Absolute measurements of the Cosmic Infrared Background using eclipsed Galilean satellites with Subaru/IRCS+AO188

2013/04/05 Green Flash

Ganymean

2013/11/11 Moonbow

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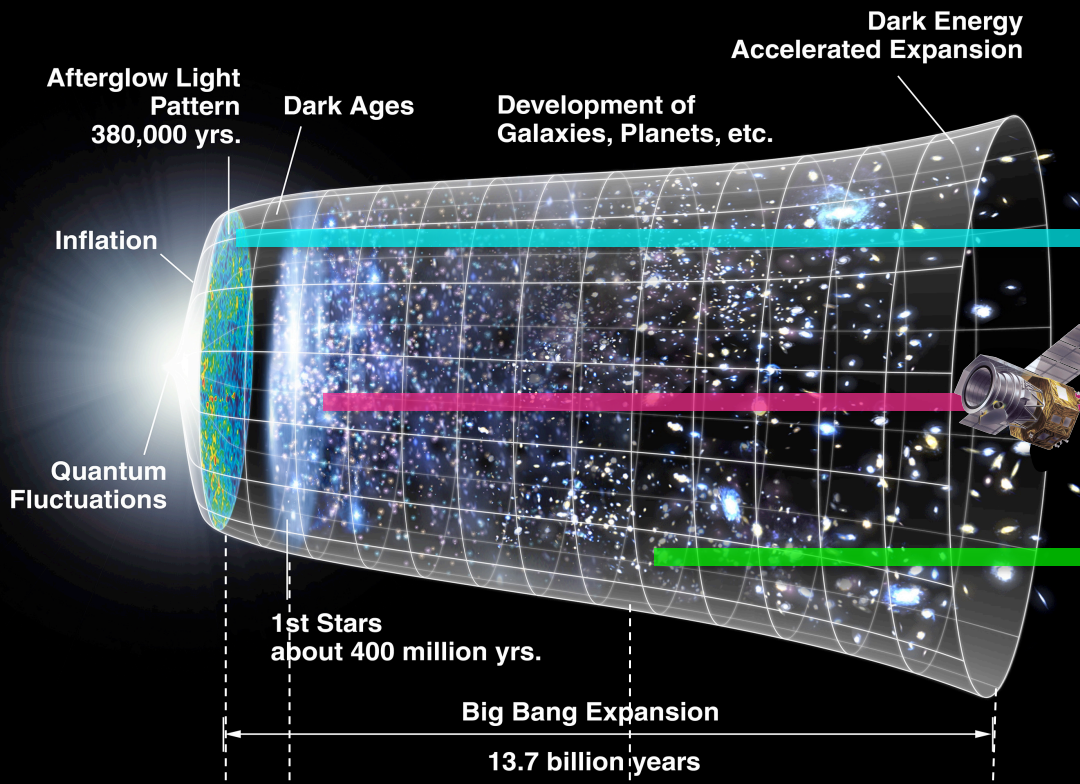
Science target : Early Universe

Structure formation history of the universe



Cosmic Microwave Background (CMB)

Cosmic Infrared Background (CIB)

