Planning for MAJIS plumes observations

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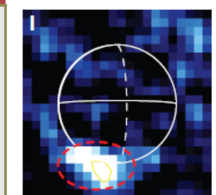
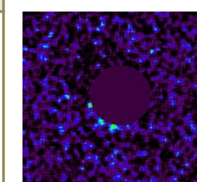
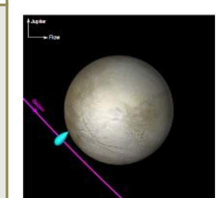
- **Evidences for plumes on Europa**

(always very close to the detection limit)

Obs date	Detection type	Inferred features	Ref
2012	Remote from HST (coincident UV emissions of H and O)	• 2 plumes 200 km high • Southern hemisphere • Water vapor ($10^{20} m^{-2}$) • Time variability (true anomaly correlation?)	**Roth et al.,2014**, Science,343,171.
2014 2015	Remote from HST (UV limb absorption against Jupiter)	• 2 plumes south + 1 plume equator • Similar column • Time variability (but not true anomaly correlation)	**Sparks et al.,2016**, ApJ,829,121.
1997 2000 (reanalyses after the first two)	In situ (Galileo magnetic field and plasma wave measurements)	• 1 detection equator • 1 possible detection polar • Column $3*10^{20} m^{-2}$ • 400 km high	**Blocker et al.,2016**, JGR,121,9794. Jia et al,2018, Nature Astr.,2,459.







- General plumes features in agreement with the Enceladus' ones (size, density, composition)
- No evidences for Ganymede and Callisto, but they cannot be ruled out

How MAJIS can detect plumes on icy satellites?

- **1) Scattering of solar light by the solid grains within the plume**
  Most common and effective approach

- **2) Light absorption against a bright source (e.g. transiting Jupiter)**
  Effective but strongly constrained in geometry

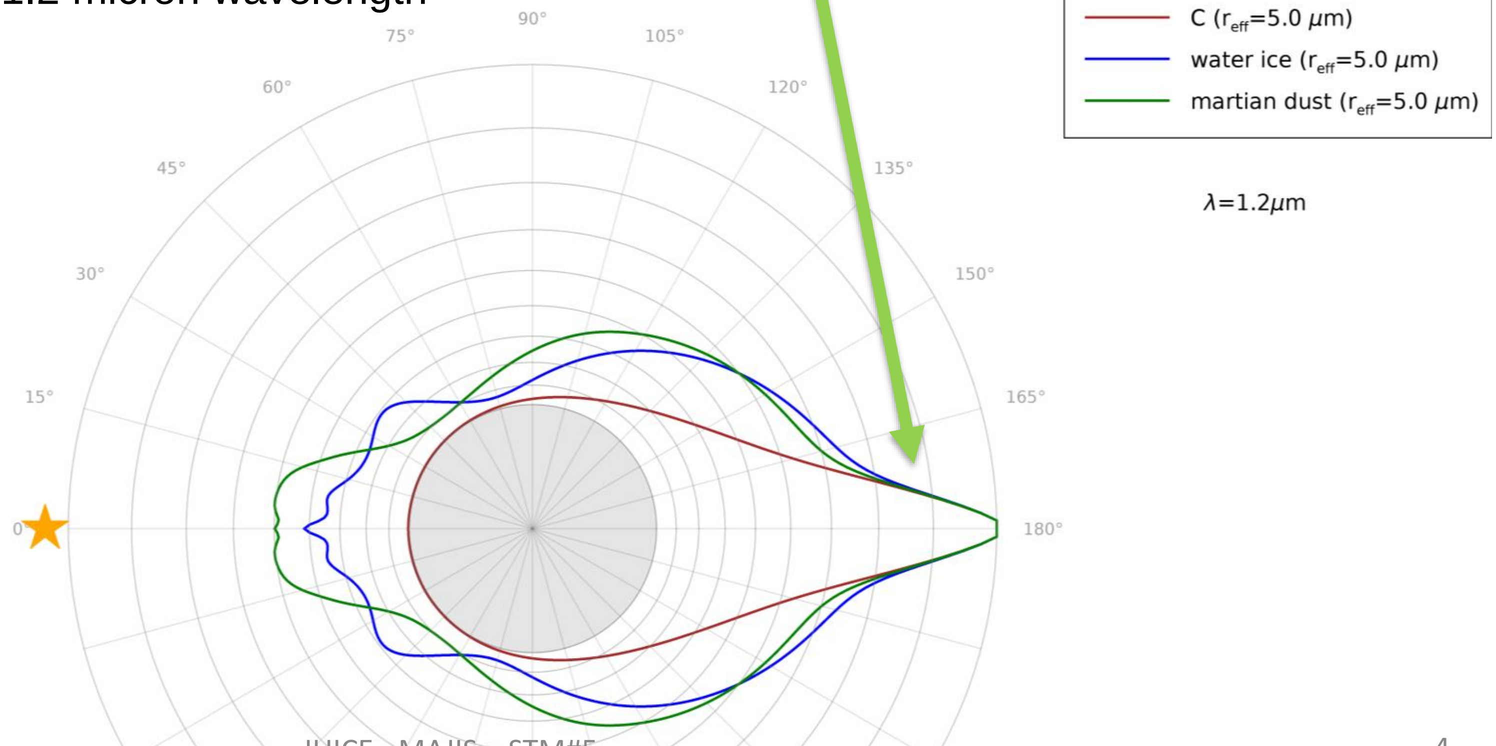
- **3) Local enhancement of limb emission by water**
  Preliminary sensitivity study show that the H2O 2.7 micron emission associated to plumes could be detected by MAJIS.

