

Les comètes

De Ptolémée à la mission ROSETTA

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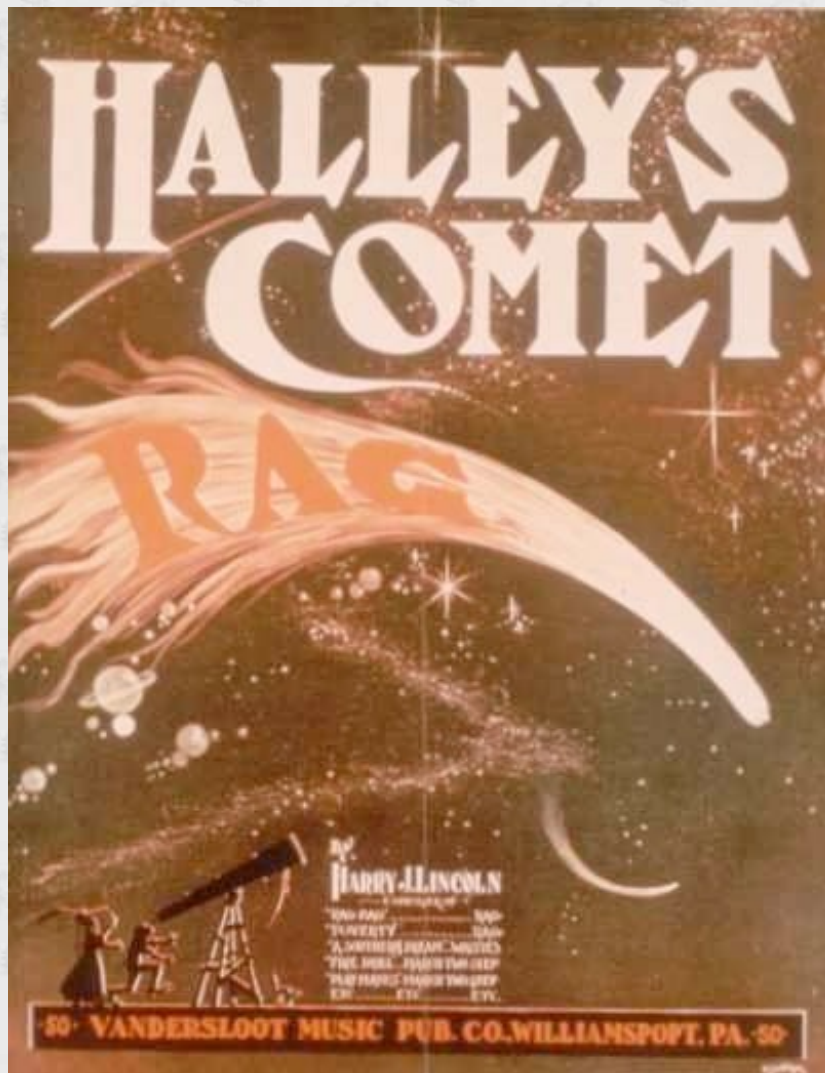


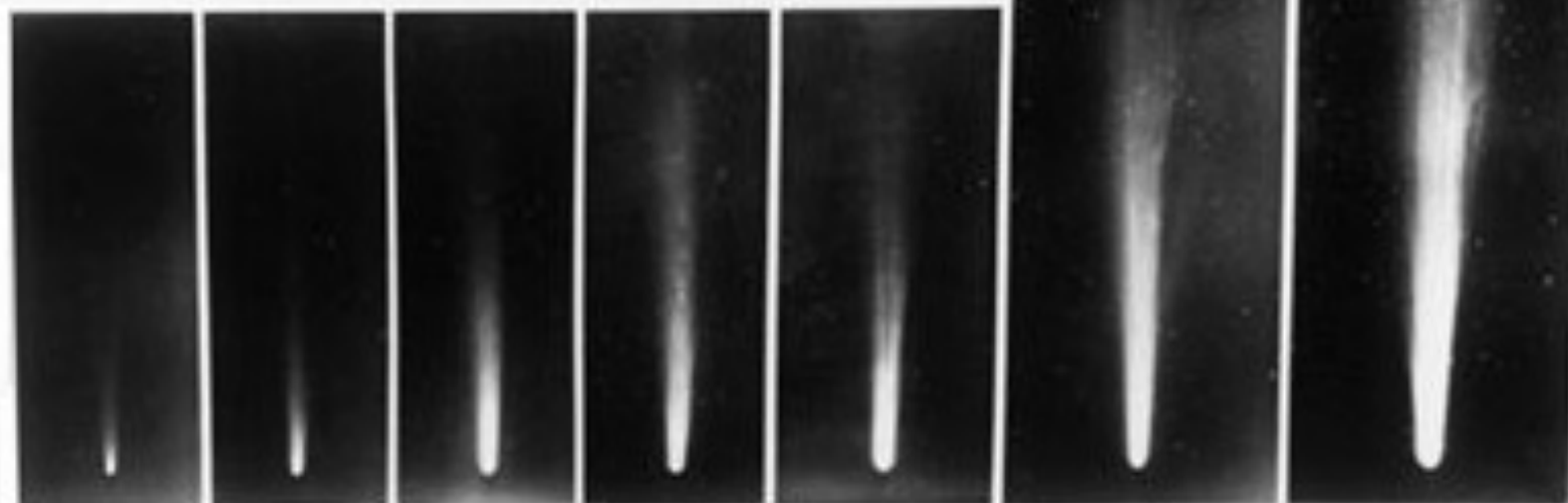


ISTI MIRANTUR STELLAS

HAROLD







April 26

April 27

April 30

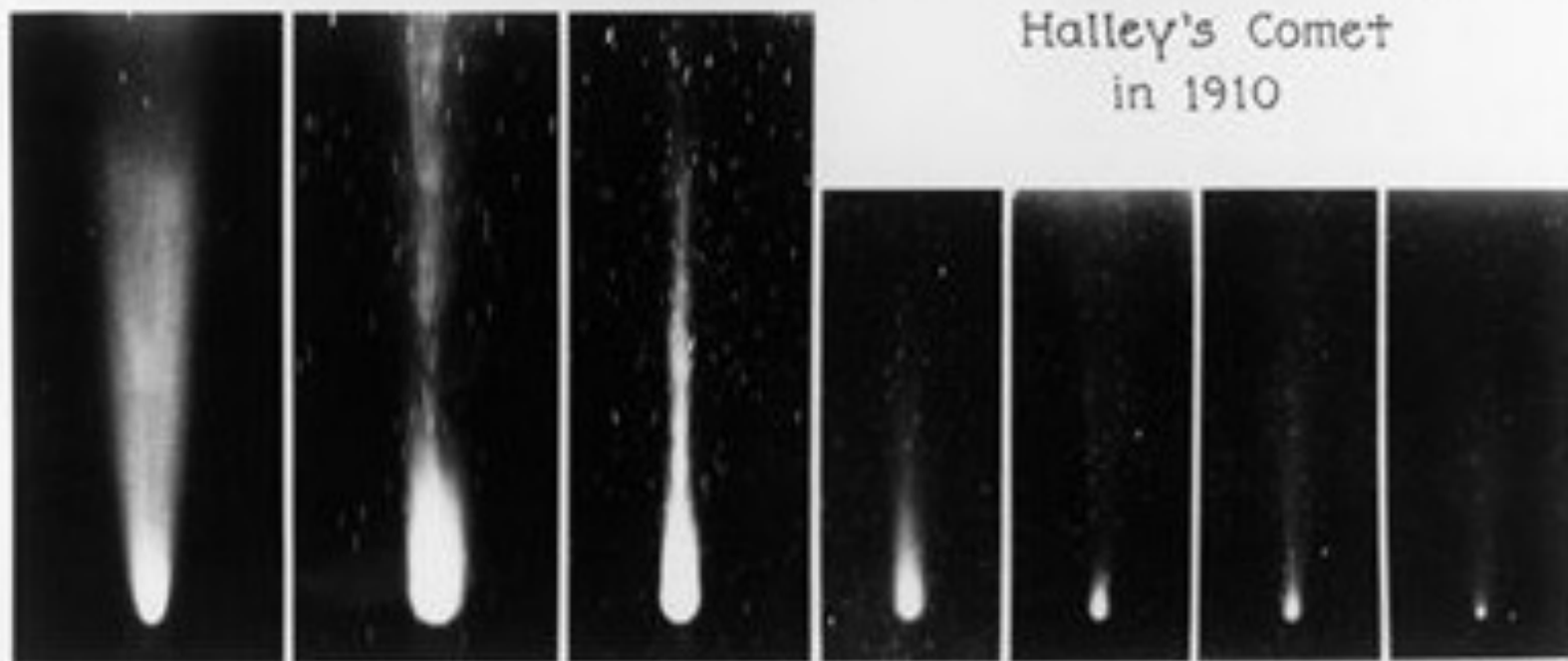
May 2

May 3

May 4

May 6

Halley's Comet in 1910



May 15

May 23


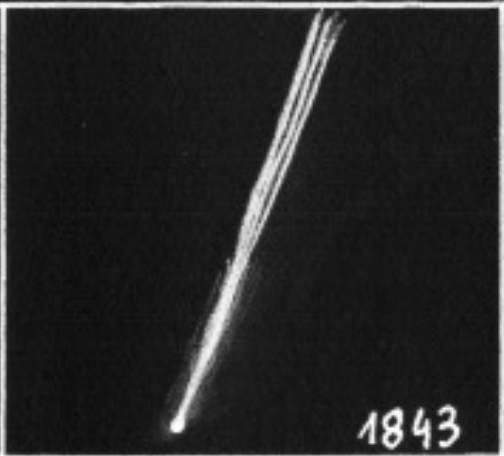

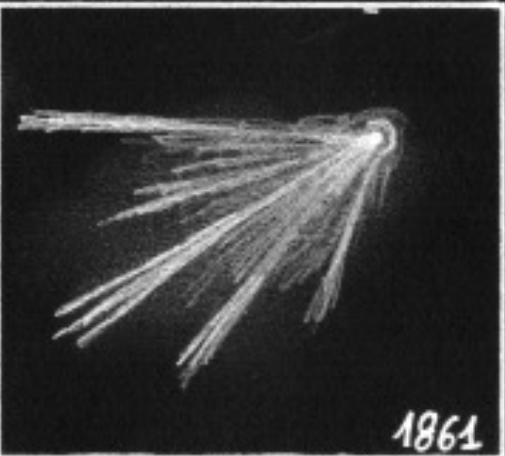


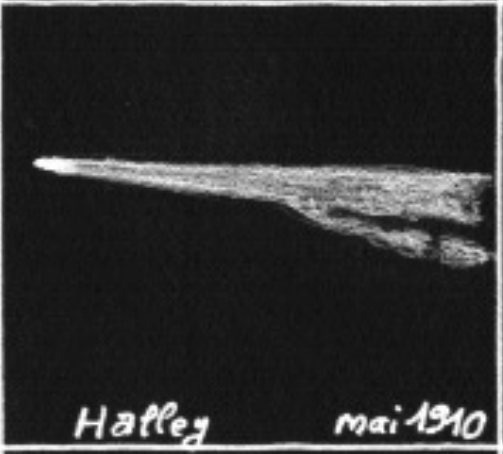




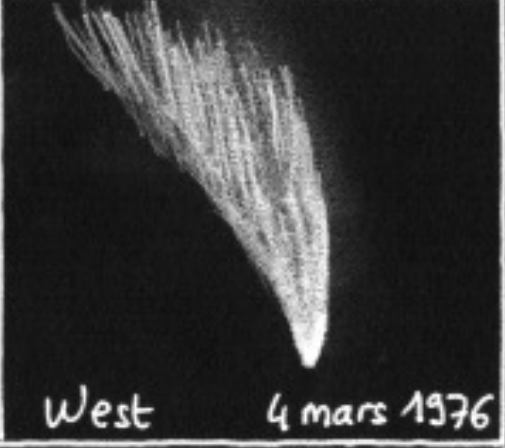
May 28

June 3

June 6

June 9

June 11

 <p>gde Ourse</p> <p>1811</p>	 <p>1843</p>	 <p>Donati 5 oct 1858</p>	 <p>1861</p>
 <p>Coggia 1874</p>	 <p>9 oct 1882</p>	 <p>Halley mai 1910</p>	 <p>Arend-Roland 25.4.1957</p>
 <p>Mrkos 22 août 1957</p>	 <p>Ikeya-Seki 29 oct 1965</p>	 <p>Bennett 25 mars 1970</p>	 <p>West 4 mars 1976</p>

" Les Grecs appellent "comète" et les Romains "étoiles chevelues" celles qui sont hérissées d'une touffe de poils couleur de sang, se dressant à leur sommet comme une chevelure.

Les Grecs nomment "Pogonias" (barbues), celles qui traînent à leur partie inférieure une crinière en forme de longue barbe.

Les "Acontias", présages d'événements tout à fait imminents, filent comme des javelots.

Les "Certias" ont la forme d'une corne.

Les "Lampadias" imitent les torches ardentes. Les "Hippias", des crinières de chevaux animées d'un mouvement très rapide et tournoyant sur elles-mêmes.

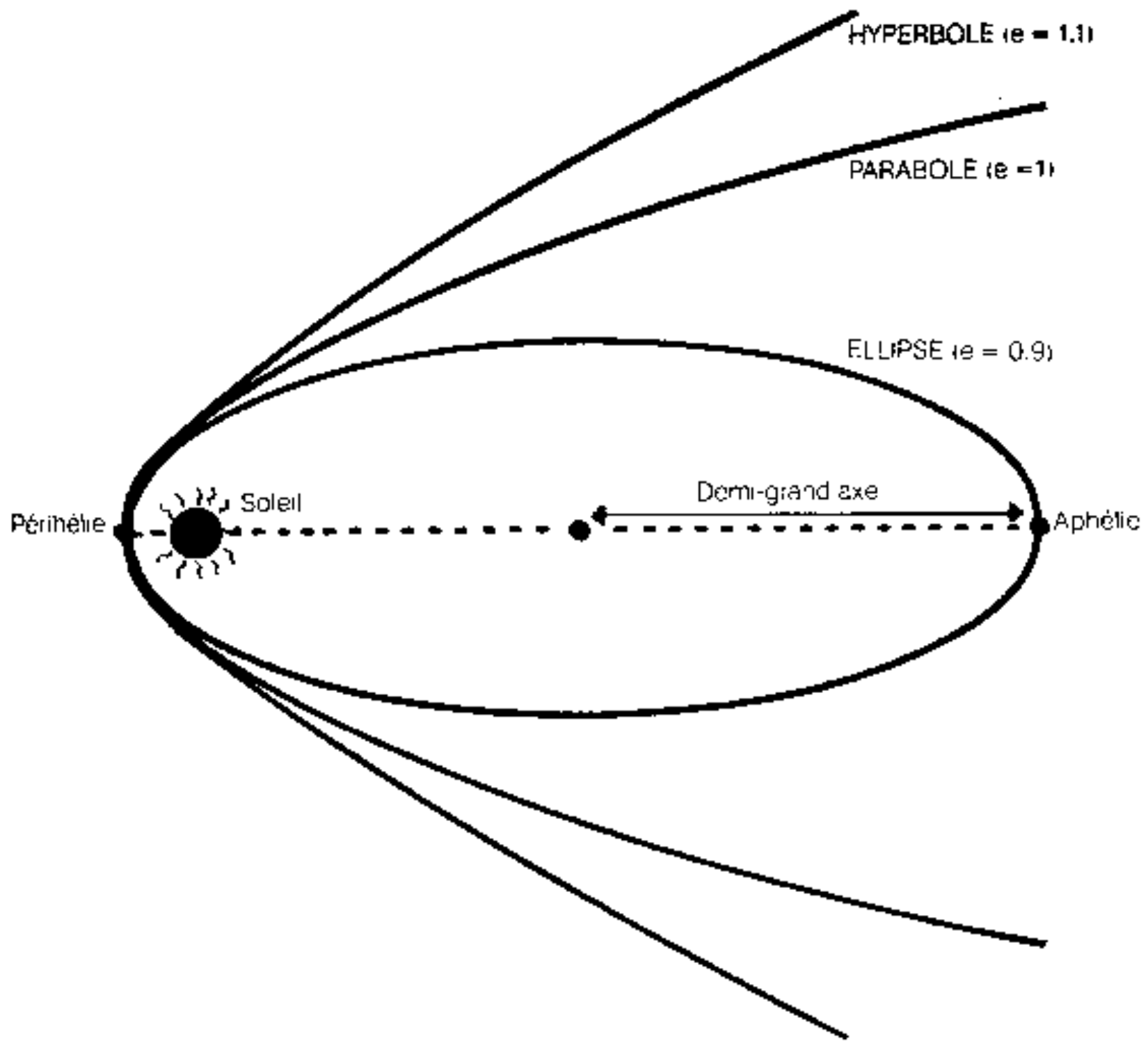
On rencontre aussi les comètes "Boucs" d'aspect poilu, enveloppées d'une sorte de nuage.

Il est arrivé une fois qu'une crinière s'est transformée en lance..."

Pline l'Ancien, 77 après Jésus Christ



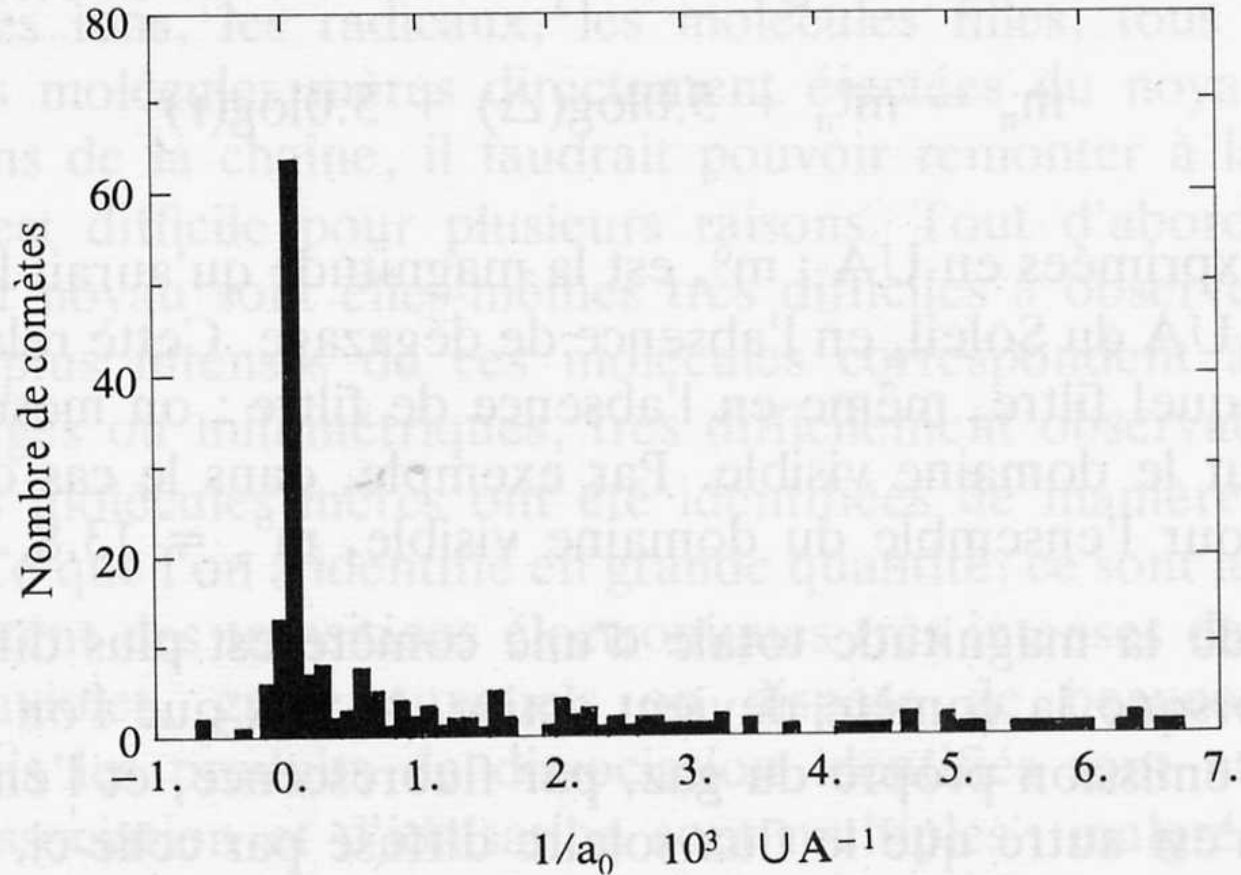
LES ORBITES DES COMÈTES

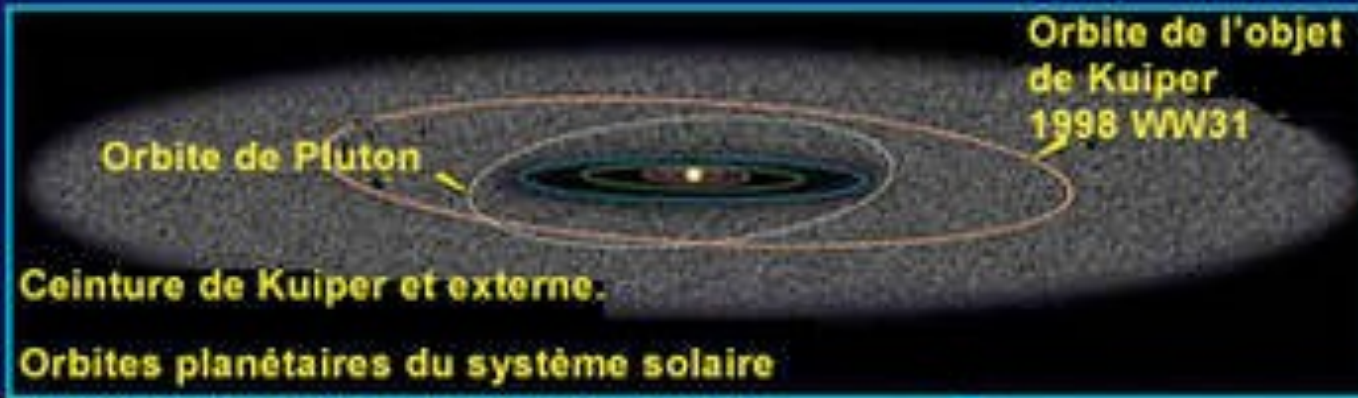


Le Nuage de Oort

Réservoir de comètes : 50000 - 100000 U.A.