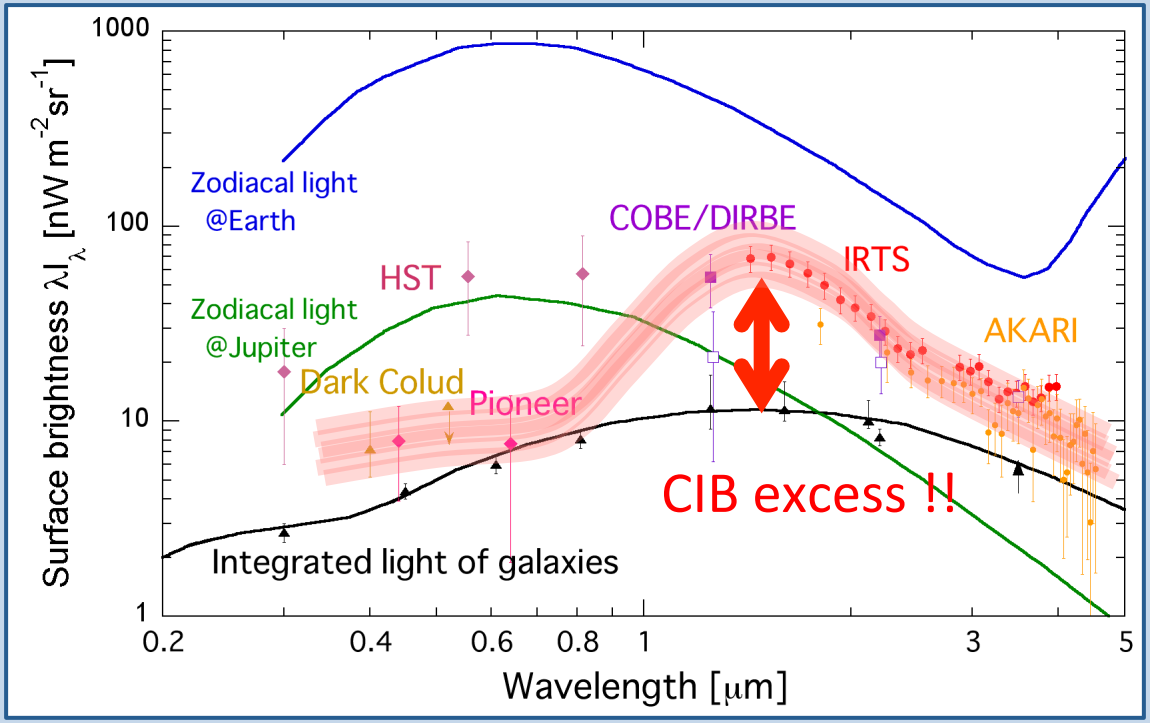
Deep Cosmological Survey

Galaxy formation & evolustion

Inflation Dark Ages Re-ionization Now

10^{-36}s 0.38M yrs. 1G yrs. 10G yrs. 137G yrs. Age of the universe

Cosmic Infrared Background



CIB spectrum with a peak at 1.5μm

Lyman-α emission from the first stars (@z~7) ?

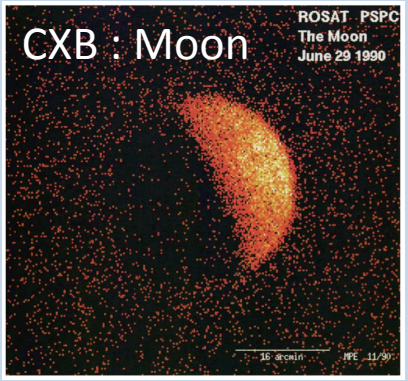
cannot be explained by foreground galaxies

