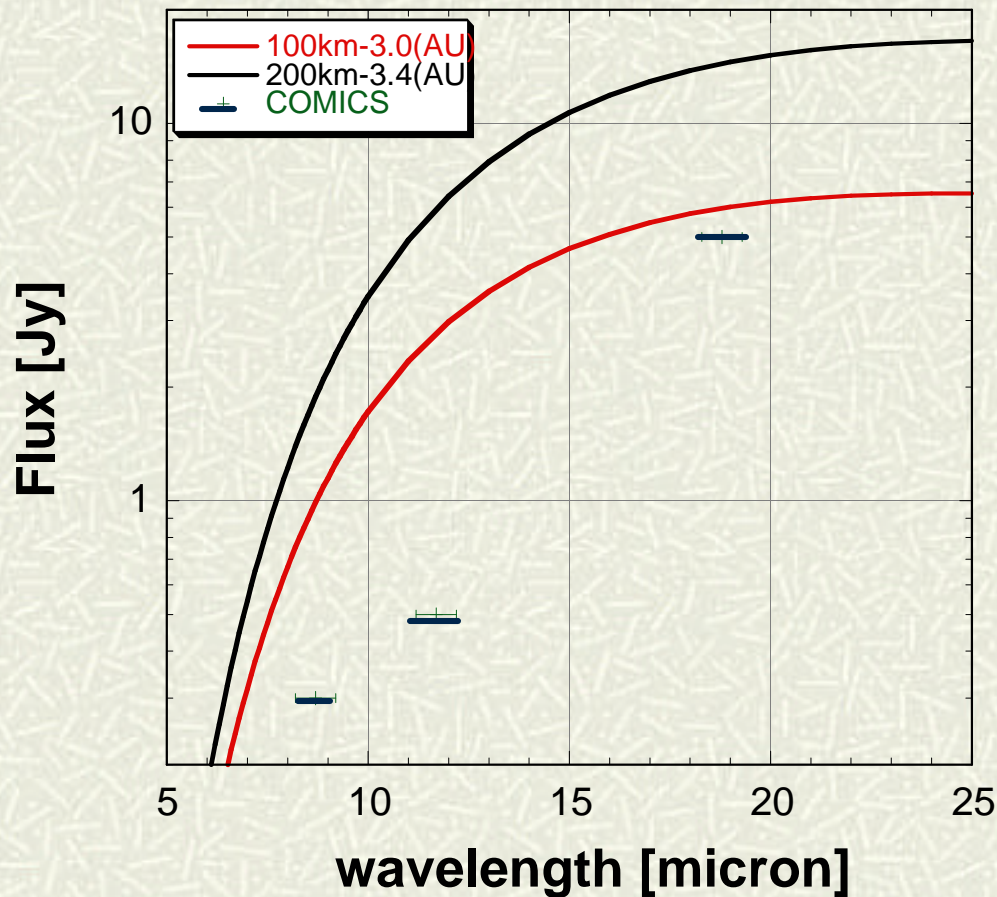
COMICS observations of 24 & 505

--> meet the requirement of at least 10 % photometric accuracy

all standard candidates have the IR observation data!

but some asteroids have only poor IR data (only IRAS)

Further observations



- 49 standard candidate asteroids can be observed with **SUBARU/COMICS** within ~10% accuracy (30sec integration 2sets)

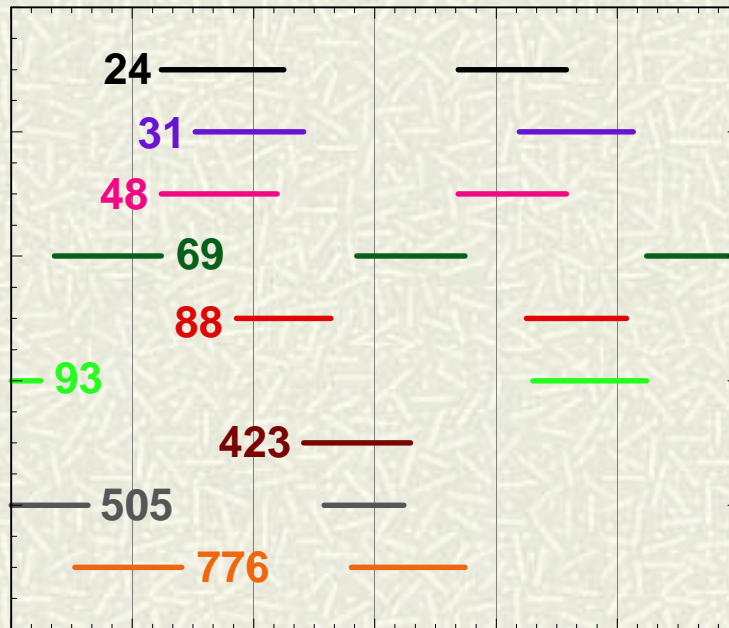
- Current status:
3 asteroids were observed at June 2004

5 Astraea
20 Massalia
511 Davida

Next steps & Future Works

Our COMCIS observations

--> all standard candidates have the IR observation data
but some asteroids have only poor IR data (only IRAS)



2004/10 2005/4 2005/10 2006/4 2006/10 2007/4 2007/10

Epoch [year/month]

--> next observation targets

31 Euphrosyne

48 Doris

69 Hesperia

88 Thisbe,

93 Minerva

423 Diotima

776 Berbericia

(24 & 505 once more)

Summary

- Asteroids are calibration standards for ASTORO-F/FIS
- 49 asteroids are prepared as calibrator candidates
- 5 asteroids were observed by SUBARU/COMICS
- All standard candidates have the IR observational data now but some asteroids have only poor IR data (only IRAS)
- We will continue thermal (MIR) observations (& mm ?) (please observe these asteroids in MIR if you can access MIR & mm? instruments/observatory)

Please ask about ASTRO-F --> Yamamura-san
TPM --> Müller-san

4 Vesta

Calibration for ASTRO-F/FIS

? ? ? ? ? ? detection limit ? ? ? ? ? ?

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