- Trajectoires = ellipses : **Comètes appartiennent au système solaire**
- Estimation = 10^{12} comètes
- 5-10 % potentiellement éjectables par perturbation gravitationnelle



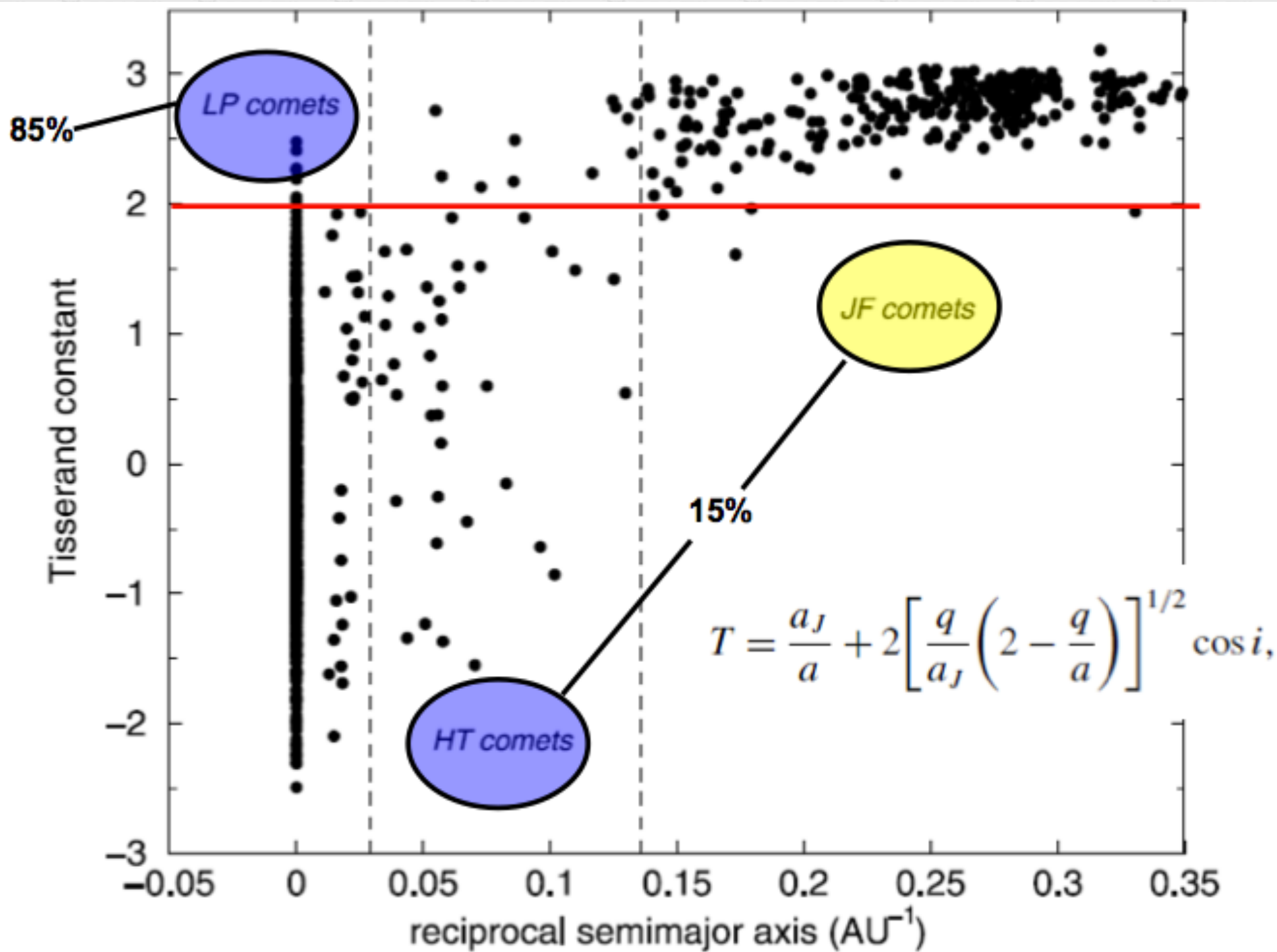


1990

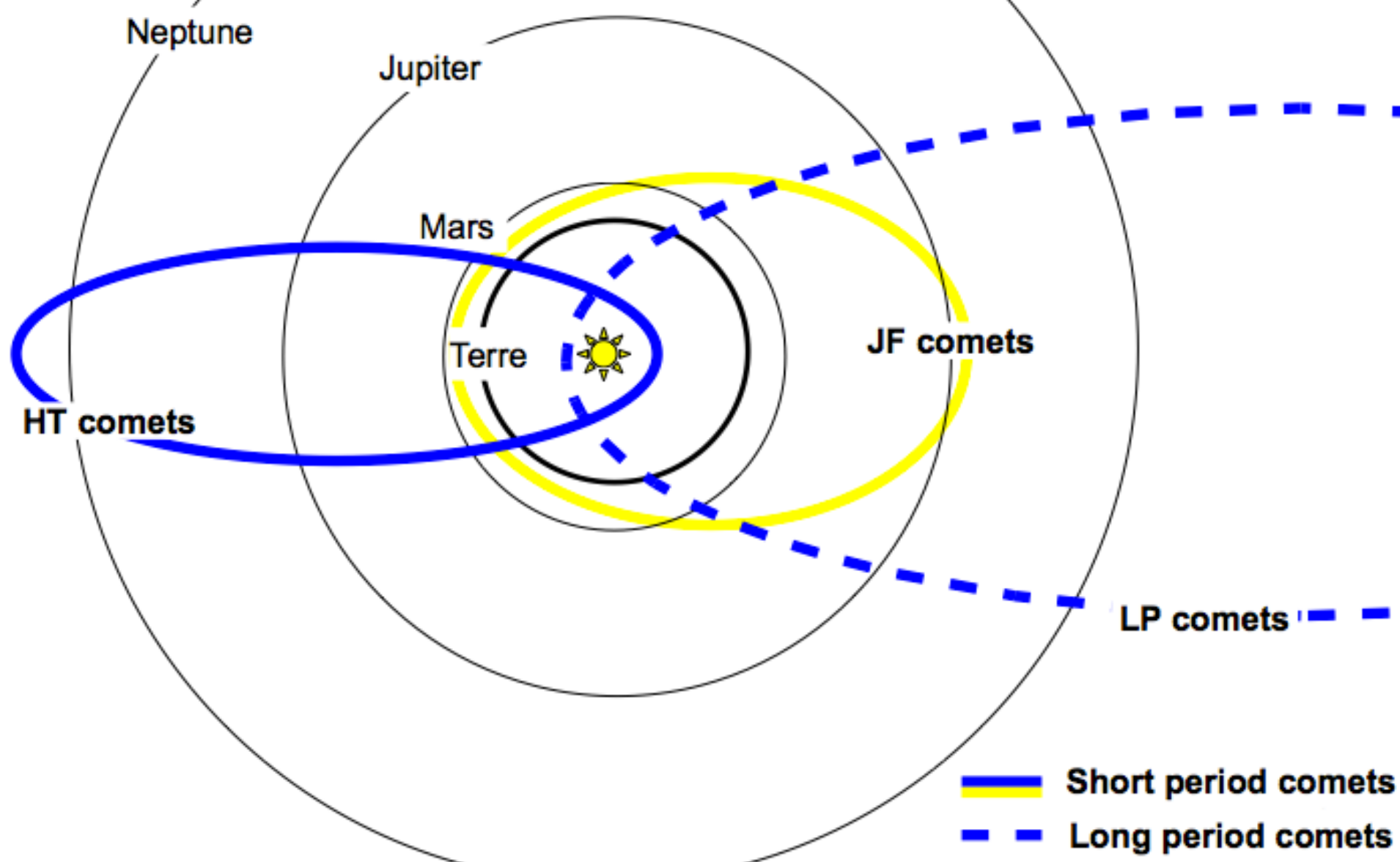
Le nuage d'Oort.
(contient des milliards de comètes)

1950

Oort Cloud cutaway drawing adapted from Donald K. Yeoman's illustration (NASA, JPL)



Comets families



Les comètes périodiques les plus connues

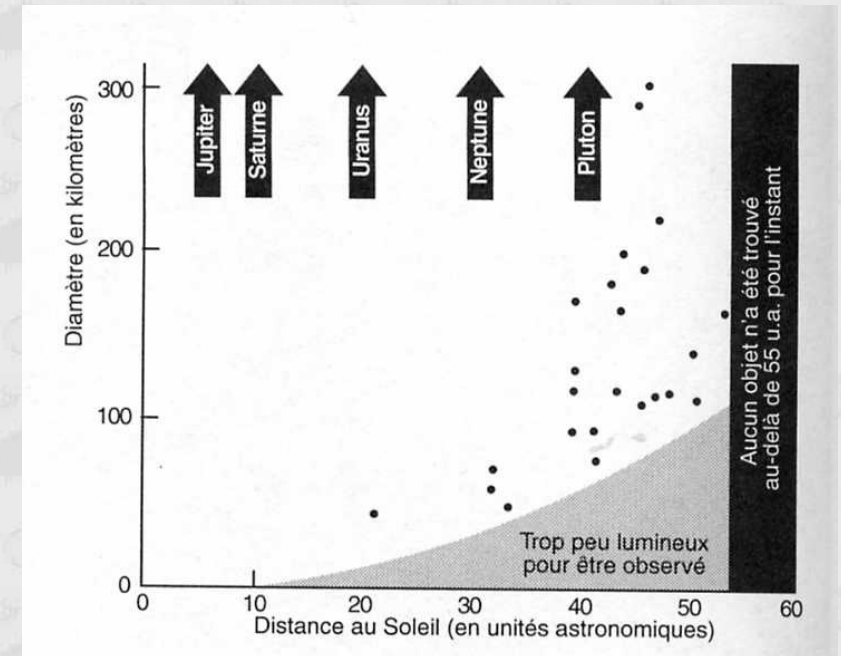
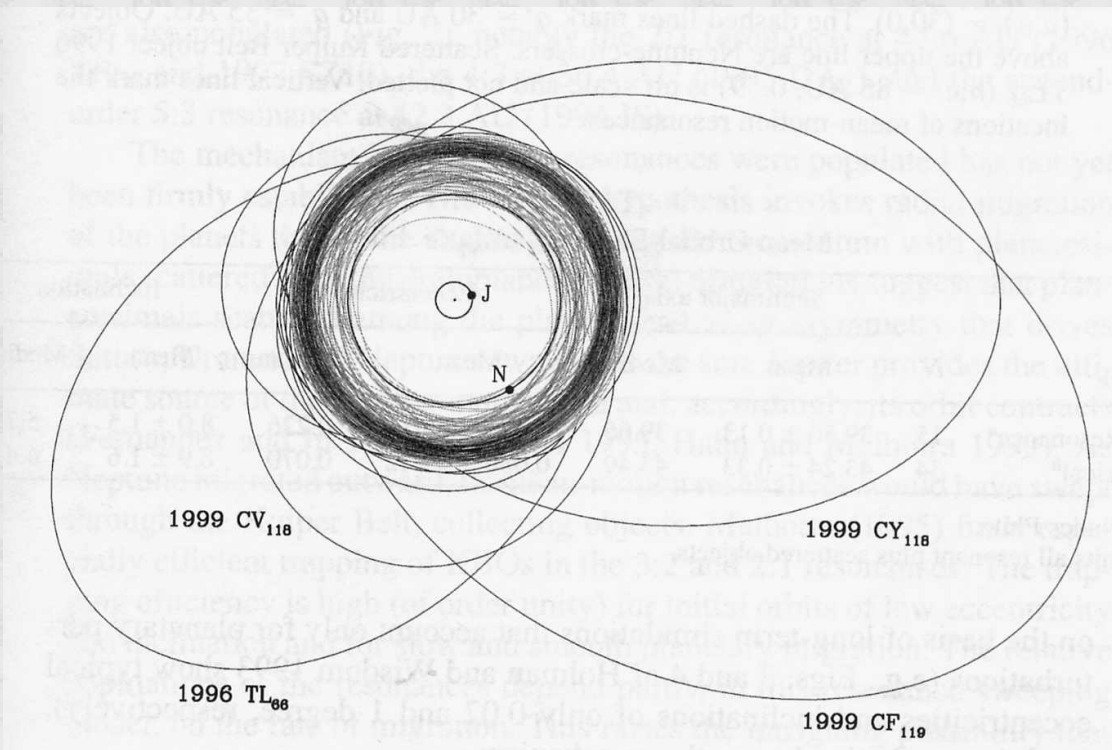
N°	Nom	P Durée de la révolution sidérale (ans)	q Distance périhélie (UA)	Q Distance aphélie (UA)
1	Encke	3.305	0.340 66	4.097 0
2	Grigg-Skjellerup	5.100	0.993 38	4.932 1
3	Tempel 2	5.270	1.369 39	4.687 6
4	Honda-Mrkos-Pajdusakova	5.279	0.578 87	5.485 1
5	Neujmin 2	5.43	1.338 18	4.840 5
6	Brorsen	5.46	0.589 85	5.613 2
7	Tempel 1	5.498	1.496 86	4.733 6
8	Tuttle-Giacobini-Kresak	5.56	1.151 92	5.125 6
9	Tempel Swift	5.68	1.152 56	5.217 3
10	Wirtanen	5.875	1.256 06	5.255 6
11	D'Arrest	6.228	1.164 00	5.606 4
12	Du Toit-Neujmin-Delporte	6.306	1.677 05	5.149 7
13	De Vico-Swift	6.31	1.624 28	5.207 3
14	Pons-Winnecke	6.362	1.254 22	5.612 6
15	Forbes	6.397	1.533 07	5.358 8
16	Kopff	6.430	1.571 99	5.343 3
17	Schwassmann-Wachmann 2	6.509	2.142 19	4.830 3
18	Giacobini-Zinner	6.517	0.993 99	5.983 6
19	Wolf-Harrington	6.551	1.621 79	5.380 3
20	Churyumov-Gerasimenko	6.588	1.298 49	5.730 3
21	Biela (noyau A)	6.62	0.860 59	6.188 5
22	Tsuchinshan 1	6.64	1.492 51	5.570 6
23	Perrine-Mrkos	6.72	1.272 21	5.847 6
24	Reinmuth 2	6.736	1.941 05	5.192 3
25	Johnson	6.763	2.195 66	4.957 1
26	Borrelly	6.765	1.316 46	5.837 2
27	Tsuchinshan 2	6.80	1.774 95	5.403 2
28	Harrington	6.802	1.582 45	5.597 5

N°	Nom	P Durée de la révolution sidérale (ans)	q Distance périhélie (UA)	Q Distance aphélie (UA)
29	Gunn	6.803	2.444 93	4.735 6
30	Arend-Rigaux	6.838	1.444 37	5.761 3
31	Brooks 2	6.878	1.840 04	5.393 0
32	Finlay	6.953	1.095 88	6.190 1
33	Taylor (noyau B)	6.97	1.951 72	5.349 1
34	Holmes	7.05	2.155 13	5.195 9
35	Daniel	7.09	1.661 66	5.722 2
36	Shajn-Schaldach	7.27	2.227 49	5.276 1
37	Faye	7.388	1.609 77	5.976 5
38	Ashbrook-Jackson	7.425	2.284 21	5.327 9
39	Whipple	7.440	2.468 63	5.153 5
40	Harrington-Abell	7.581	1.773 77	5.944 6
41	Reinmuth 1	7.631	1.994 74	5.757 2
42	Oterma	7.88	3.387 82	4.532 2
43	Arend	7.984	1.846 91	6.142 1
44	Schaumasse	8.18	1.195 94	6.924 2
45	Jackson-Neujmin	8.39	1.427 75	6.829 0
46	Wolf	8.43	2.506 05	5.777 2
47	Comas Solà	8.55	1.768 77	6.592 8
48	Kearns-Kwee	9.01	2.228 58	6.430 1
49	Swift-Gehrels	9.23	1.353.85	7.443 7
50	Neujmin 3	10.57	1.976 33	7.657 5
51	Klemola	10.97	1.765 91	8.107 5
52	Gale	10.99	1.182 91	8.704 3
53	Väisälä 1	11.28	1.866 13	8.192 8
54	Slaughter-Burnham	11.62	2.543 36	7.716 3
55	Van Biesbroeck	12.41	2.409 69	8.310 0
56	Wild	13.29	1.980 42	9.242 0
57	Tuttle	13.77	1.022 93	10.464 9
58	Du Toit 1	14.976	1.293 97	10.857 7
59	Schwassmann-Wachmann 1	15.03	5.447 49	6.731 5
60	Neujmin 1	17.93	1.542 57	12.158 2
61	Crommelin	27.89	0.743 36	17.649 8
62	Tempel-Tuttle	32.91	0.981 73	19.537
63	Coggia-Stephan	38.84	1.595 29	21.344
64	Westphal	61.86	1.254 02	30.03
65	Olbers	69.47	1.178 66	32.62
66	Pons-Brooks	70.98	0.773 88	33.51
67	Brorsen-Metcalf	71.93	0.484 89	34.10
68	Halley	76.09	0.587 21	35.33
69	Herschel-Rigollet	155	0.748 49	56.94

Techniques sensibles d'observation : années 1990...