difficulty of the zodiacal light subtraction

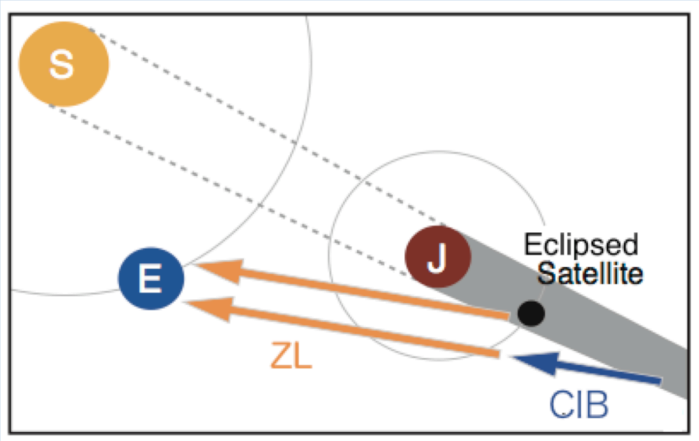
Galilean satellite occulting method

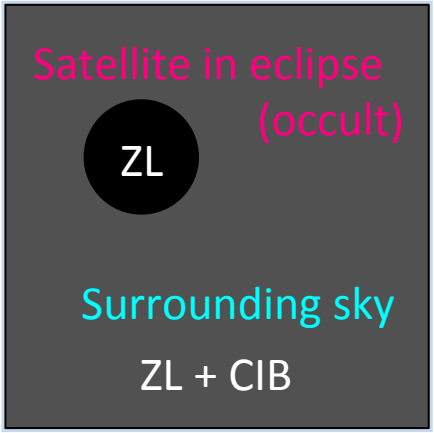
Galilean satellites
- × Io (volcanic activity)
- ○ Europa, Ganymede, Callisto

Other planet systems?
- Marts : still within ZL cloud
- Saturn and father : eclipses are rare



Schmitt et al. (1991)





CIB brightness without any ZL subtraction uncertainty

Subaru Observation : IRCS+AO188

Target : All targets are different non-sidereal objects!

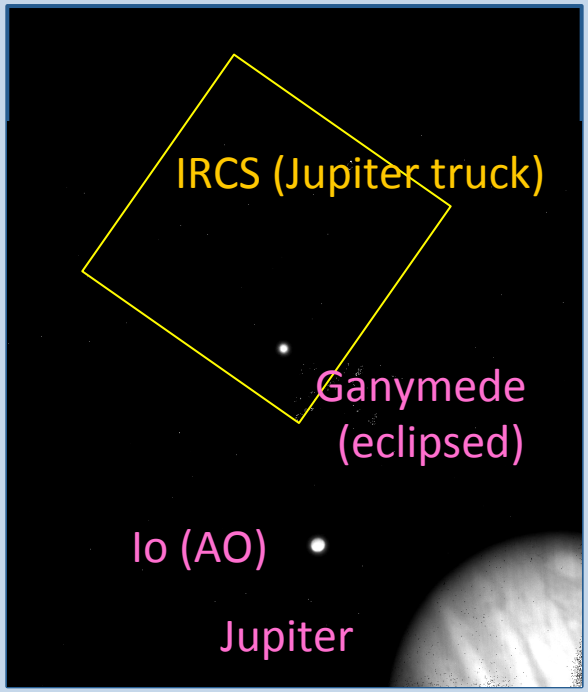
- Observation target : Ganymede
- AO Guide Star : Io
- Telescope trucking : Jupiter (out of FOV)

AO special observation

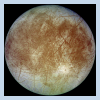
- HOWFS : non-sidereal offset trucking
  close the AO loop
  monitor the sky condition
- LOWFS : monitor the surface brightness
  of Ganymede at V-band simultaneously.

Target Elevation is very low.

- ADC
- Telescope operation



Our observation log

Europa 

2012/02/21	Subaru/IRCS	1.25 μm (J-band)	0.57-0.62	<1.5 μJy
2013/04/08	Hubble/WFC3	1.49 μm (F139M)	0.54-0.76	<5.5 μJy
2013/11/18	Subaru/IRCS	1.69 μm (CH4-long)	0.76-0.85	<88 μJy

Ganymede 

2012/07/26	Subaru/IRCS	1.25 μm (J-band)	0.86-0.95	60-100 μJy
2012/05/26	Spitzer/IRAC	3.60 μm (CH1)	>0.87	<3.6 μJy
2013/02/05	Hubble/WFC3	1.60 μm (F160W)	0.77-0.94	60-80 μJy
2013/05/05	Hubble/WFC3	1.49 μm (F139M)	0.79-0.74	25-35 μJy