We will concentrate on 1) in the following.

Detection of scattered light strongly depends on:

- **Solar phase angle**, due to the scattering properties.
- **Spatial resolution**, due to the pixel filling factor.

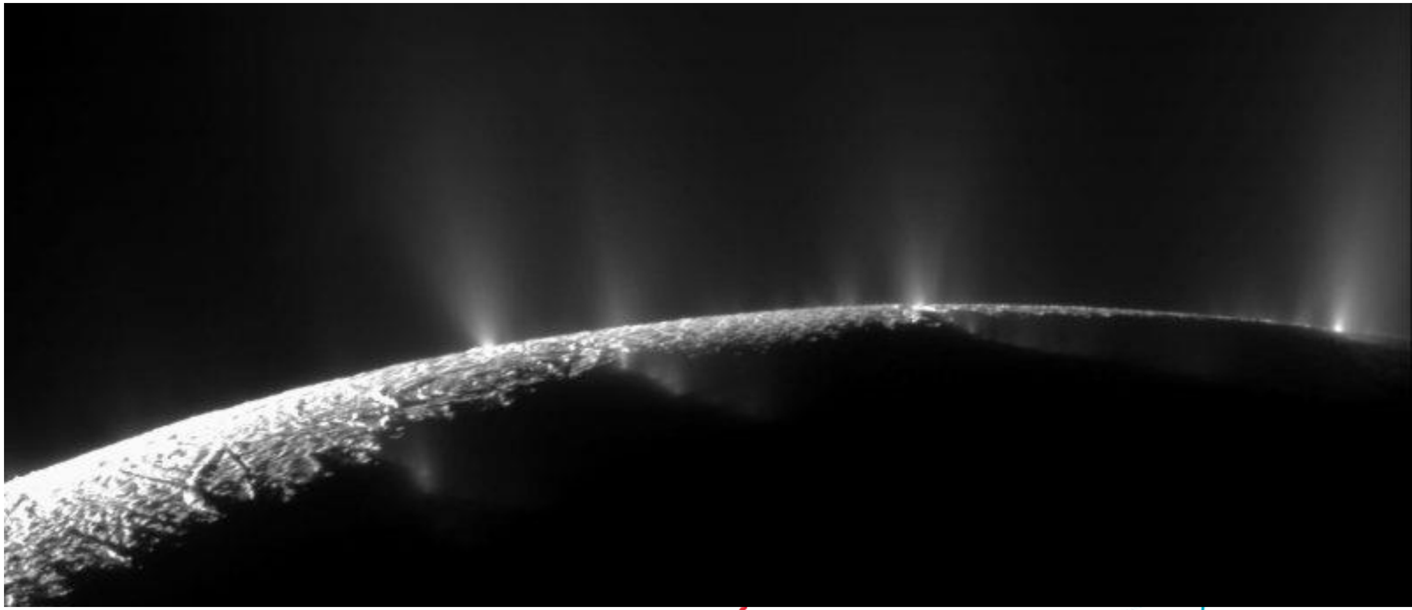
Whatever the composition, the forward scattering peak is very pronounced. Here shown for grain size distribution with reff=5 micron at 1.2 micron wavelength



Hence, most likely detection in limb viewing at high solar phase angle (like Enceladus from Cassini).