Ceintures de Kuiper = Objets transneptuniens (KBOs)

- $\sim 10^5$ objets
- $d = 30-55$ U.A.
- masse totale = $0.1 M_T$
- **source probable des comètes à courte période**



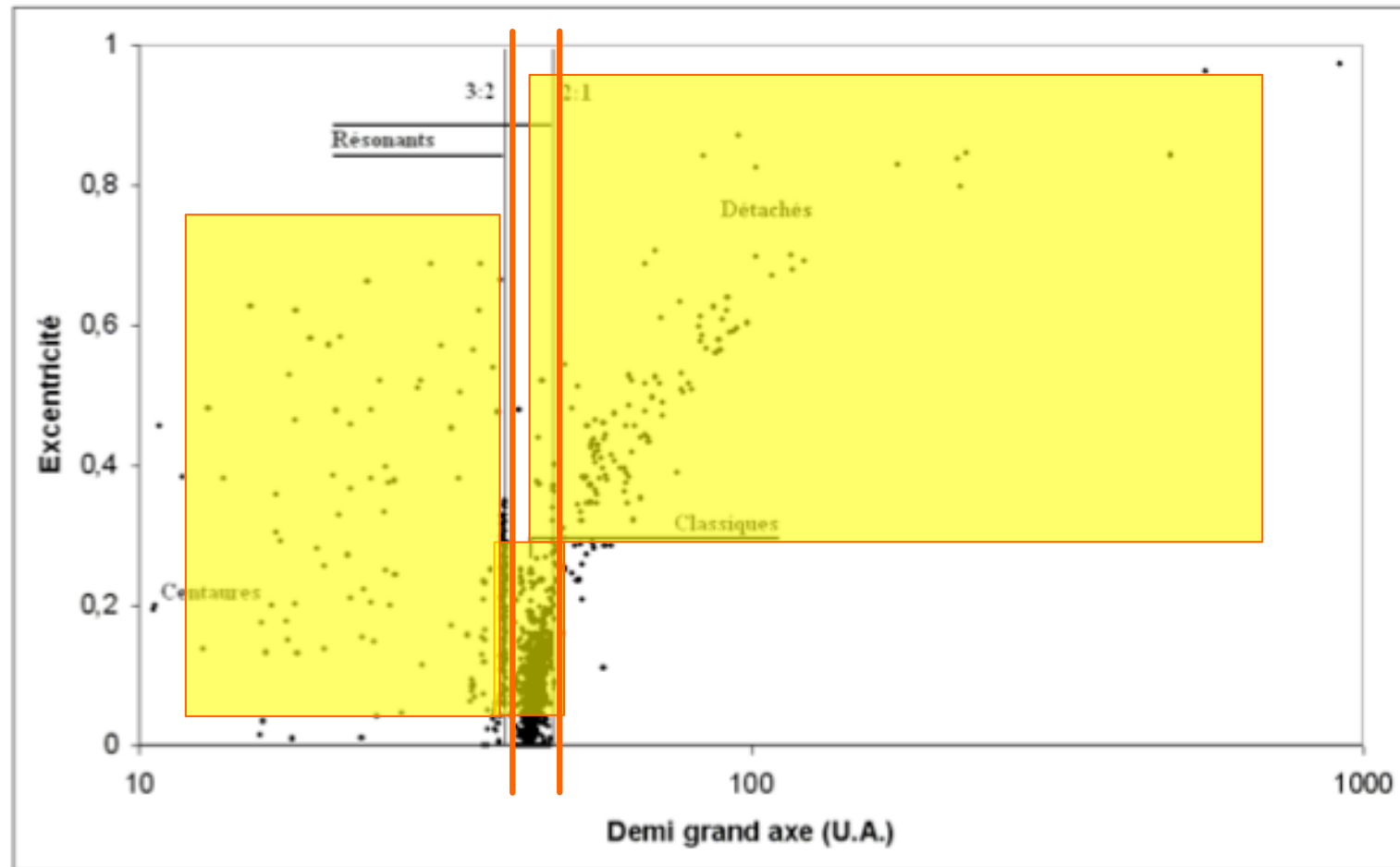
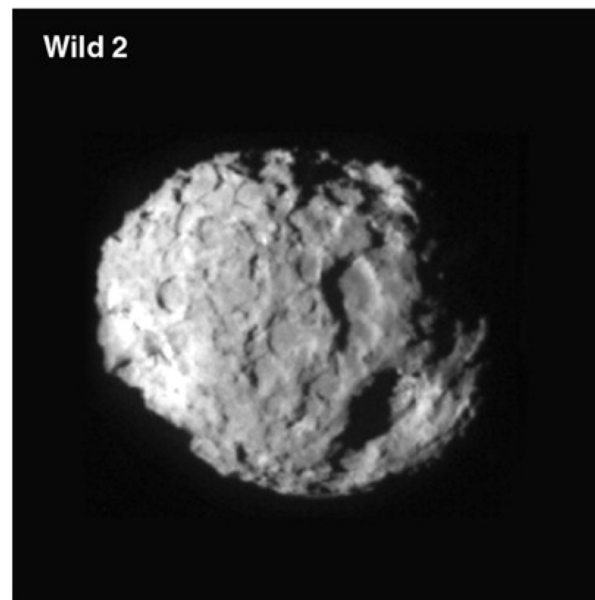
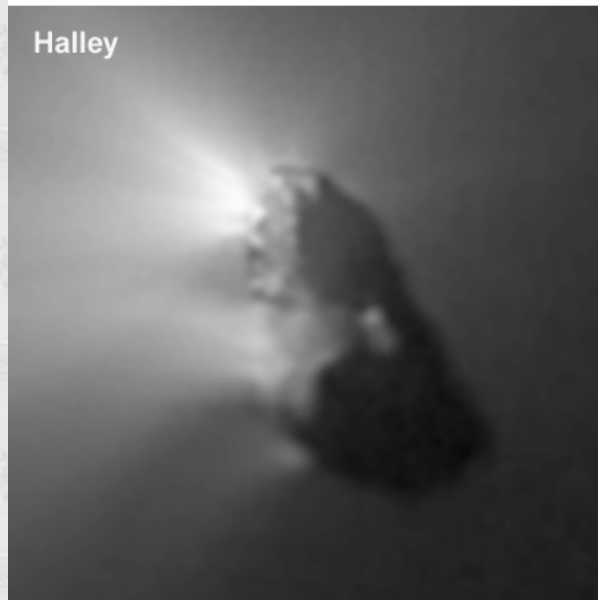
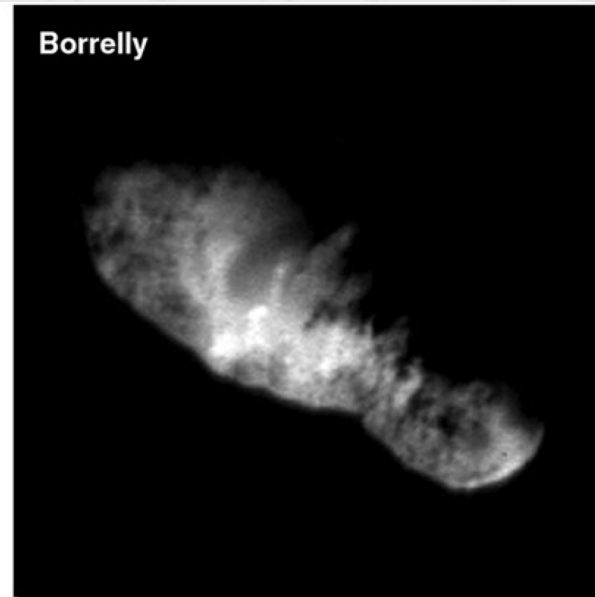
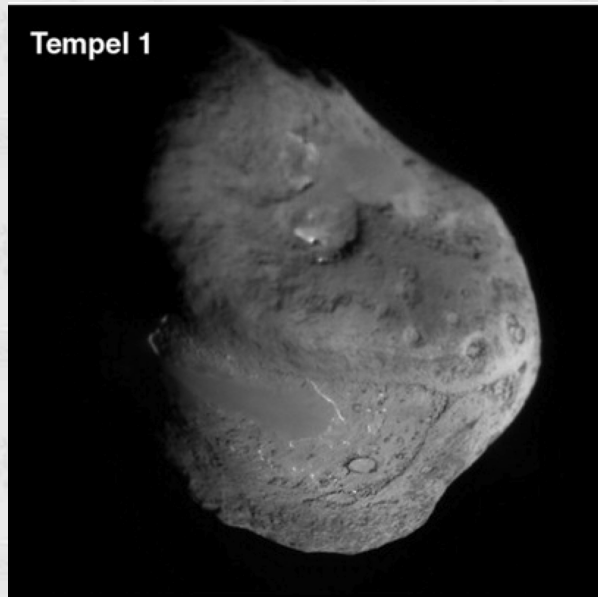


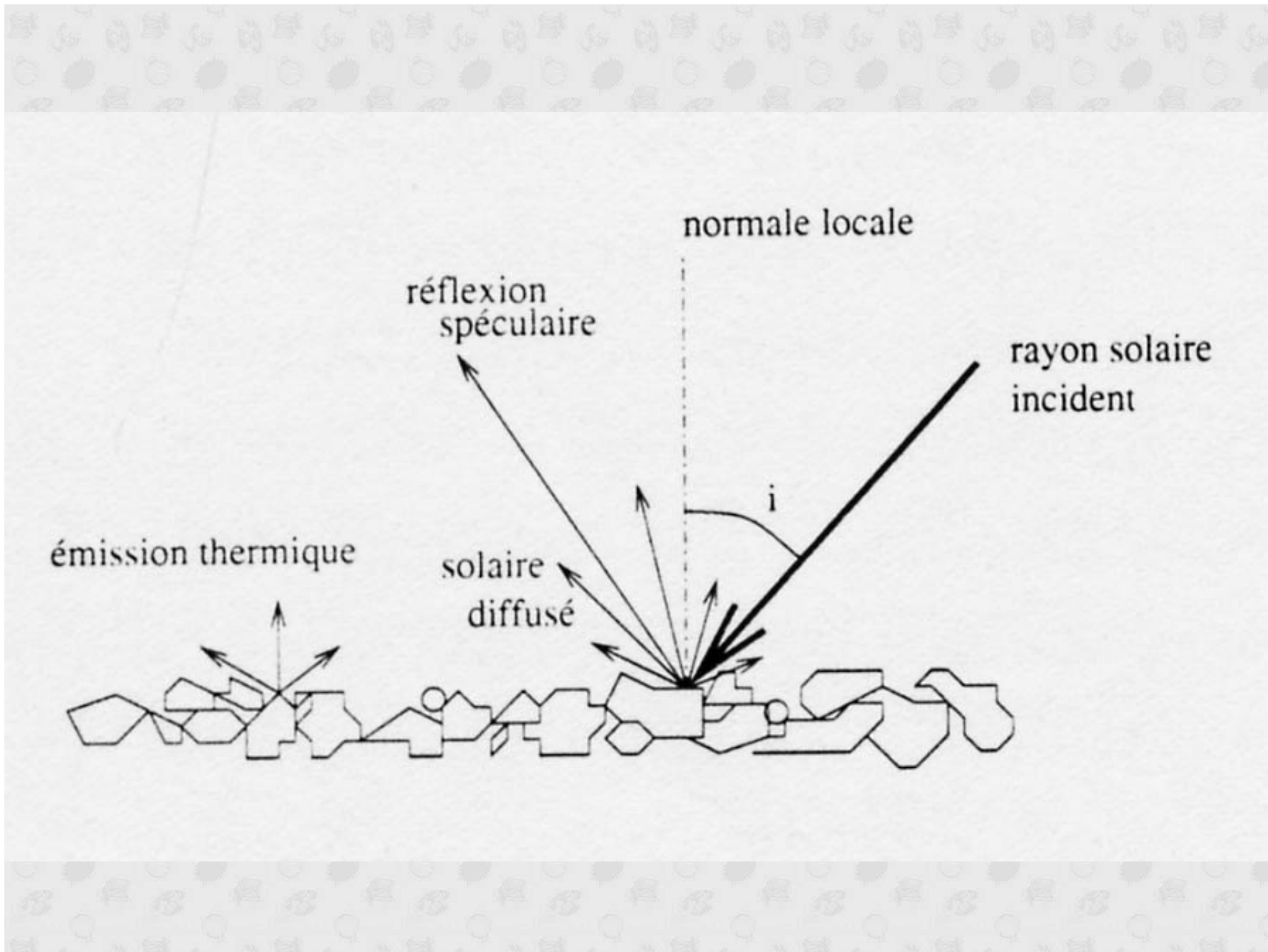
FIG. 1.3 – Répartition de tous les OTNs et des Centaures recensés au début de l'année 2007 par le *Minor planet Center*. L'excentricité des objets est exprimée en fonction du demi grand-axe.



OBSERVER LEURS SURFACES

Modèle de la boule de neige sale



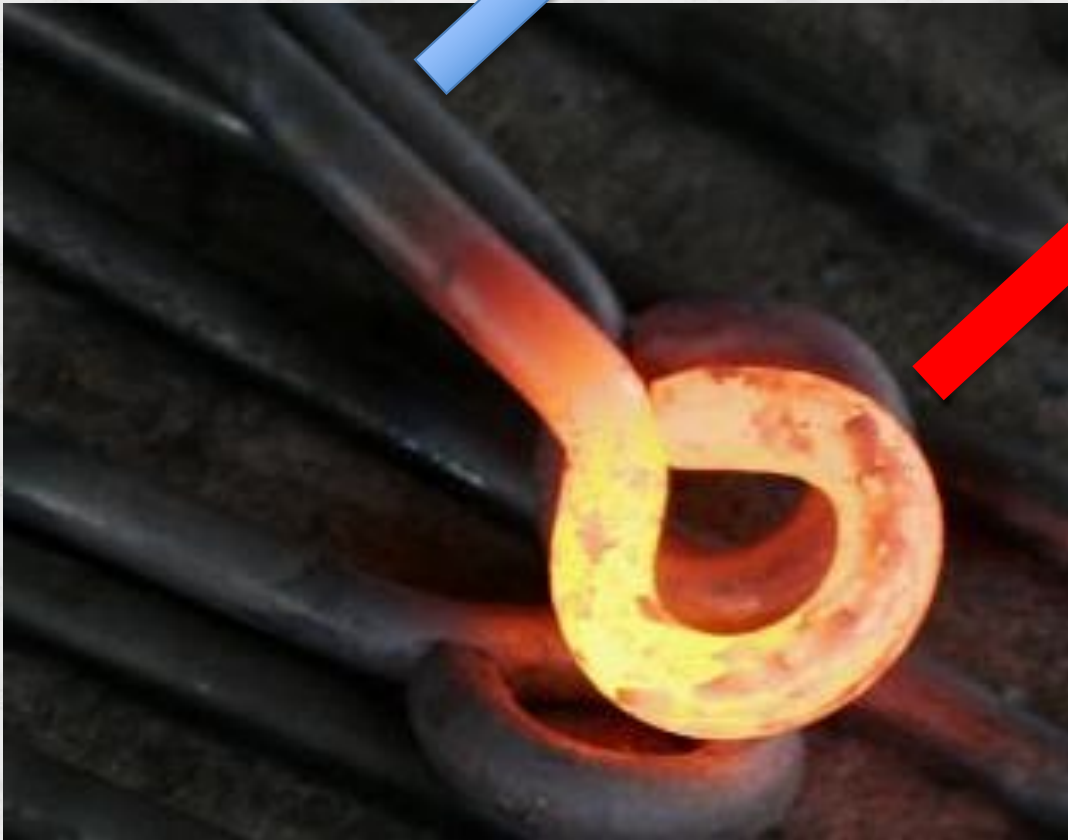




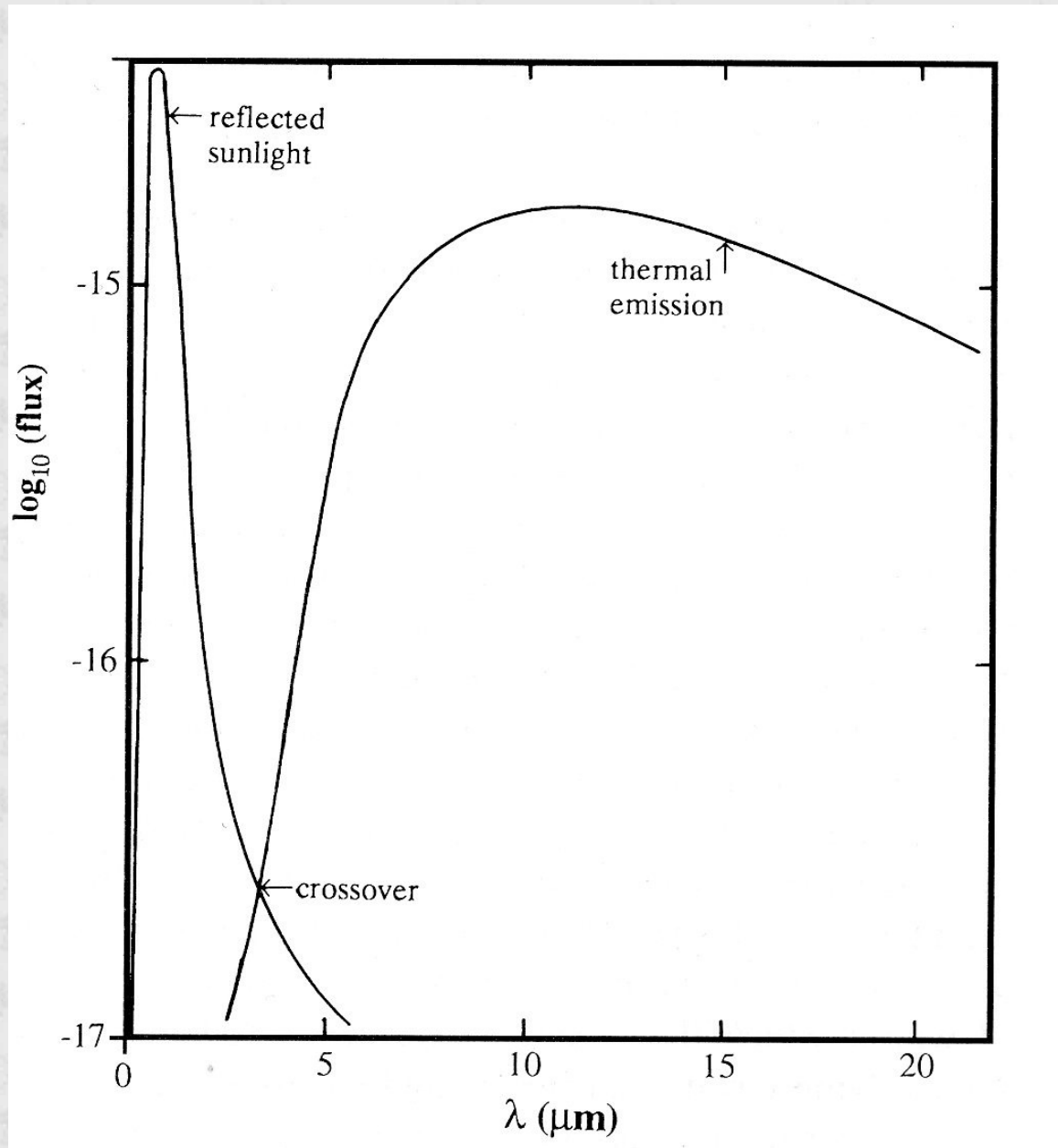


$\sim 10 \mu\text{m}$

$\sim 400 \text{ nm}$



Emission et réflexion par les surfaces planétaires



✘ Nous ne pouvons pas afficher l'image.

Astéroïdes :

⇒ Reflectance

⇒ Emission thermique

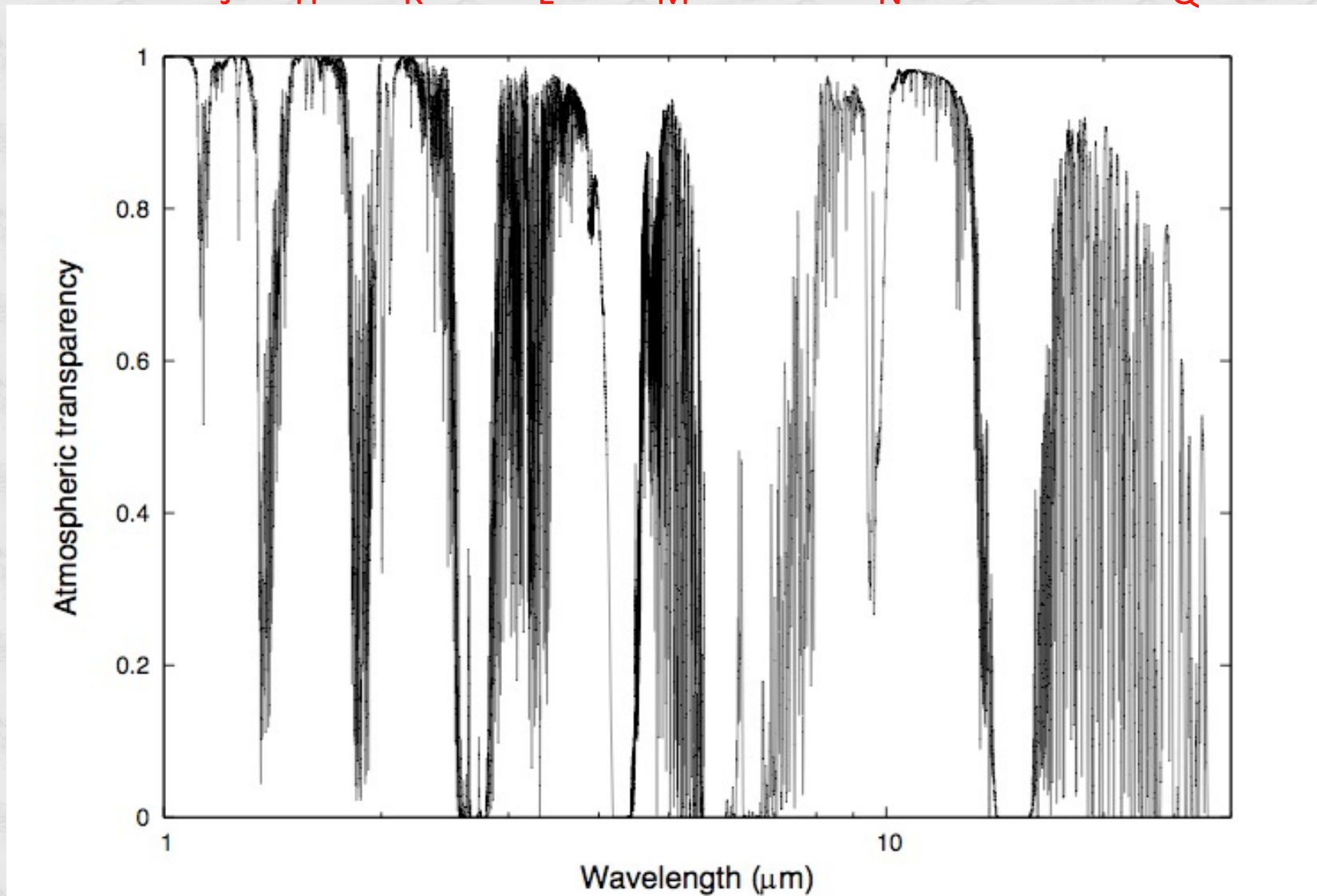
Objets glacés :