Callisto 

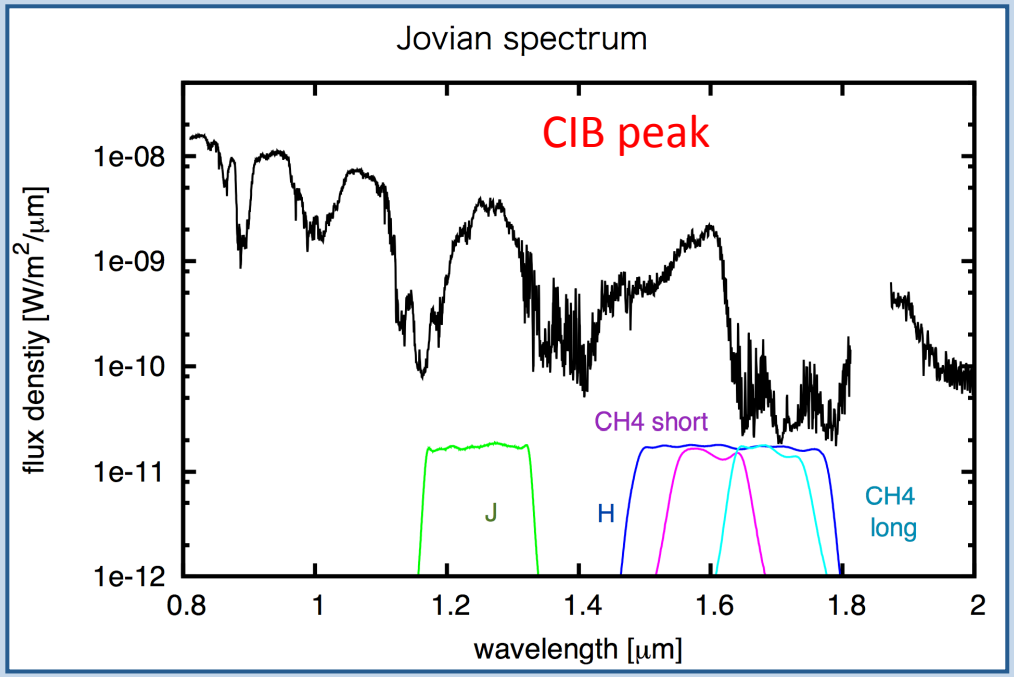
2013/10/20	Subaru/IRCS	1.25 μm (J-band)	0.88-0.94	20-40 μJy