Plumes more likely detected by JANUS camera, if it is be able to cover all the satellite's limb in the FOV.

MAJIS should be fundamental in follow-ups observations, to measure spectral features of plumes, spectral slope and absorption bands



We identified so far several opportunities for MAJIS observations of plumes, on all icy Galilean satellites, by combining solar phase angle and resolution constraints

Table 1 - Statistics of plume detection time windows for MAJIS with two versions of the planned trajectory.

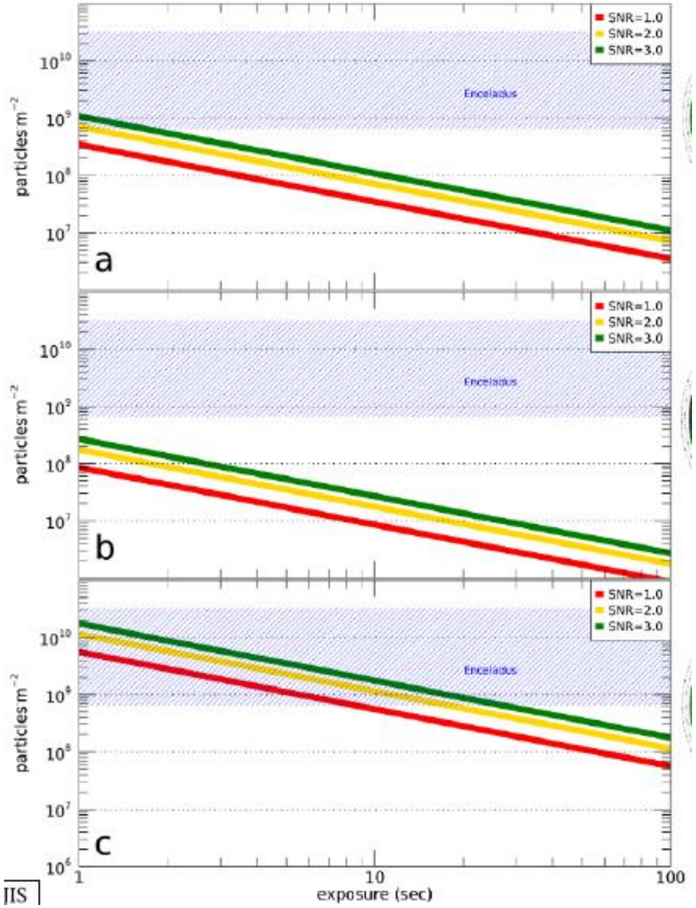
target	trajectory version	time windows with phase angle > 140° and MAJIS resolution < 100 km/pixel			MAJIS resolution, km/pixel	
		number	total time	first occurrence	most common	best case
EUROPA	3.0	27	25.9 h	2029 Oct 08	60	1.3
	4.0	21	19.7 h	2031 Dec 03	60	60
GANYMEDE	3.0	82	130.6 h	2029 Oct 07	1.0	0.4
	4.0	113	175.5 h	2029 Oct 06	1.1	0.4
CALLISTO	3.0	7	7.9 h	2030 Sep 23	0.4	0.4
	4.0	12	10.8 h	2030 Aug 10	0.4	0.4

The preliminary sensitivity studies show that MAJIS should be able to detect the signal of a plume with a density like the Enceladus' one, or even 1-2 order of magnitude thinner.

Here the case of Ganymede plume detection with SNR 1,2, or 3 in three study cases

study case	obs. dist. (km)	phase angle (°)	Sun dist. (AU)	resolution (km/pix)	MAJIS filling factor
a) distant flyby *(2030,Dec)*	189000	174	5.33	28	0.35
b) close flyby *(2030, Sep)*	4500	175	5.37	0.7	1.0
c) high orbit *(2032, Nov)*	7700	135	5.10	1.2	1.0

The «close flyby» case seems the most promising so far…



Distant flyby

Close flyby

High orbit

Next steps

1. SNR evaluation is currently done with modeled instrumental parameters that should be updated as soon as possible, as well as including despiking as noise source.

2. SNR evaluation related to the plume spectral parameters (slopes, absorption bands)

3. Data volume of these observations should be small, but spectral editing can be very effective in further reducing it. To be better evaluated.

4. Establish effective observing strategies in synergy with JANUS and other instruments.

Suggestions are welcome..

Thank you!