⇒ Réflectance

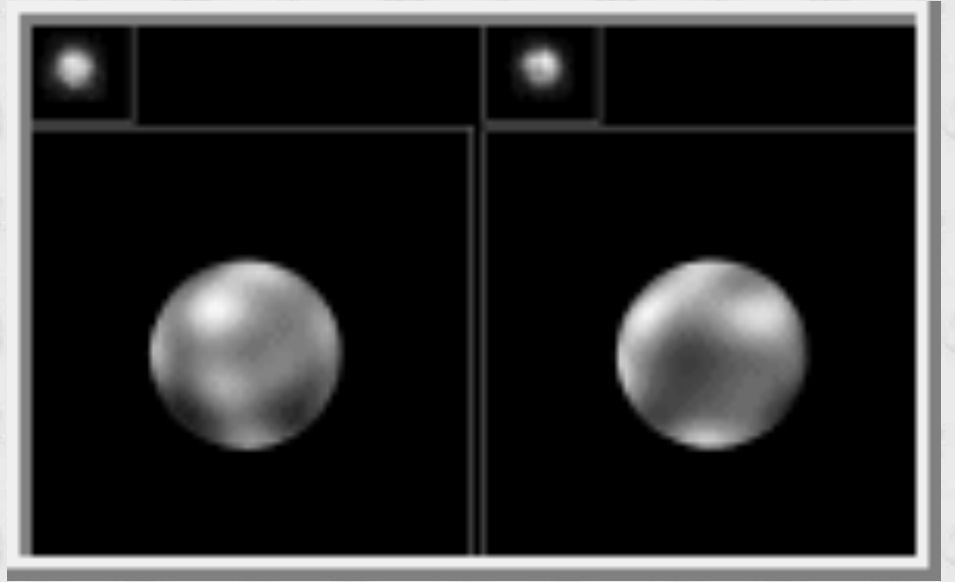
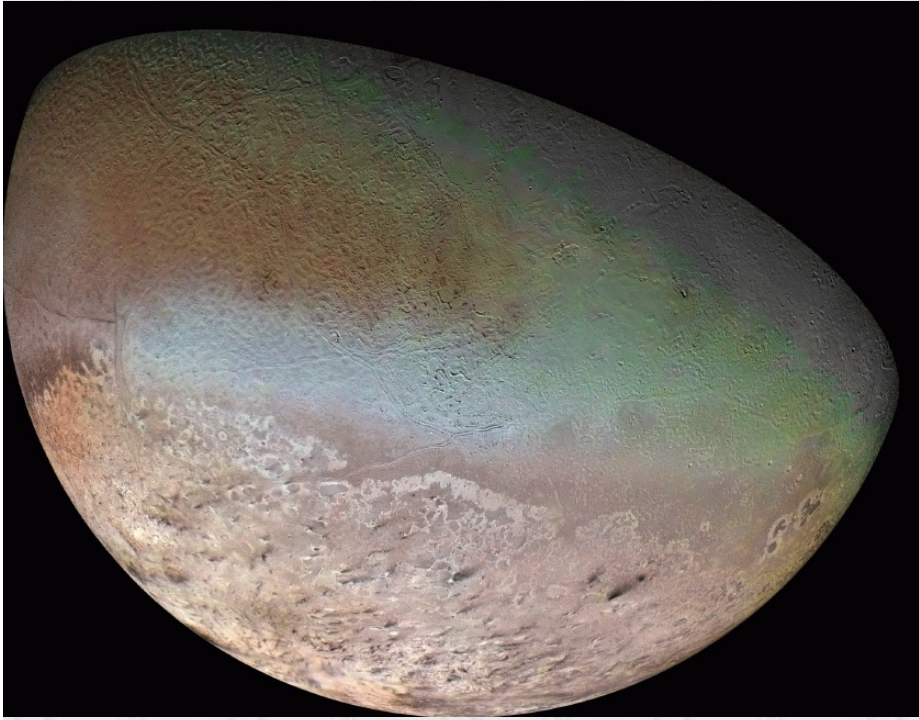
⇒ Emission far-IR

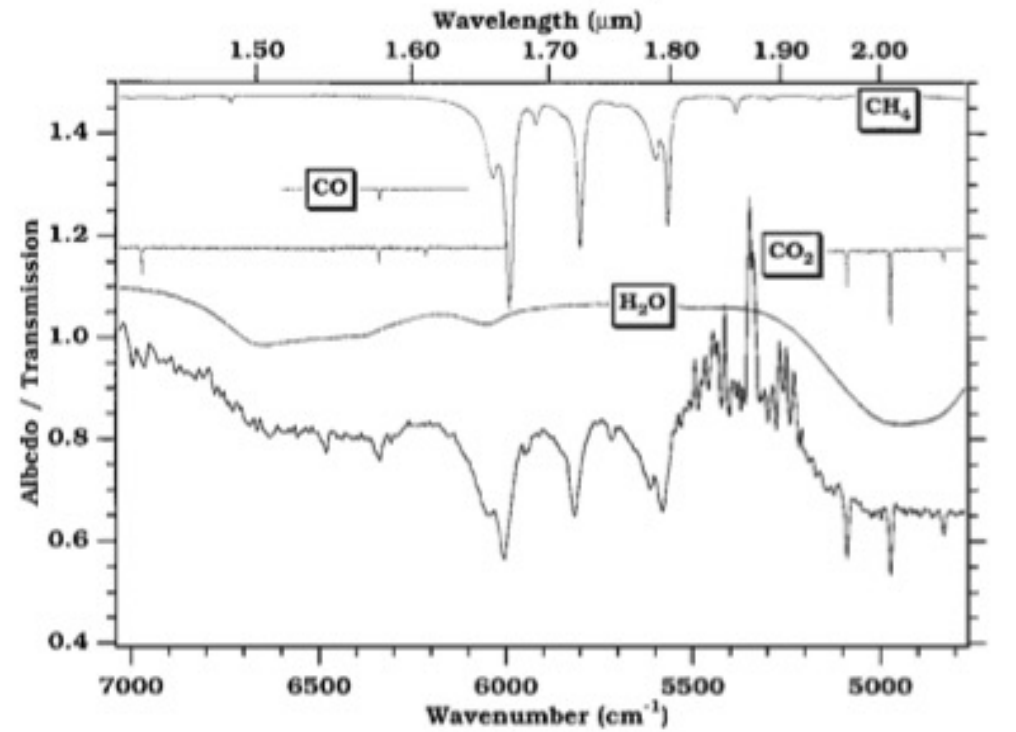
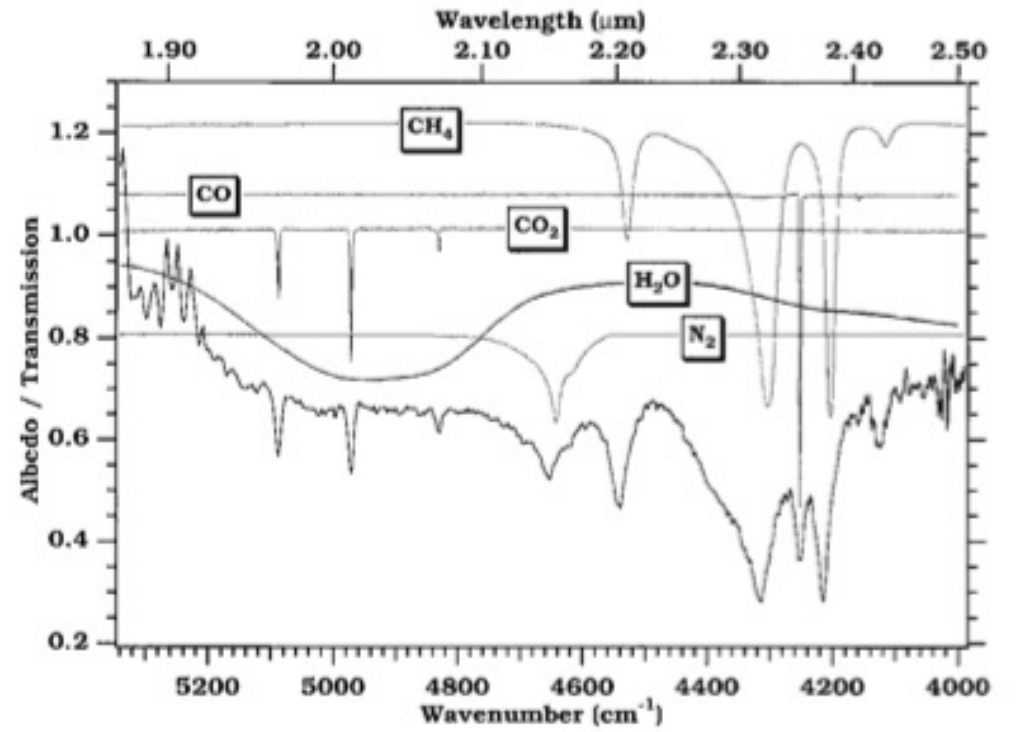
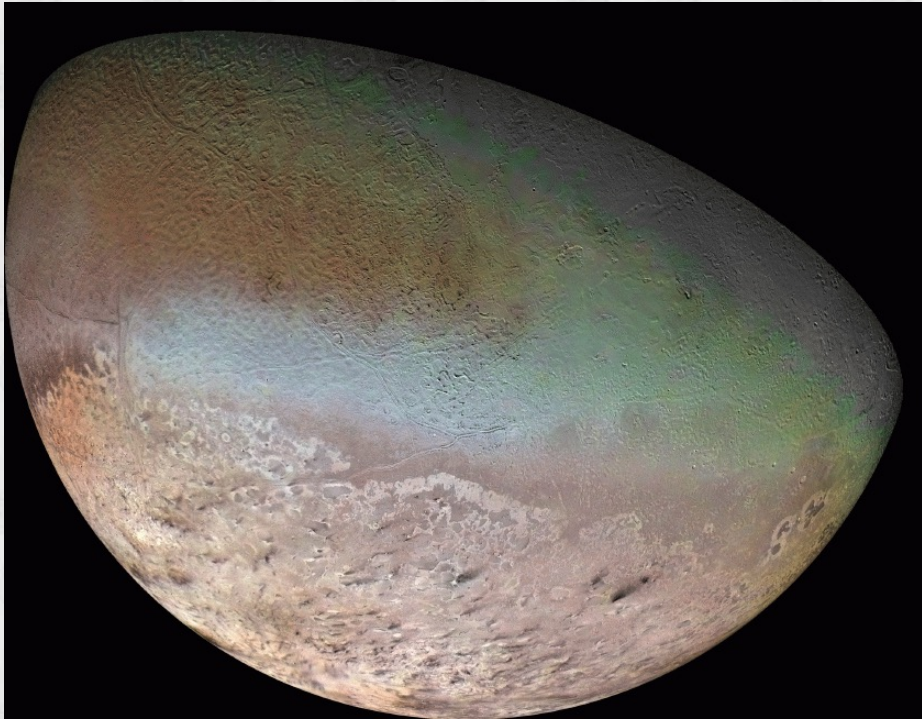
Fenêtres atmosphériques

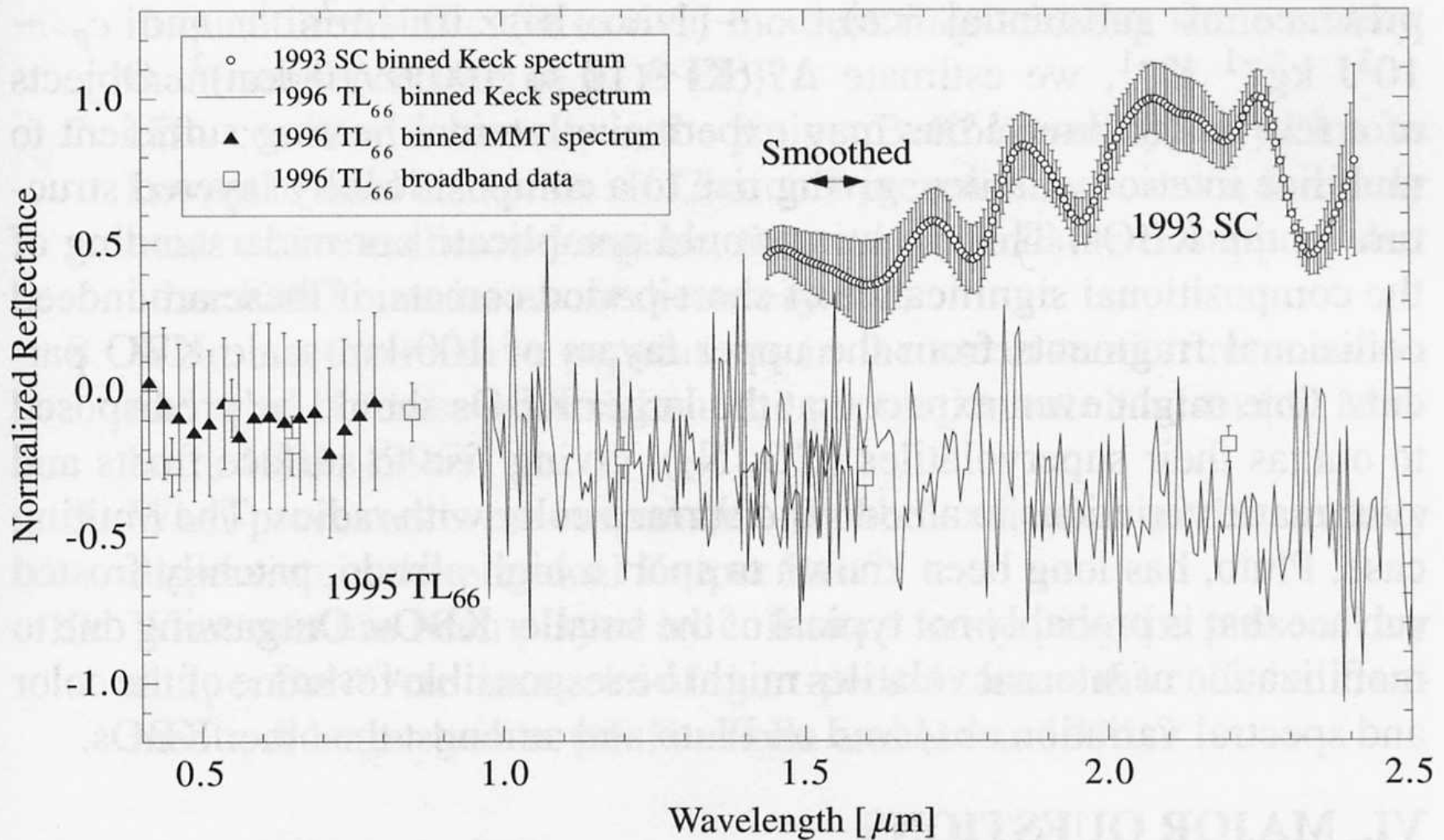
~20 μm
→
Q



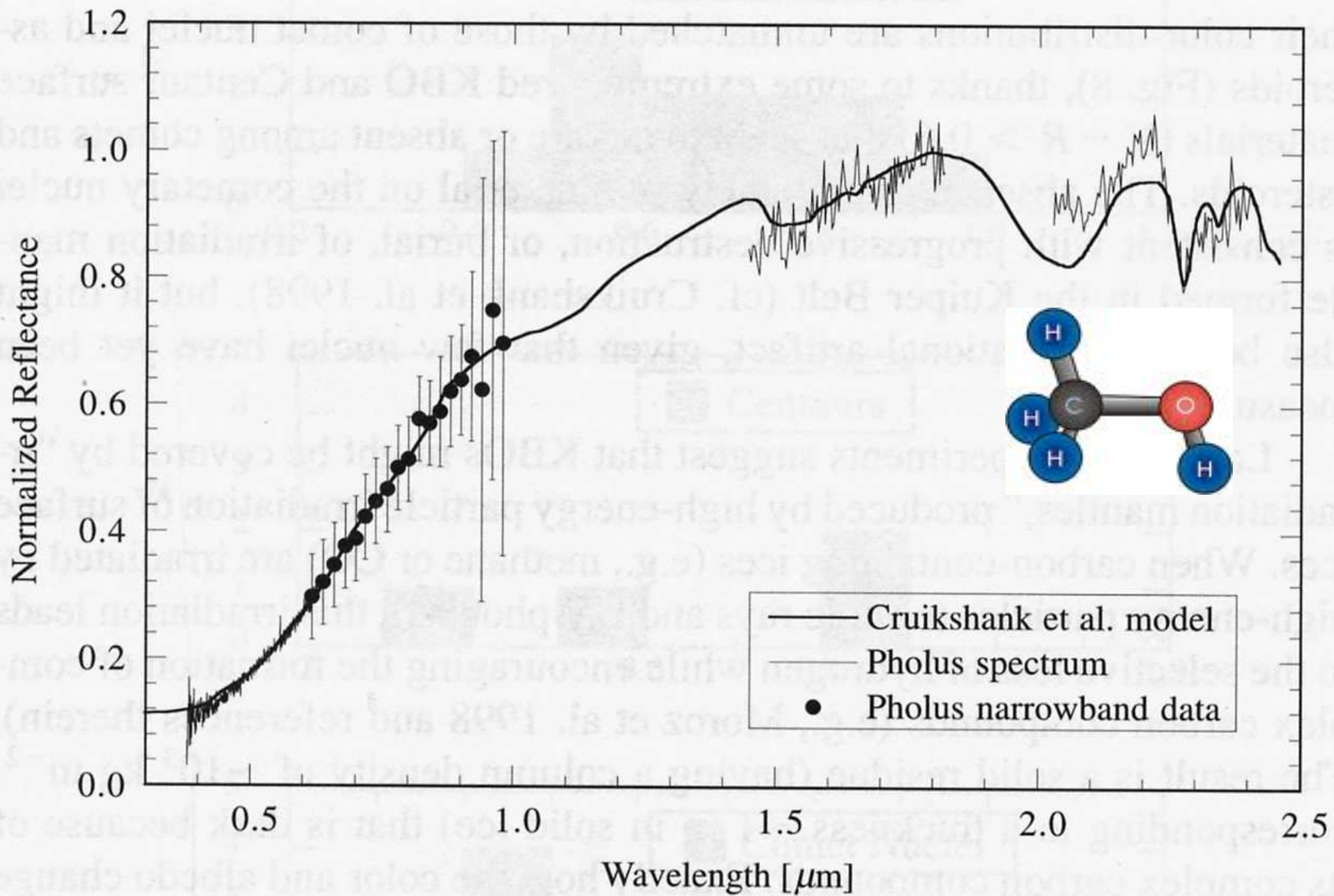
Observatoires satellitaires IR : IRAS, ISO, SPITZER

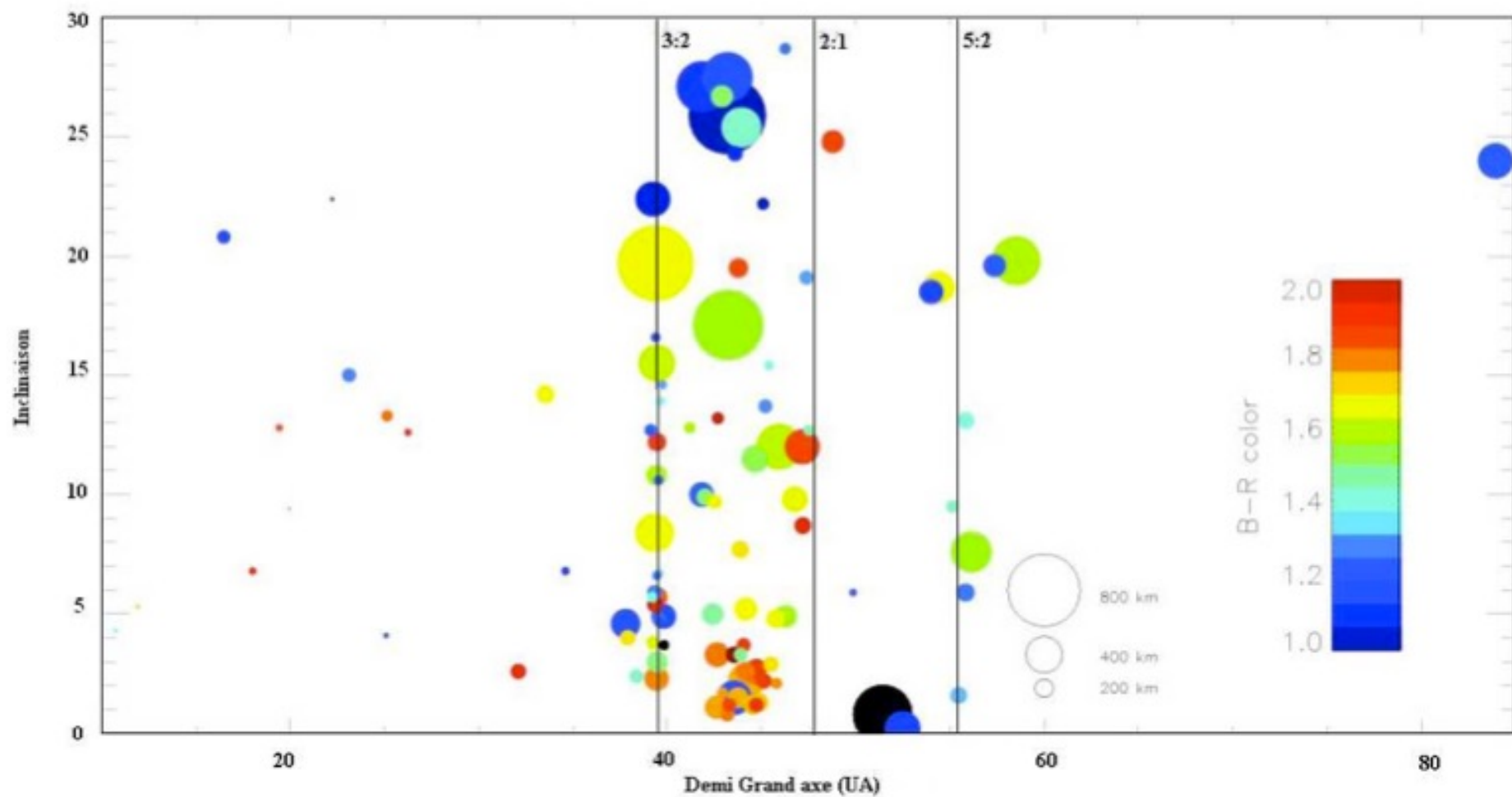






Infrared reflectance spectra of 1993 SC and 1996 TL₆₆. The 1993 SC spectrum has been smoothed to a resolution of 0.08 μm (by R. Brown). The 1996 TL₆₆ spectrum is shown unsmoothed (Luu and Jewitt 1996), ruling out a surface of pure water ice. The spectra are vertically displaced for clarity.