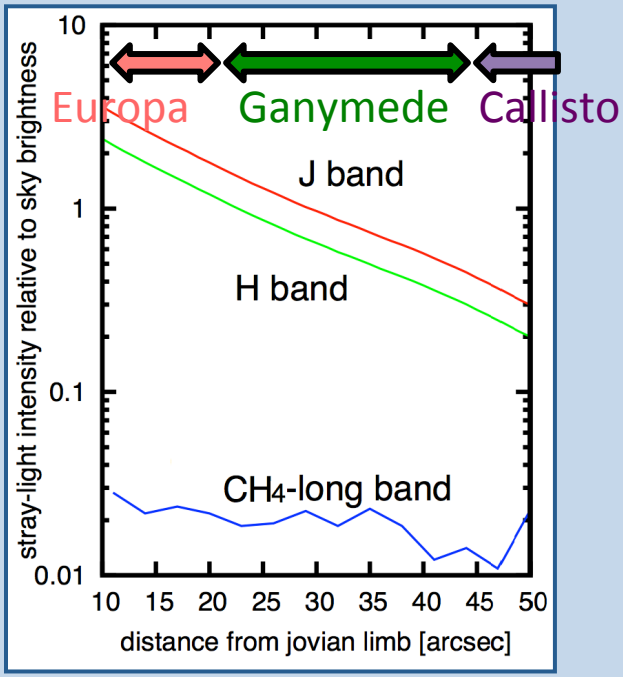
Stray-light investigation

To reduce the stray-ligh is very important

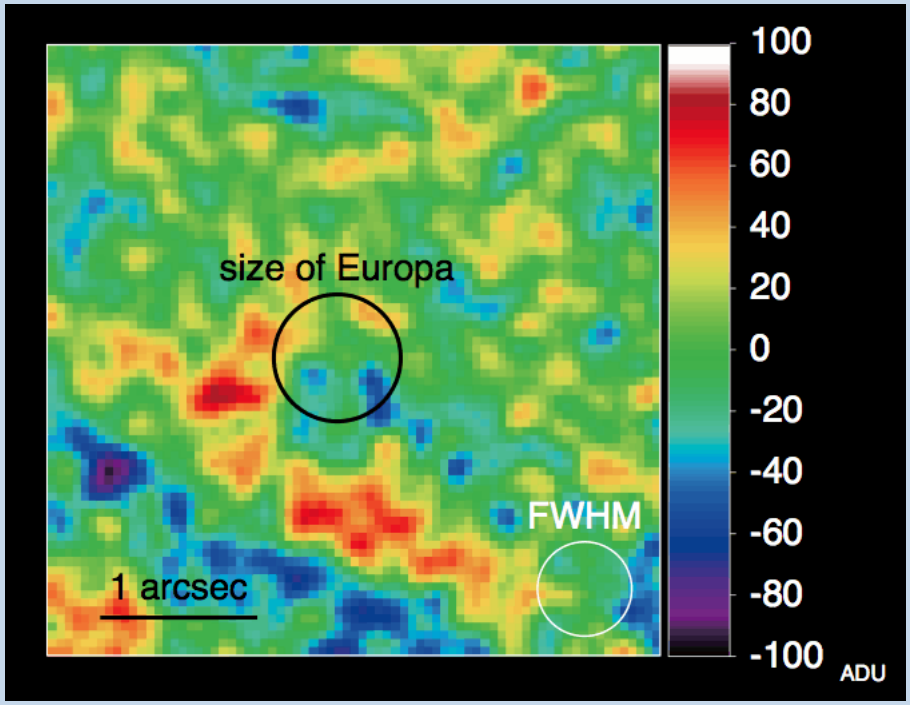
- Scattered Jovian light in the earth atmosphere
- Scattered/reflected Jovian light inside the optics

CH4-long band reduces Jovian stray light

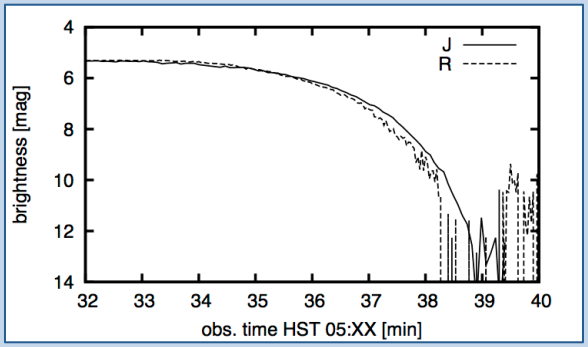




Result : Europa eclipse



- dark (non detection)
- Always bad weather …
- Comparable to the expected CIB intensity



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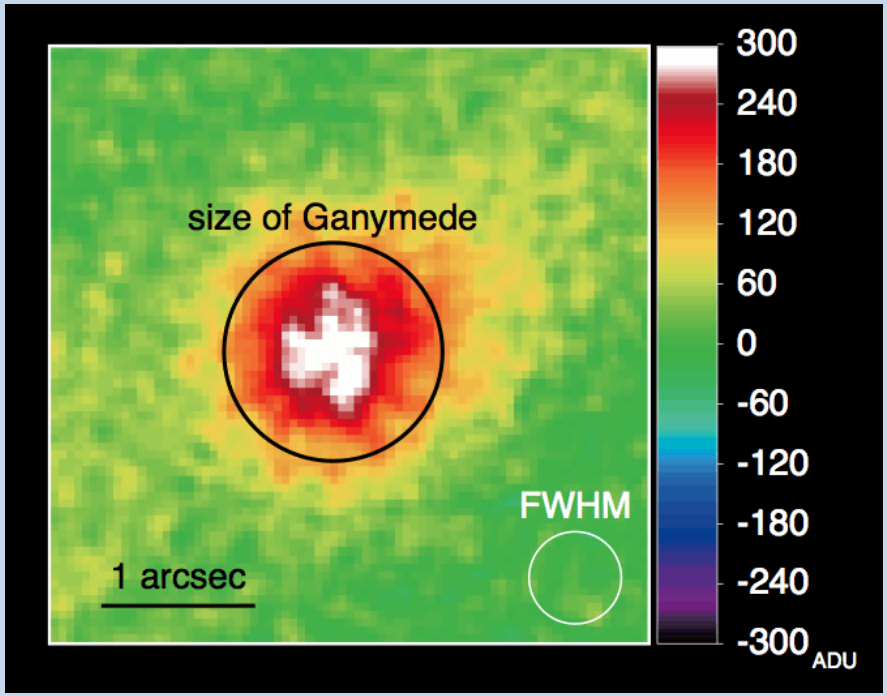
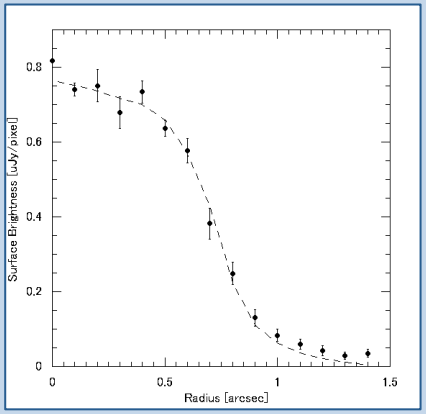
Result : Ganymede eclipse



- Positive detection !!
- Ganymede is bright even in eclipse (~1e-5)
- uniform



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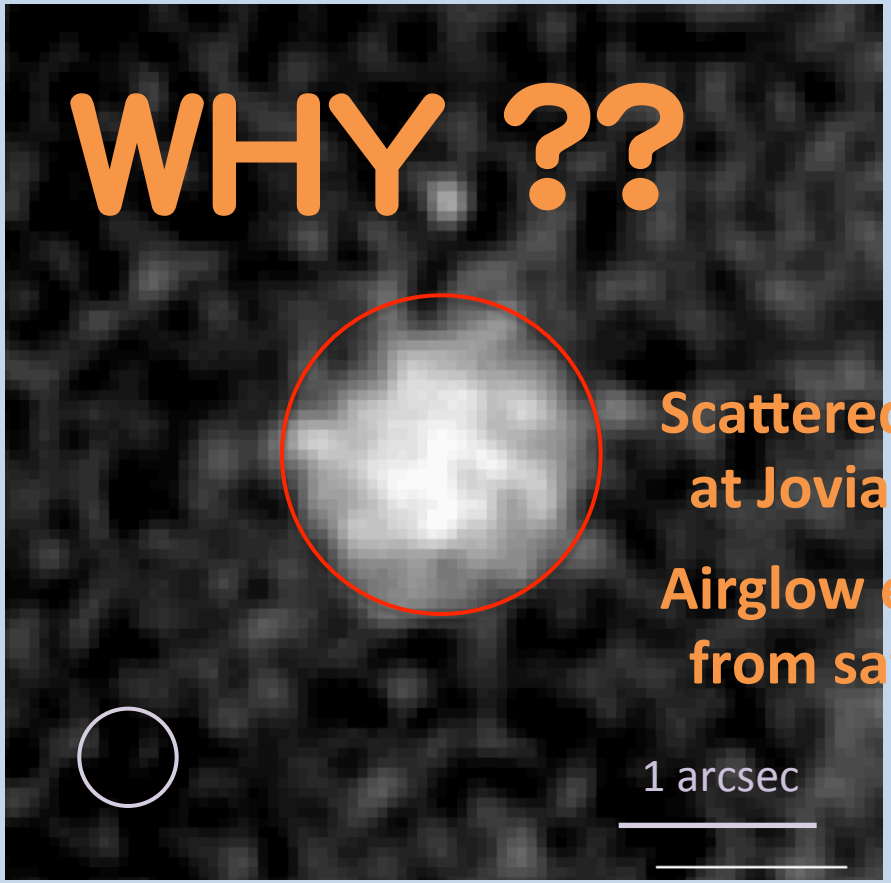
Result : Callisto eclipse