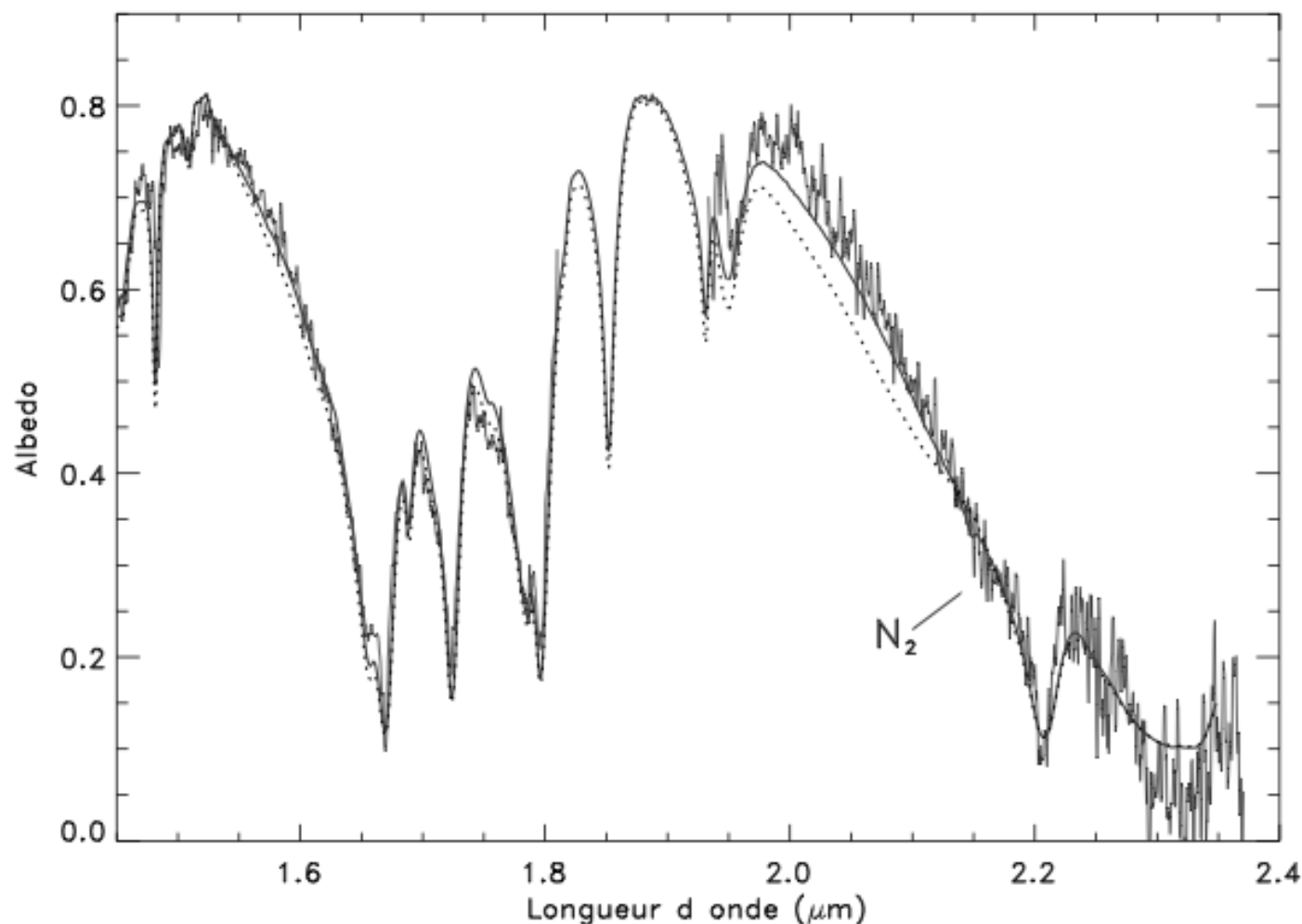
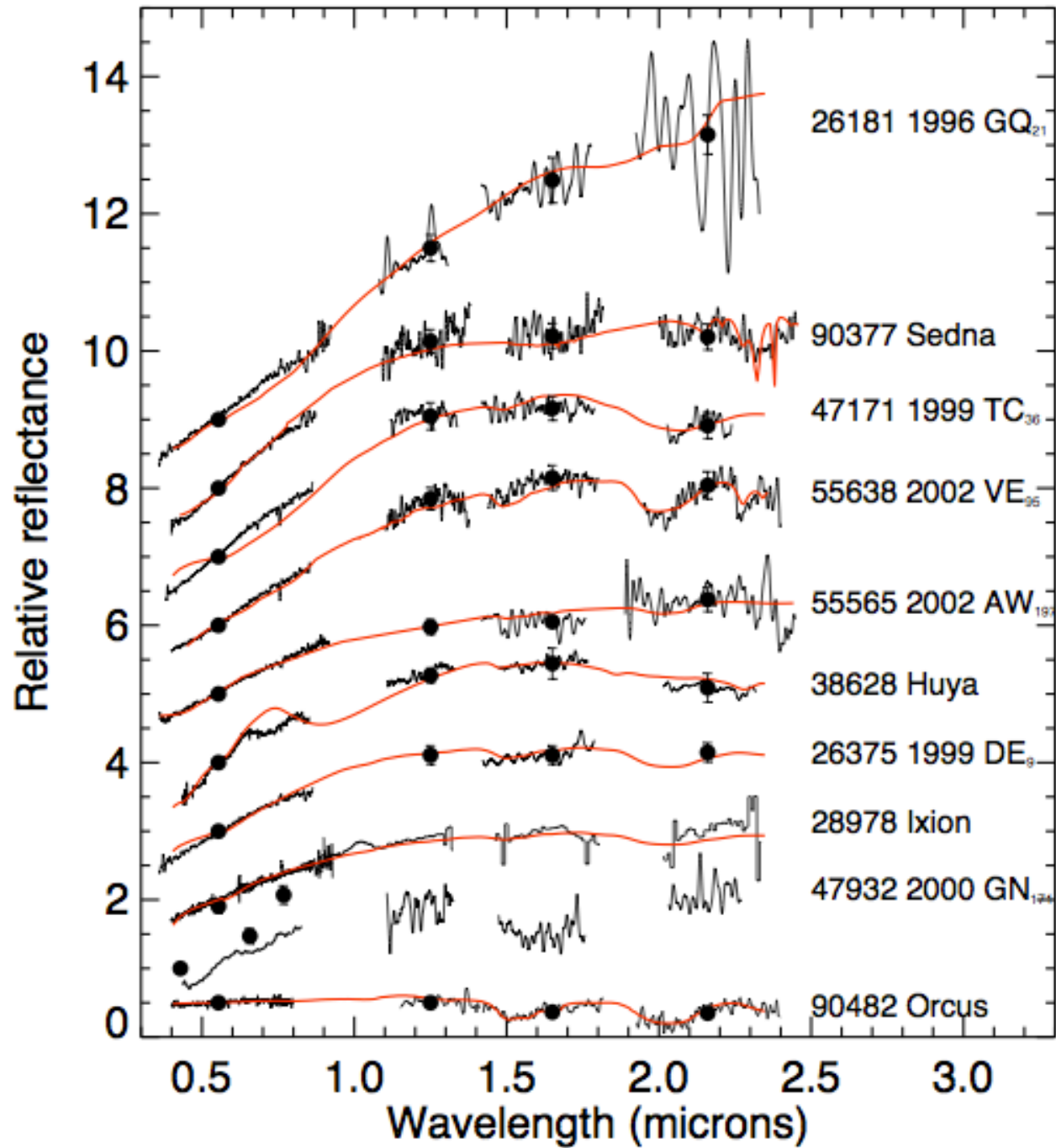


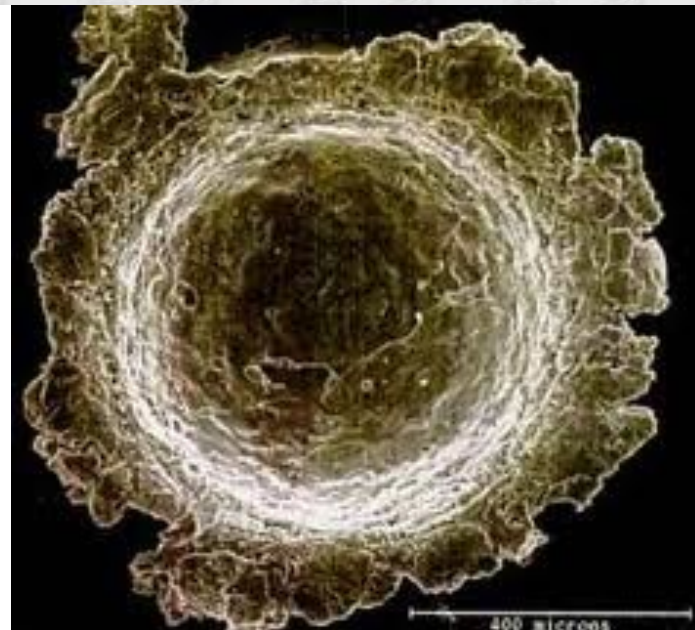
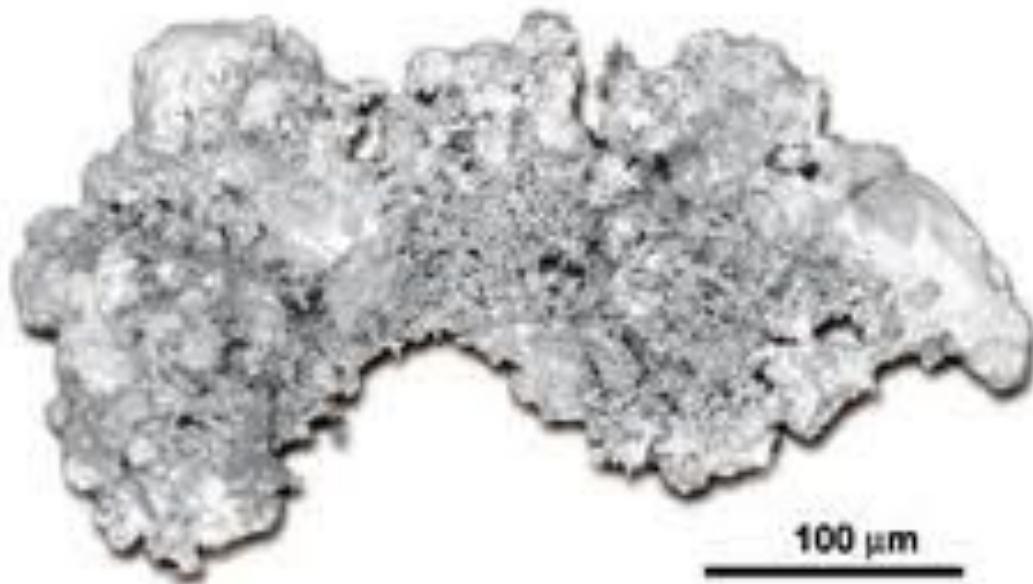
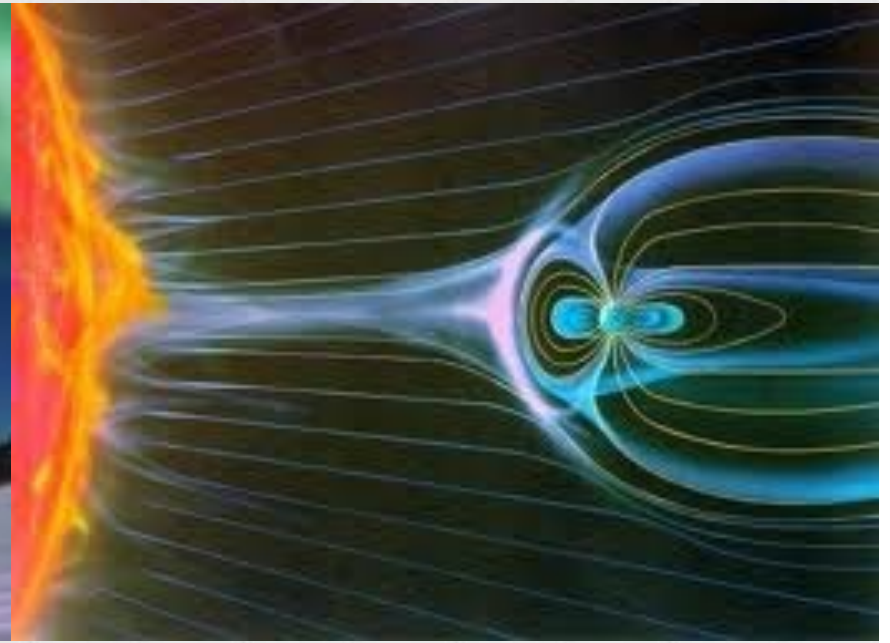
FIG. 8.5 – Spectre et modèles d'Eris sur l'intervalle spectral allant de 1,45 à 2,4 μm . Le meilleur ajustement des modèles (courbe en continu) est obtenu en considérant un mélange composé de 50% de méthane pur et 50% d'un mélange de différentes glaces ($\text{CH}_4, \text{N}_2, \text{H}_2\text{O}$ et glace de Tholin). Le même modèle mais sans utiliser de N_2 est présenté pour la comparaison (courbe en pointillés). Le second modèle s'ajuste moins bien au spectre de l'objet. Ces modèles ont été réalisés en considérant un albédo à 0,55 μm de 0,86 (Brown et al., 2006a).

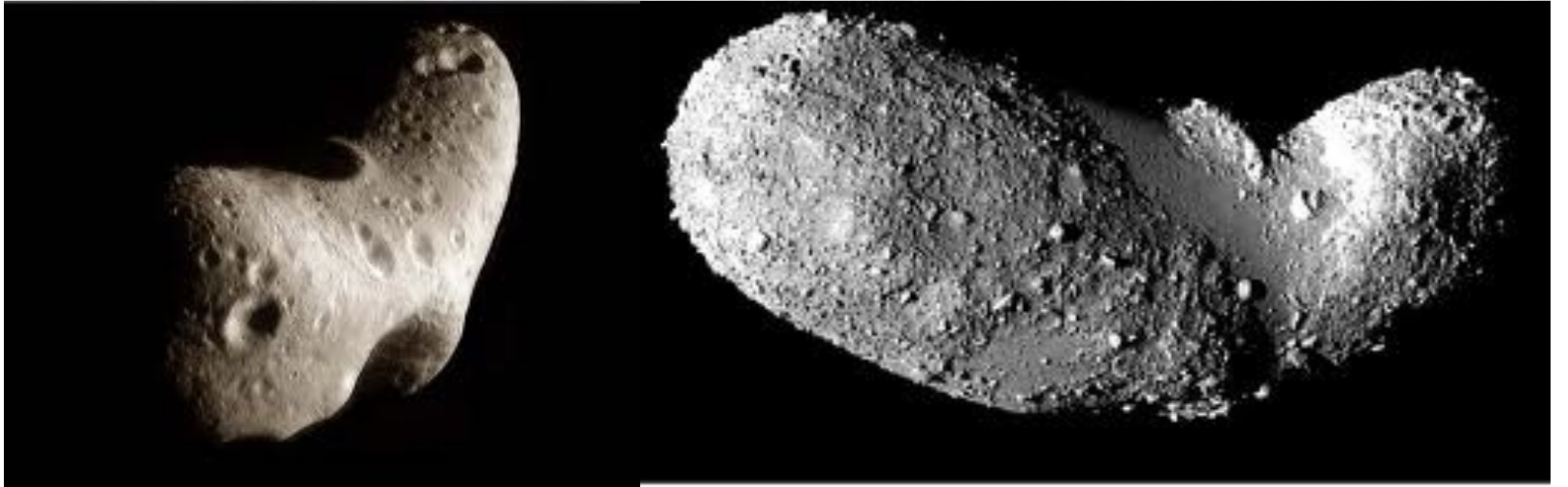
TNOs



TAB. 7.1 – Diamètre (en kilomètres), glaces observées, groupe taxonomique (Barucci et al., 2005a) et groupe dynamique (C :Centaures, Cl :Classiques, R :Résonants, Di : Dispersés, De : Détachés) des OTNs et des Centaures disponibles dans la littérature. Quatre groupes taxonomiques ont été identifiés et nommés : BB, BR, IR, et RR. Le groupe BB contient les objets dont les couleurs sont les plus neutres et RR ceux dont les couleurs sont les plus rouges, tandis que les autres groupes ont des comportements et des couleurs intermédiaires.