- Positive detection !!
- Callisto is bright even in eclipse (~1e-6)
- uniform

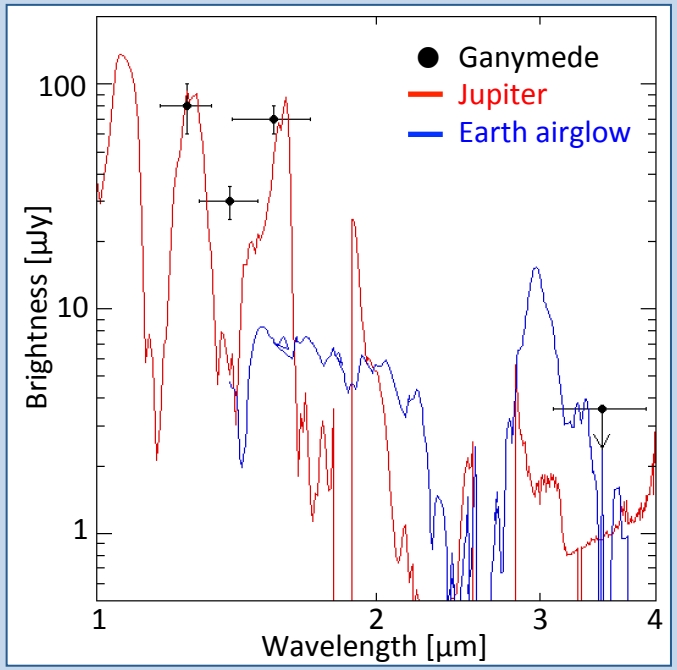
Scattered sunlight at Jovian upper atmosphere ?

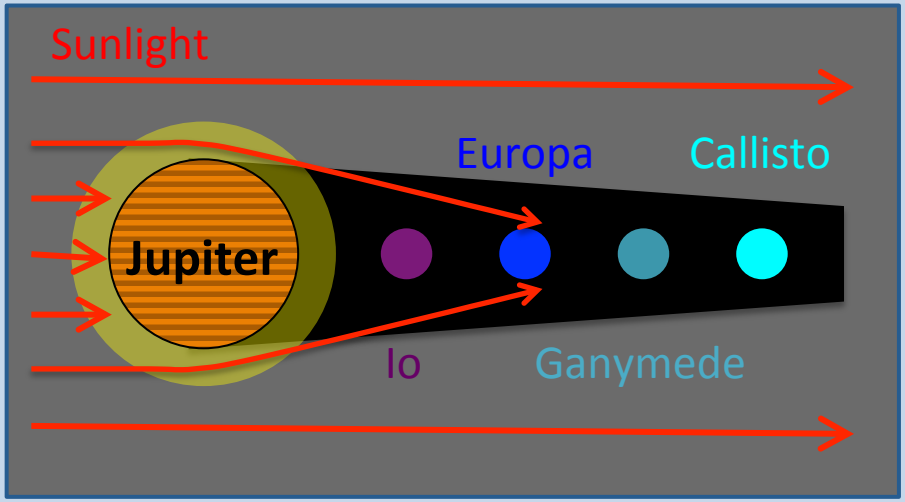
Airglow emission from satellites' diffuse atmosphere ?

2013/10/20	Subaru/IRCS	1.25 μm (J-band)	0.88-0.94	20-40 μJy

Why positive detection (1) ??

Ganymede spectrum in eclipse looks similar to Jovian spectrum
-> scattered sunlight at Jovian upper atmosphere ?



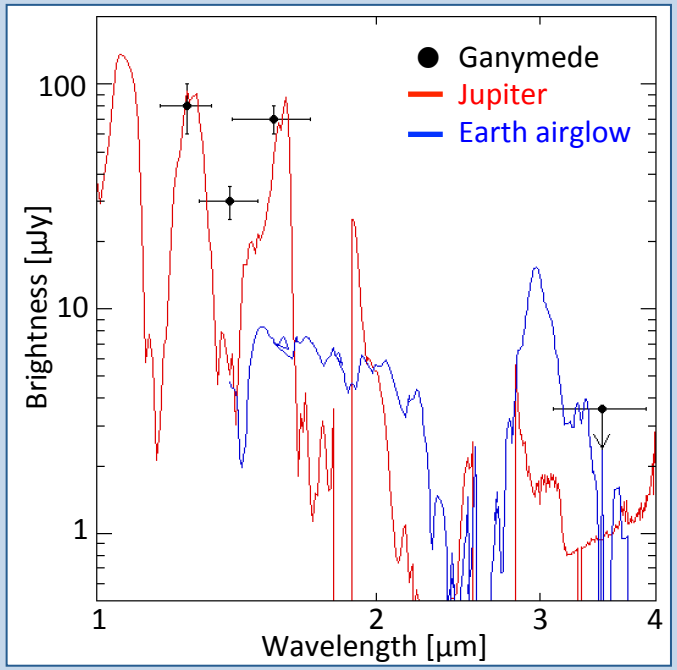


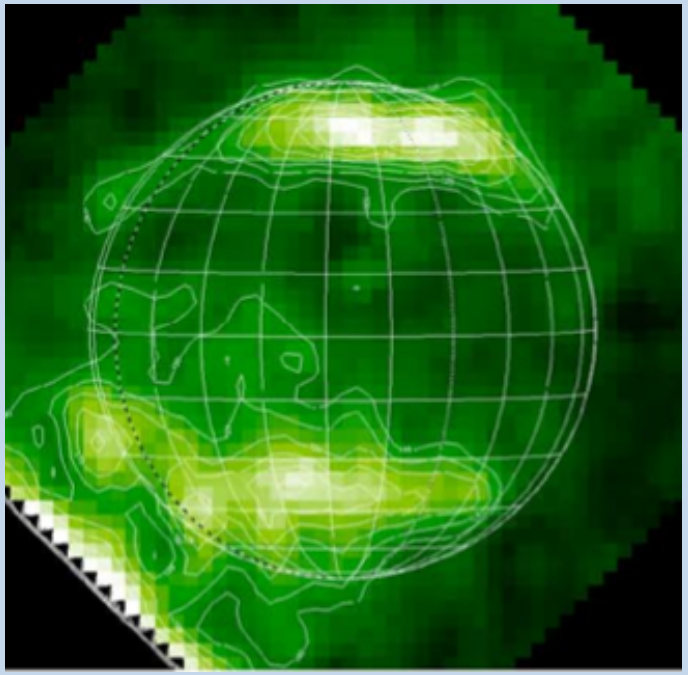
Callisto was darker than Ganymede ?
Jovian atmosphere modeling is on-going !!

Why positive detection (2) ??

Airglow emission from satellites' diffuse atmosphere ?

(c.f.) OH emission on the earth





Summary

- We have done the deep imaging observations of the Galilean satellites (Europa, Ganymede, and Callisto) eclipsed by jovian shadow with Subaru/IRCS, Hubble/WFC3, and Spitzer/IRAC.

- We found that Europa in eclipse was dark enough to measure the CIB.
- CIB brightness will be measured with S/N~5 for 3 hours integration.

- We discovered that Ganymede and Callisto in eclipse were surprisingly bright at 1.5 μm.
  - scattered sunlight at Jovian upper atmosphere ?