Objet	Glaces (Ref.)	Diamètre (Ref.)	Tax.	Dyn.
2060 Chiron	H ₂ O (Lu00, Fo99, Ro03)	150 ± 10 (Fe02)	BB	C
5145 Pholus	H ₂ O, CH ₃ OH (Cr98)	190 ± 20 (Da93)	RR	C
8405 Asbolus	non (Ke00, Ba00, Ro02)	75 ± 10 (Fe02, St)	BR	C
10199 Chariklo	H ₂ O (Br98)	230 ± 30 (St)	BR	C
15789 (1993 SC)	non (Je01)	330 ± 66 (Th00)	RR	R
15874 (1996 TL ₆₆)	non (Lu98)	630 ± 90 (Th00)	BB	Di
19308 (1996 T0 ₆₆)	H ₂ O (Br99)	<900 (Al04)	BB	Cl
20000 Varuna (2000 WR ₁₀₆)	H ₂ O (Li01)	586 ± 150 (St)	IR	Cl
26181 (1996 GQ ₂₁)	non (Dor03)	400 (*)	RR	Di
26375 (1999 DE ₉)	H ₂ O (Je01)	500 (*)	IR	Di
28978 Ixion (2001 KX ₇₆)	H ₂ O ? (Li02)	480 ± 140 (St)	IR	R
31824 Elatus (1999UG ₅)	H ₂ O (Bau02)	40 (*)	IR	C
32532 Thereus	H ₂ O (Ba02, Me05)	85 ± 15 (St)	BR	C
38628 Huya (2000 EB ₁₇₃)	H ₂ O ? (Br00, Je01, dB04)	500 ± 70 (St)	IR	R
47171 (1999 TC ₃₆)	H ₂ O (Dot03, Me05)	420 ± 65 (St)	RR	R
47932 (2000 GN ₁₇₁)	non (dB04)	400 (Sh02)	IR	R
50000 Quaoar (2002 LM ₆₀)	H ₂ O (Je04)	1280 ± 190 (Br04)	RR	Cl
52872 Okyrhoe	H ₂ O ? (Dot03)	50 ± 10 (St)	BR	C
54598 Bienor	H ₂ O (Dot03)	180 ± 30 (St)	BR	C
55565 (2002 AW ₁₉₇)	H ₂ O ? (Dor05)	700 ± 90 (Cr05)	IR	Cl
55576 Amycus (2002 GB ₁₀)	H ₂ O ? (Dor05)	120 (*, Fo04)	RR	C
55638 (2002 VE ₉₅)	H ₂ O, CH ₃ OH (Ba06)	400 (Or05, *)	RR	R
63252 (2001 BL ₄₁)	non (Dor03)	20 (*)	BR	C
79360 (1997 CS ₂₉)	non (Gr05)	400 (*)	RR	Cl
83982 Crantor (2002 GO ₉)	H ₂ O (Dor05)	65 (*)	RR	C
90377 Sedna (2003 VB ₁₂)	CH ₄ , N ₂ (Ba05a, Tr05)	2000 (*)	RR	De
90482 Orcus (2004 DW)	H ₂ O (Fo04, dB05, Tr05)	1500 (*)	BB	R
136108 (2003 EL ₆₁)	H ₂ O (Tr07, Me07)	1500 (Ra06)	BB	R
136199 Eris (2003 UB ₃₁₃)	CH ₄ (Br05)	2500 (Br05, Be06)	BB	Di
136472 (2005 FY ₉)	CH ₄ (Li06)	1600 ± 500 (Li06)	BR	R
134340 Pluton	CH ₄ , CO, N ₂ (Ow93)	2350 ± 60 (Mi93, Th89)	BR	R
Charon	H ₂ O, NH ₃ (Br00c)	1208 ± 15 (Si06, Gu06)	BB	

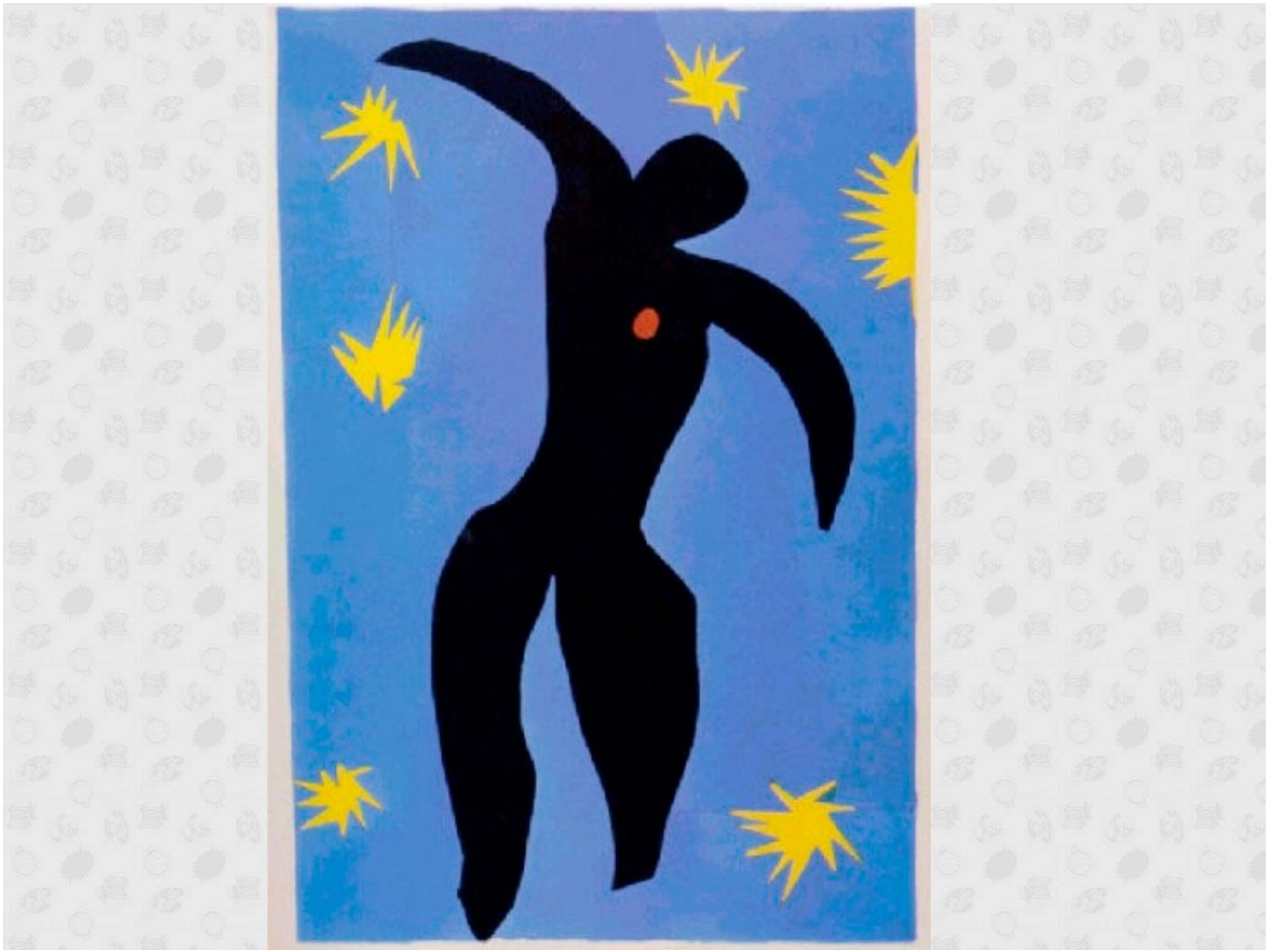




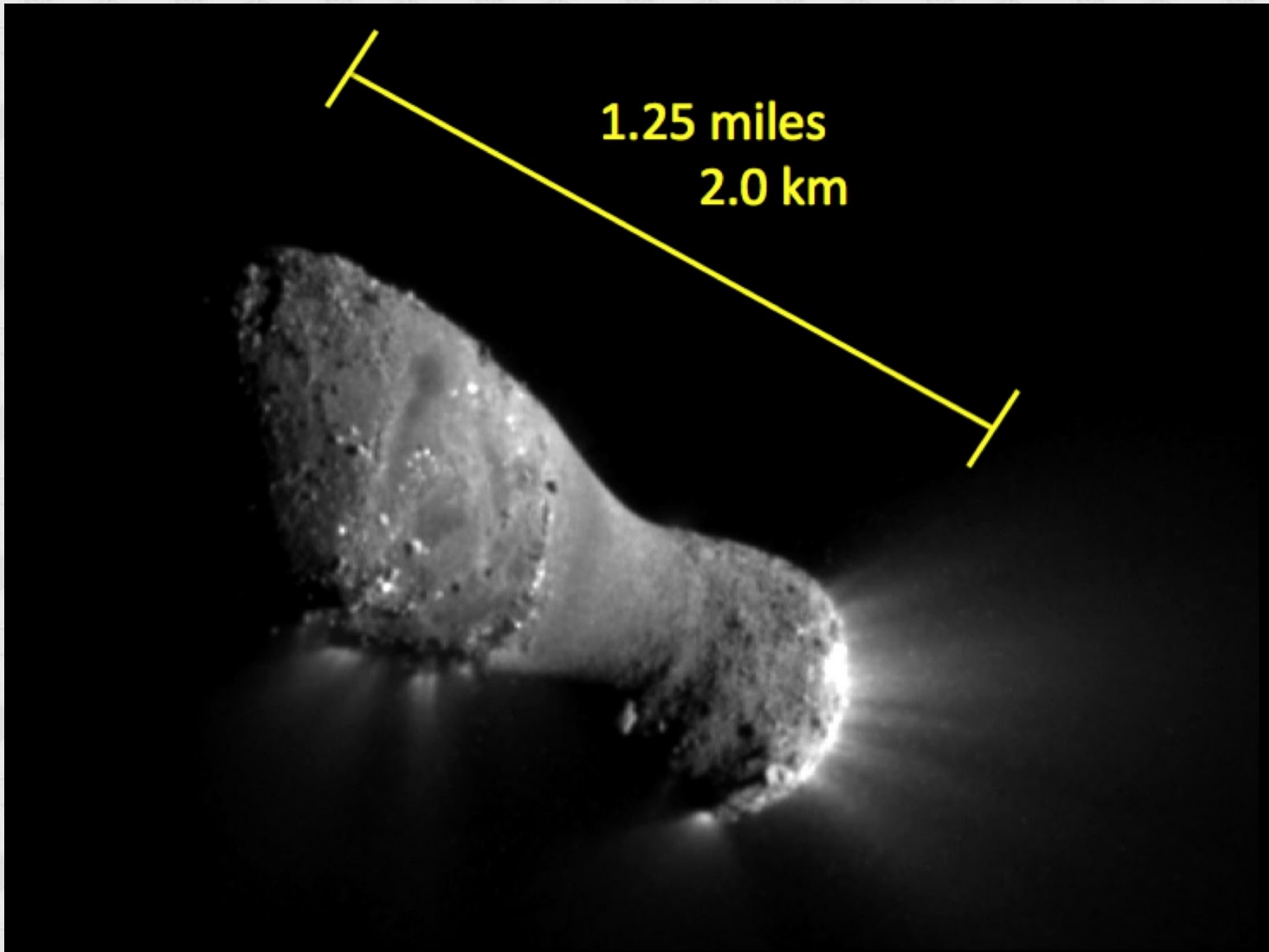


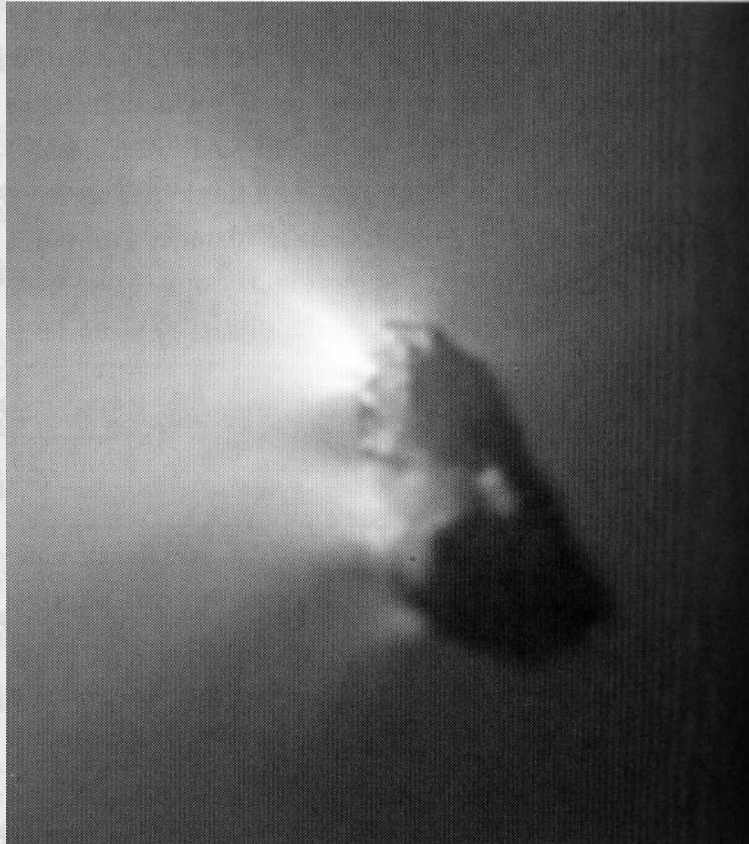
UNE COMÈTE SE SUBLIME...

...ET SE RÉVÈLE.



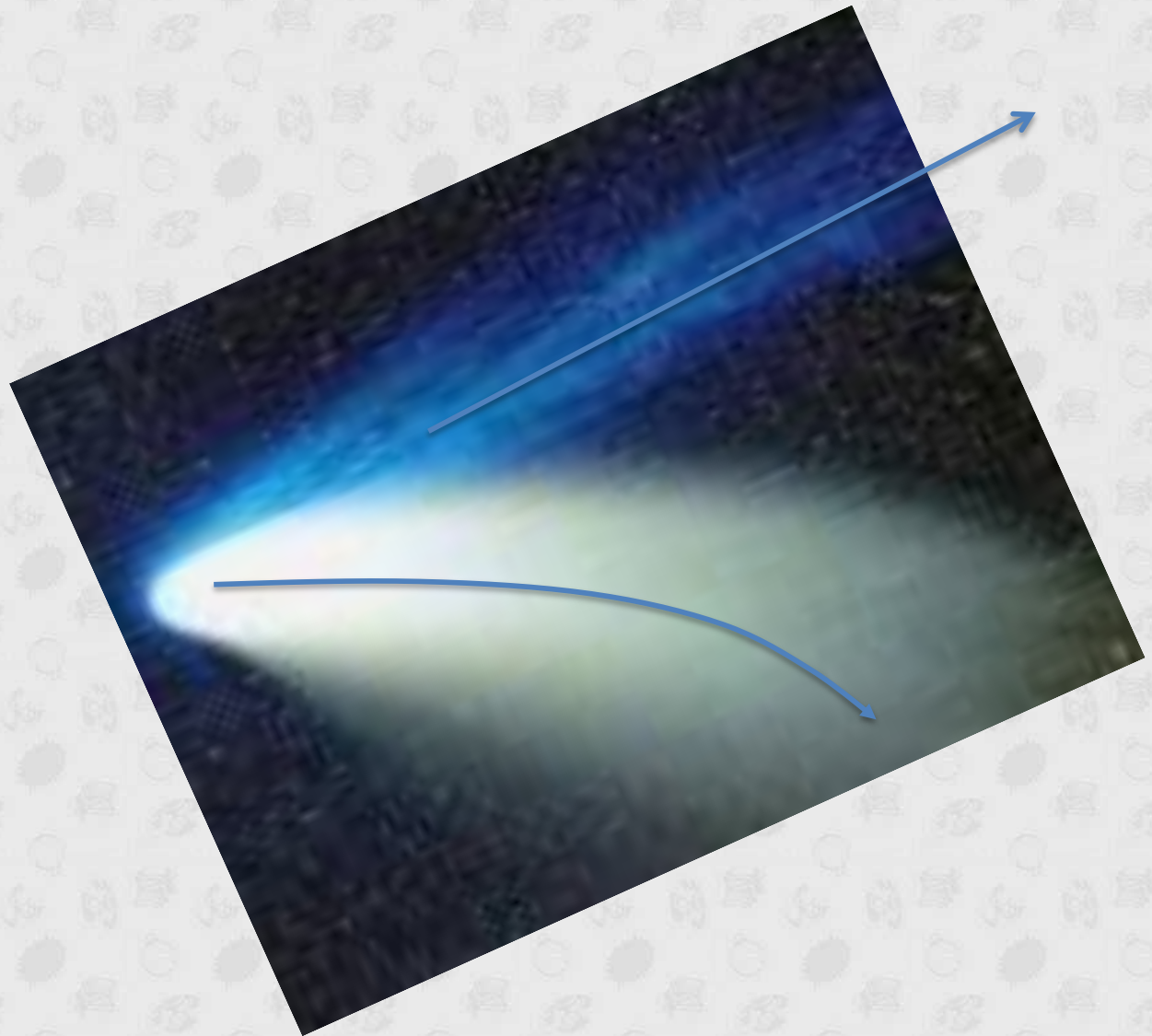
Comète Hartley (Mission NASA EPOXI)







Observation des comètes actives



Structure et composition

Queue d'ions

Queue de poussières

Coma (ou chevelure)

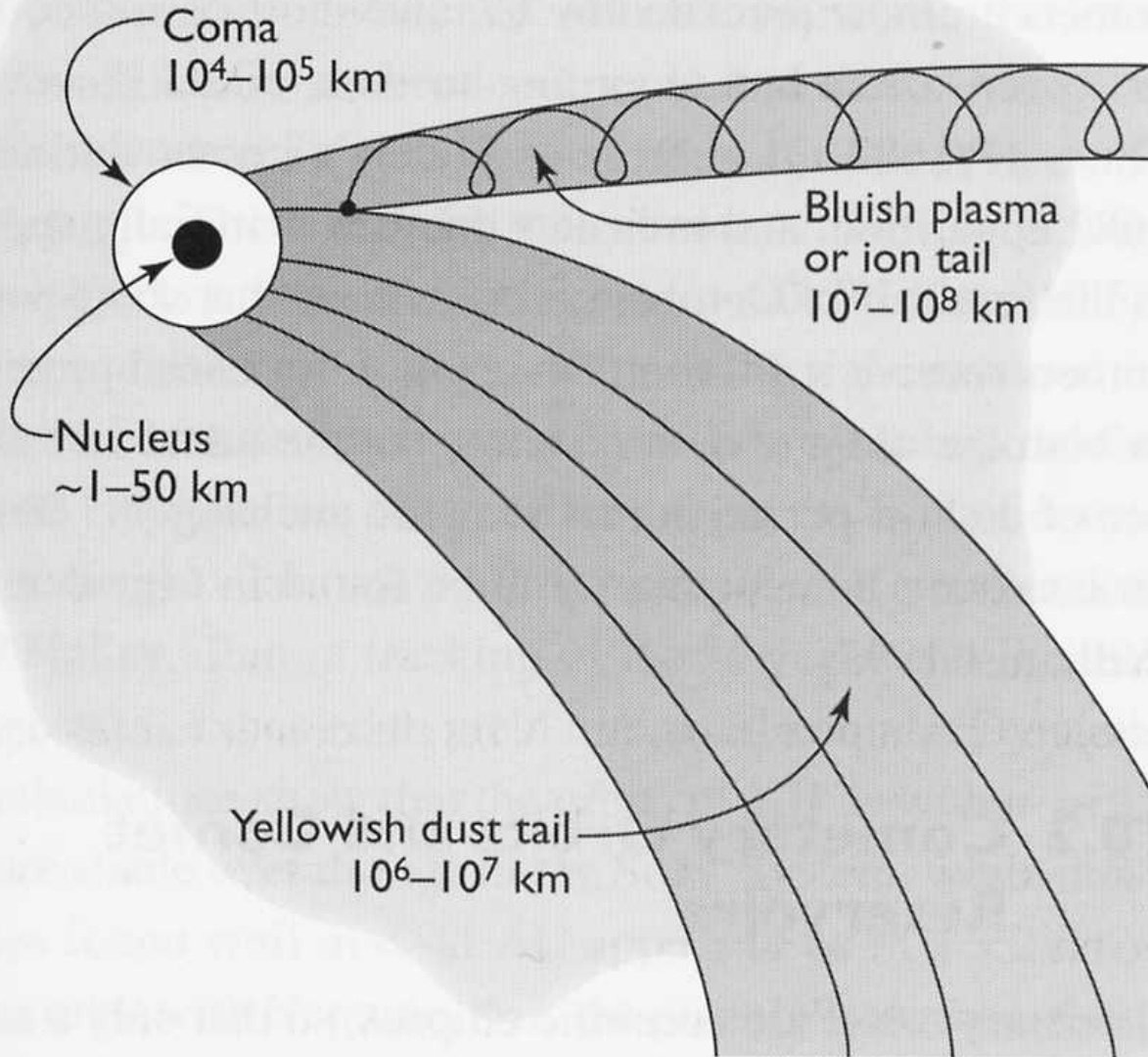
Hydrogen cloud
 10^6 – 10^7 km

Coma
 10^4 – 10^5 km

Bluish plasma
or ion tail
 10^7 – 10^8 km

Nucleus
 ~ 1 – 50 km

Yellowish dust tail
 10^6 – 10^7 km



Molécules

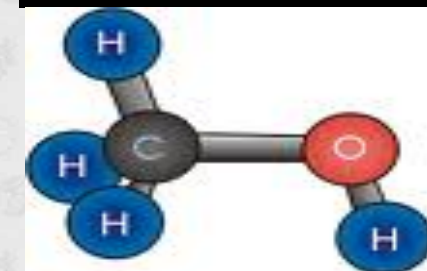
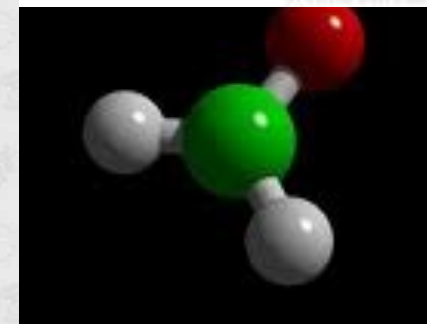
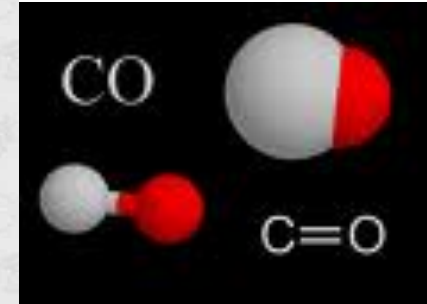
Molecule	Abundances of Cometary Volatiles		Method ^b	N ^c	Comments
	Abundance ^a				
	Hale-Bopp	Other Comets			
H ₂ O	= 100	= 100	IR	6	Also indirect (from OH, O, H)
CO	20	1–20	UV, radio, IR	>5	Extended source?
CO ₂	20 ^d	3–10	IR	3	
H ₂ CO	0.1–1	0.1–1	Radio, IR	>5	Extended source
CH ₃ OH	2	1–7	Radio, IR	>5	
HCOOH	~0.05		Radio	1	
HNCO	0.1		Radio	2	
NH ₂ CHO	~0.01		Radio	1	
HCOOCH ₃	~0.05		Radio	1	
CH ₄	~0.6		IR	2	
C ₂ H ₂	~0.1		IR	2	
C ₂ H ₆	~0.3		IR	2	
NH ₃	0.6		Radio, IR	3	
HCN	0.2	0.05–0.2	Radio, IR	>5	
HNC	0.04		Radio	2	Extended source?
CH ₃ CN	0.02		Radio	2	
HC ₃ N	0.03		Radio	1	
H ₂ S	1.5	0.2–1.5	Radio	>5	
H ₂ CS	~0.02		Radio	1	
CS	0.2	0.2	UV, radio	>5	From CS ₂ ?
OCS	0.5		Radio, IR	2	Extended source?
SO	~0.5		Radio	1	From SO ₂ ?
SO ₂	~0.1		Radio	1	
S ₂		0.005	UV	2	

^a Abundance relative to water. See text for references. All abundances were measured at $r_h \sim 1$ AU except for CO₂ in Hale-Bopp. Listed abundances may be uncertain by a factor of 2 or more for some species and may not pertain to nucleus production for "extended sources."

^b Method of observation.

^c Number of comets in which this species was reliably and directly observed.

^d Measured at $r_h = 2.9$ AU.



Atomes


Atomes et molécules observés dans les comètes par spectrométrie UV et visible

Atome ou molécule	Bande ou raie caractéristique	Transition	Année de première détection
H I	1 216 Å	$2p^0 \rightarrow 2s$	1972
	6 563 Å	$2D \rightarrow 2P^0$	1974
			1975
O I	1 304 Å	$3S^0 \rightarrow 3P$	1972
	[O I] 2 972 Å	$1S \rightarrow 3P$	1980
	6 300 Å	$1D \rightarrow 3P$	1958
	5 577 Å	$1S \rightarrow 3P$	1984
C I	1 561 Å	$3D^0 \rightarrow 3P$	1974
	1 657 Å	$3P^0 \rightarrow 3P$	1974
[C I]	1 931 Å	$1D \rightarrow 1P^0$	1976
C II	1 335 Å	$2D \rightarrow 2P^0$	1976
SI	1 814 Å	$3P \rightarrow 3S^0$	1980
Na I	3 303 Å	$2P^0 \rightarrow 2S$	1967
	5 890 Å	$2P^0 \rightarrow 2S$	1967
K I	7 665 Å	$2P^0 \rightarrow 2S$	1967
	4 044 Å	$2P^0 \rightarrow 2S$	1967
Ca II	3 934 Å	$2P^0 \rightarrow 2S$	1967
Cr I	3 579 Å	$7P^0 \rightarrow 7S$	1967
Mn I	4 031 Å	$6P^0 \rightarrow 6S$	1967
Fe I	3 441 Å	$5P^0 \rightarrow 5D$	1967
	3 570 Å	$3G^0 \rightarrow 5F$	1967
	3 581 Å	$5G^0 \rightarrow 5F$	1967
	3 720 Å	$5F^0 \rightarrow 5D$	1967
	3 749 Å	$5F^0 \rightarrow 5F$	1967
	3 813 Å	$3P^0 \rightarrow 5F$	1967
	3 816 Å	$3D^0 \rightarrow 3F$	1967
	3 820 Å	$5D^0 \rightarrow 5F$	1967
	3 860 Å	$5D^0 \rightarrow 5D$	1967
	4 046 Å	$3F^0 \rightarrow 3F$	1967
	Ni I	3 381 Å	$1P^0 \rightarrow 1D$
3 446 Å		$3D^0 \rightarrow 3D$	1967
3 458 Å		$3F^0 \rightarrow 3D$	1967
3 462 Å		$5F^0 \rightarrow 3D$	1967
3 525 Å		$3P^0 \rightarrow 3D$	1967
3 566 Å		$1D^0 \rightarrow 1D$	1967
3 619 Å		$1F^0 \rightarrow 1D$	1967
Cu I	3 248 Å	$2P^0 \rightarrow 2S$	1967
C ₂	2 313 Å	$D^1\Sigma_u^+ \rightarrow X^1\Sigma_g$	1980
	5 165 Å	$d^3\Pi_g \rightarrow a^3\Pi_u$	1882
	7 715 Å	$A^1\Pi_u \rightarrow X^1\Sigma_g^+$	1981

Ions et Radicaux

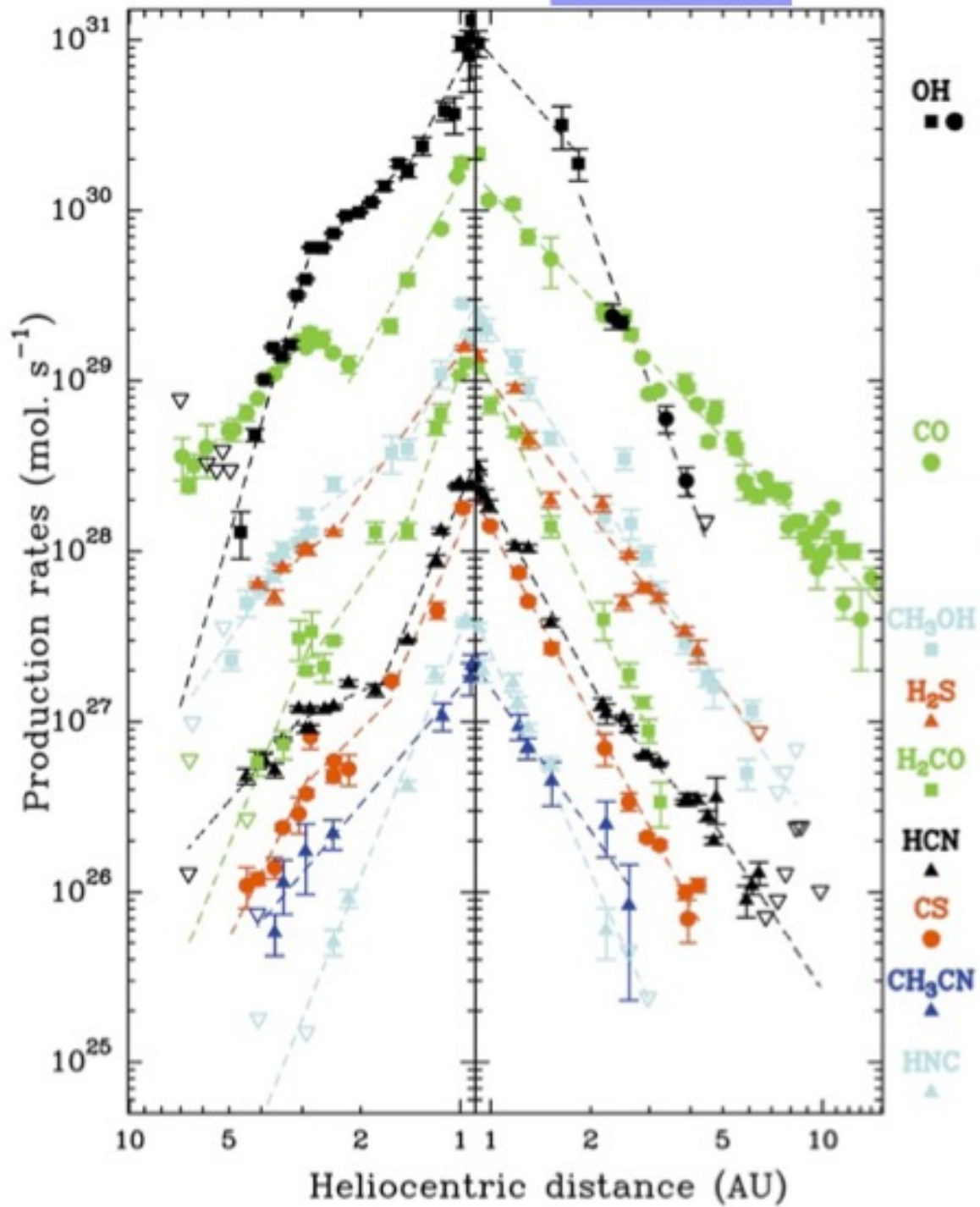
Atome ou molécule	Bande ou raie caractéristique	Transition	Année de première détection
$^{12}\text{C}^{13}\text{C}$	4 745 Å	$d^3\Pi_g \rightarrow a^3\Pi_u$	1943
		\rightarrow	1964
C_3	4 040 Å	$\tilde{A}^1\Pi_u \rightarrow \tilde{X}^1\Sigma_g^+$	1882
			1951
CH	3 889 Å	$B^2\Sigma^- \rightarrow X^2\Pi_r$	1940
	4 315 Å	$A^2\Delta \rightarrow X^2\Pi_r$	1938
CN	3 883 Å	$B^2\Sigma^+ \rightarrow X^2\Sigma^+$	1882
	7 873 Å	$A^2\Pi_i \rightarrow X^2\Sigma^+$	1948
CO	1 510 Å	$A^1\Pi \rightarrow X^1\Sigma^+$	1976
CS	2 576 Å	$A^1\Pi \rightarrow X^1\Sigma^+$	1980
NH	3 360 Å	$A^3\Pi_i \rightarrow X^3\Sigma^-$	1941
NH_2	5 700 Å	$\tilde{A}^2A_1 \rightarrow \tilde{X}^2B_1$	1943
OH	3 090 Å	$A^2\Sigma^+ \rightarrow X^2\Pi_i$	1941
CH^+	4 225 Å	$A^1\Pi \rightarrow X^1\Sigma^+$	1941 b
CN^+	2 181 Å	$f^1\Sigma \rightarrow a^1\Sigma$	1980
	3 185 Å	$c^1\Sigma \rightarrow a^1\Sigma$	
CO^+	2 190 Å	$B^2\Sigma^+ \rightarrow X^2\Sigma^+$	1976
	3 954 Å	$B^2\Sigma^+ \rightarrow A^2\Pi_i$	1950
	4 273 Å	$A^2\Pi_i \rightarrow X^2\Sigma^+$	1910
			1950
CO_2^+	2 890 Å	$B^2\Sigma_u^+ \rightarrow X^2\Pi_g$	1976
	3 509 Å	$\tilde{A}^2\Pi_u \rightarrow \tilde{X}^2\Pi_g$	1950
H_2O^+	6 198 Å	$\tilde{A}^2A_1 \rightarrow \tilde{X}^2B_1$	1974
N_2^+	3 914 Å	$B^2\Sigma_u^+ \rightarrow X^2\Sigma_g^+$	1910
OH^+	3 565 Å	$A^3\Pi_i \rightarrow X^3\Sigma^-$	1950

(D'après S. Wykoff, *Comets, ibid.*)

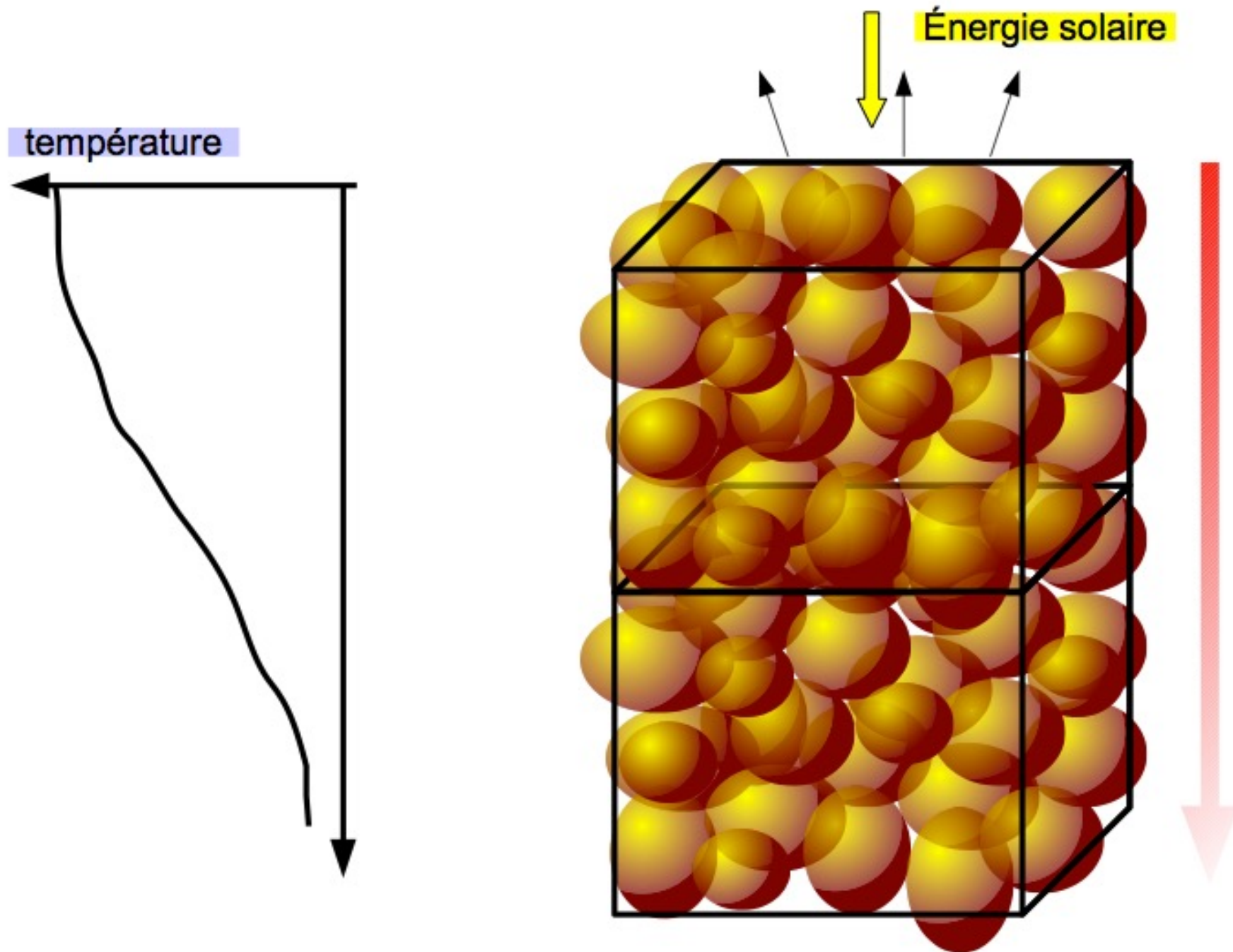
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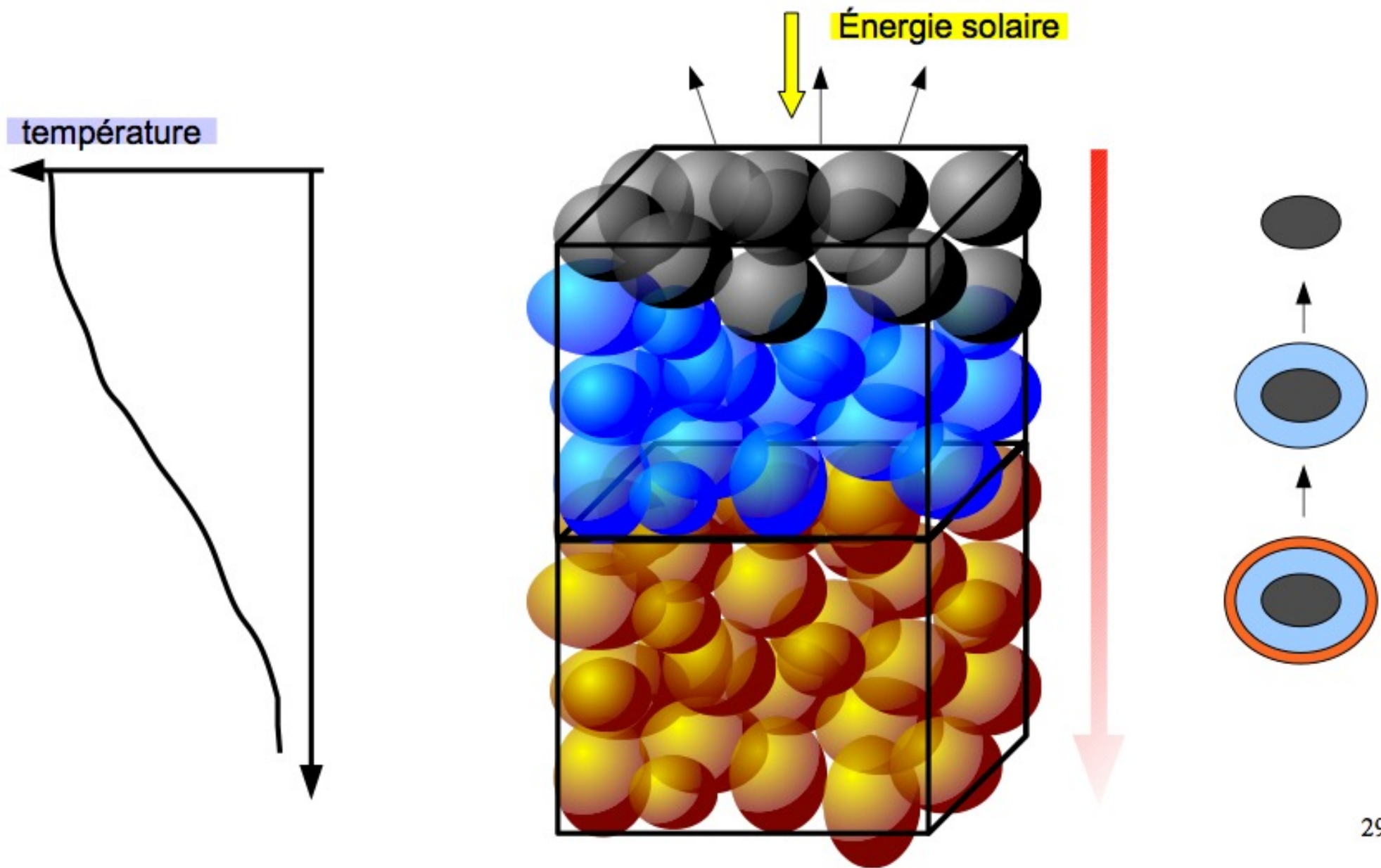
Comet C/1995 01 (Hale-Bopp)

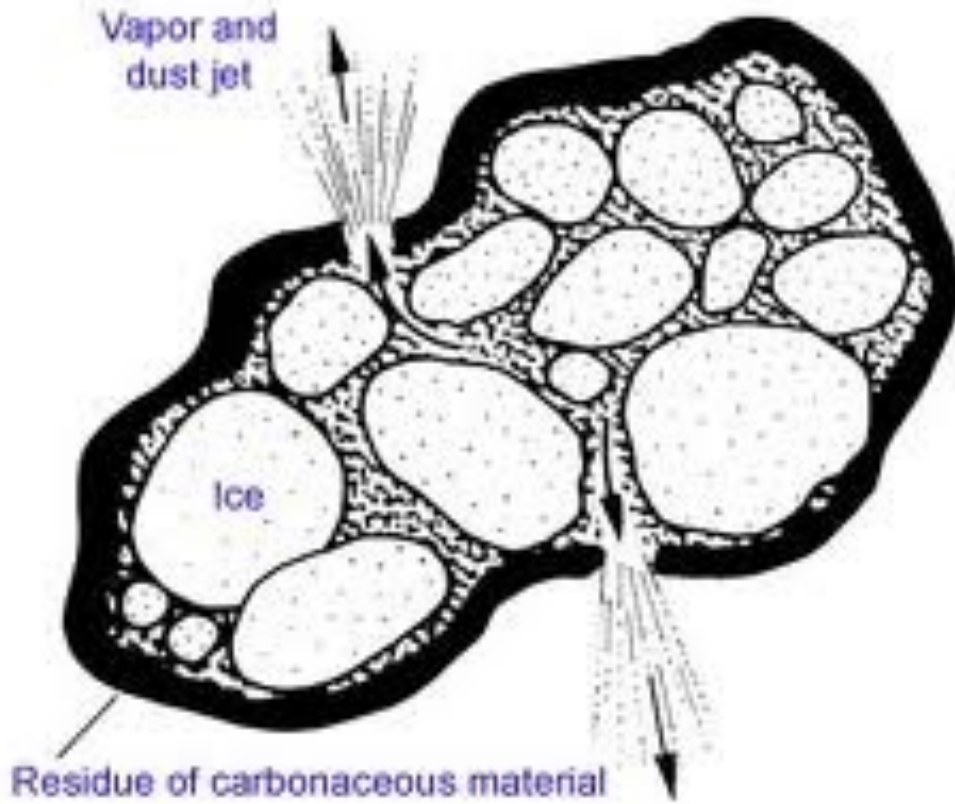


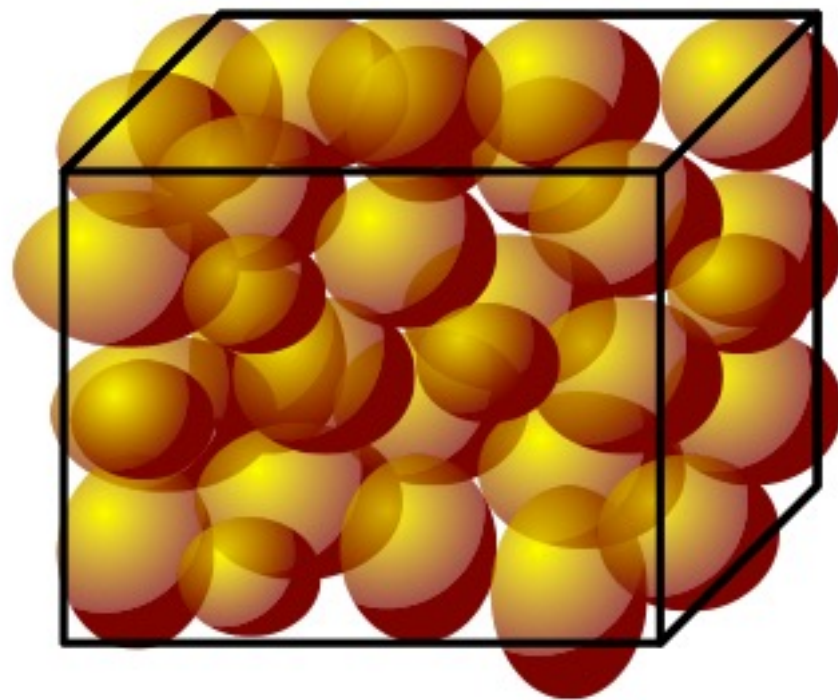
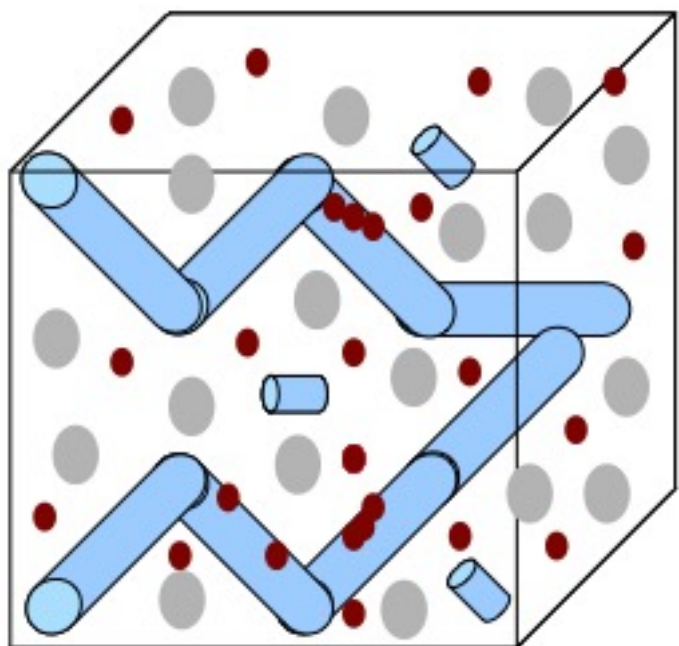
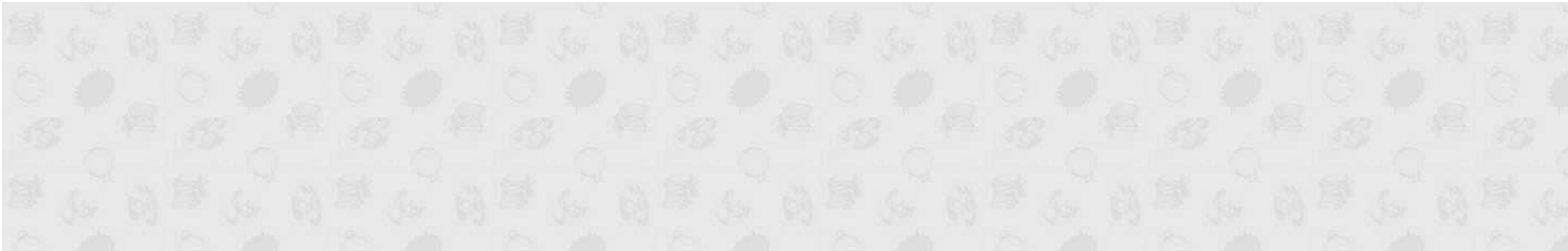
Différenciation d'un noyau cométaire



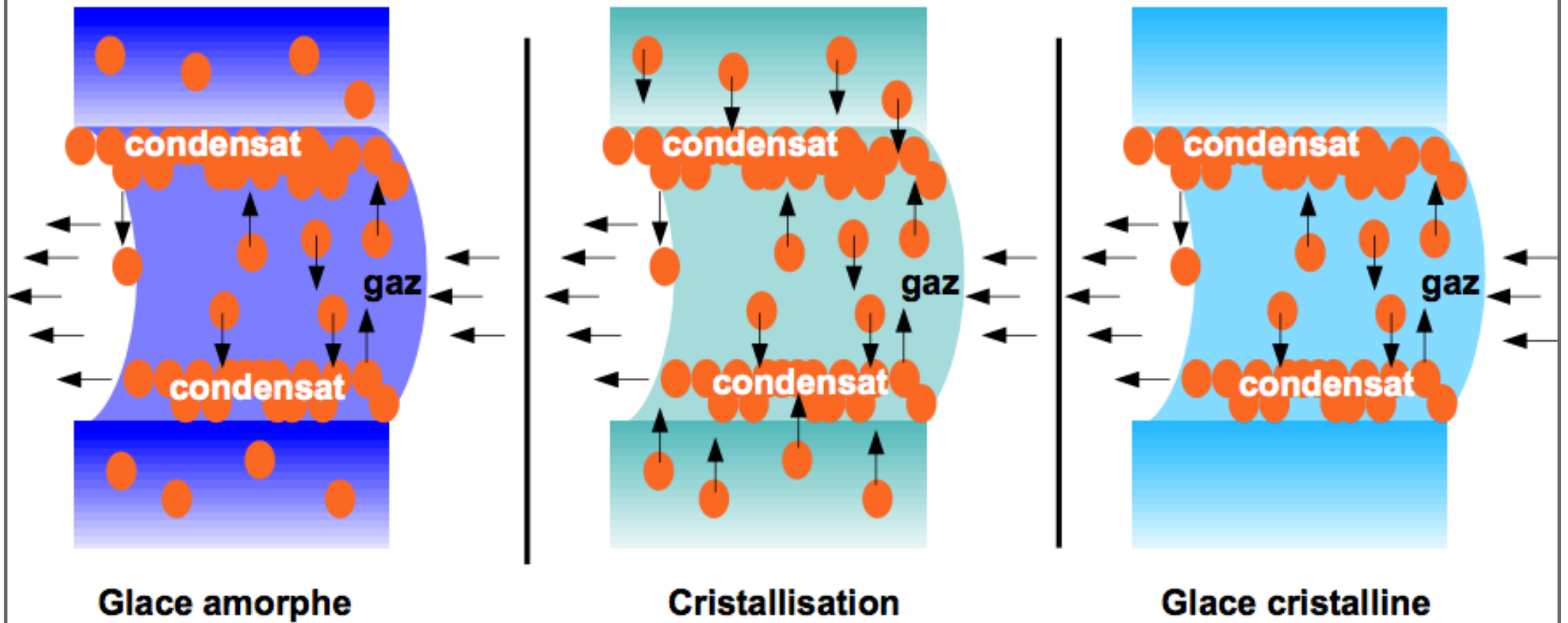
Différenciation d'un noyau cométaire



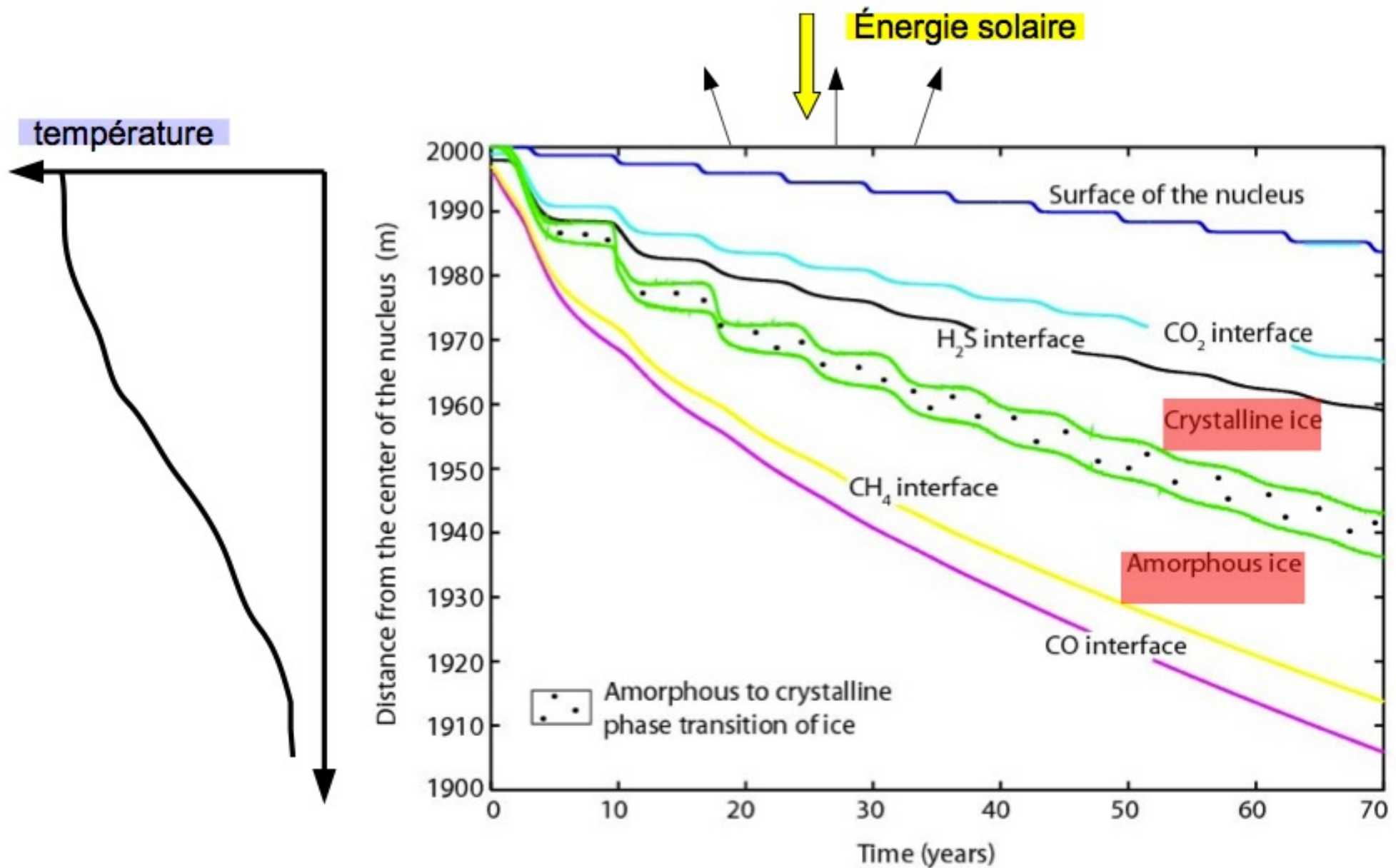


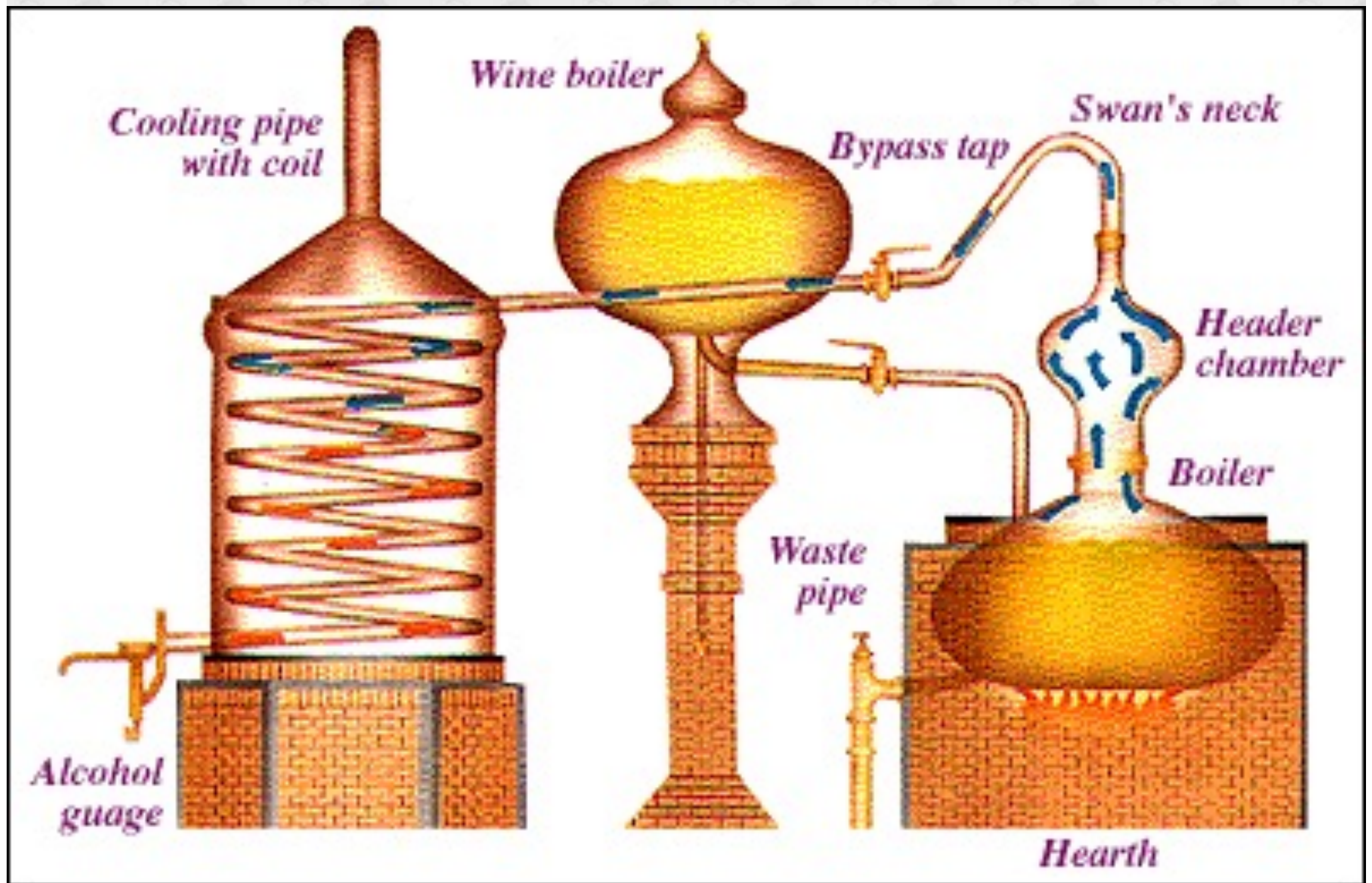


Coupe d'1 pore

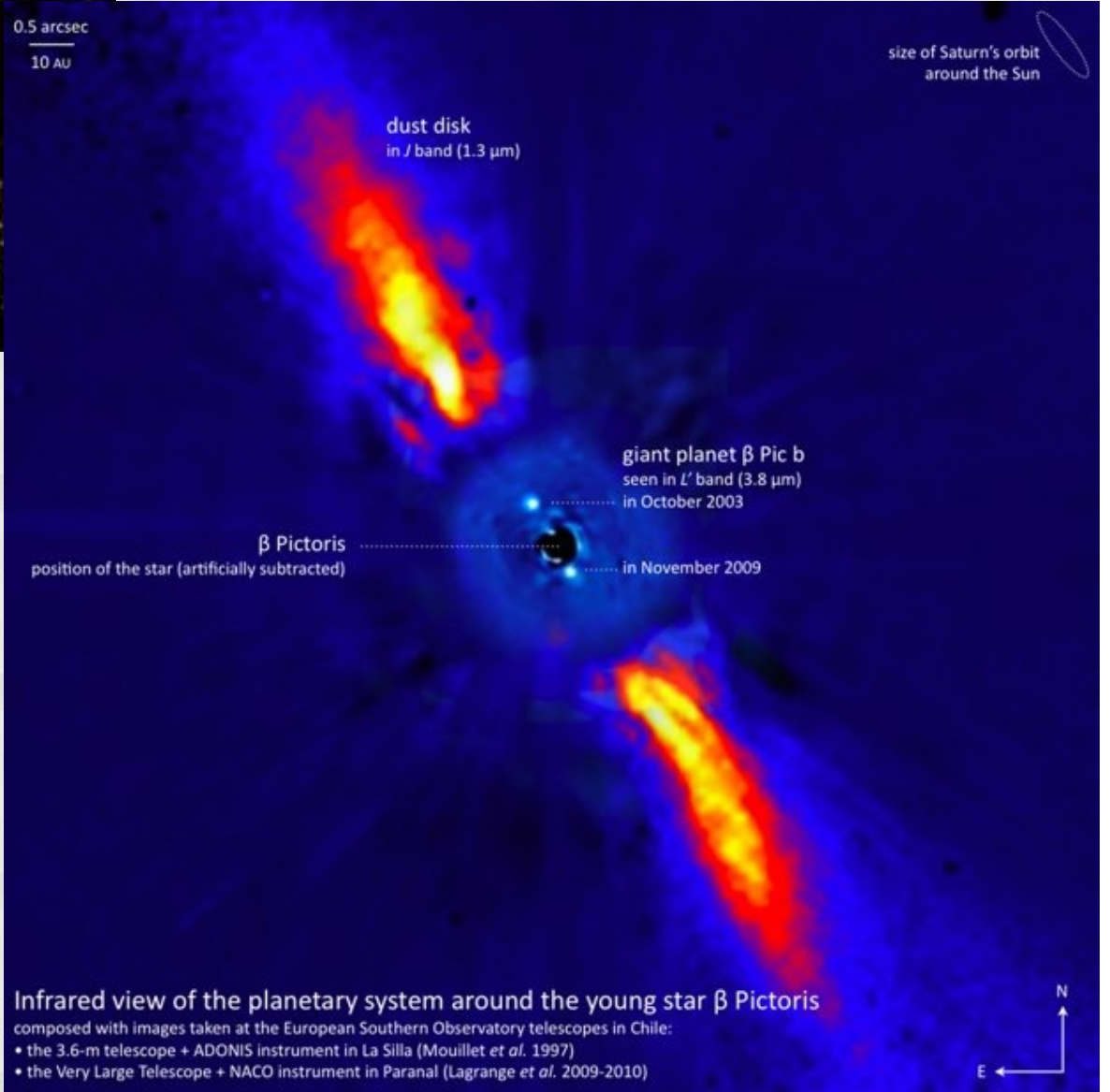
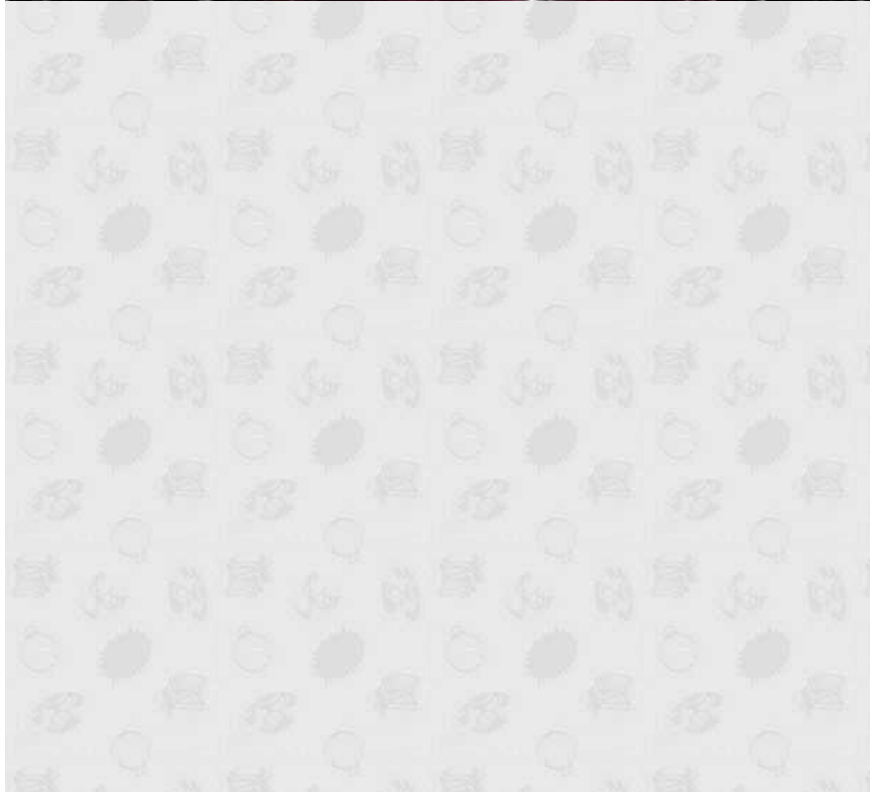


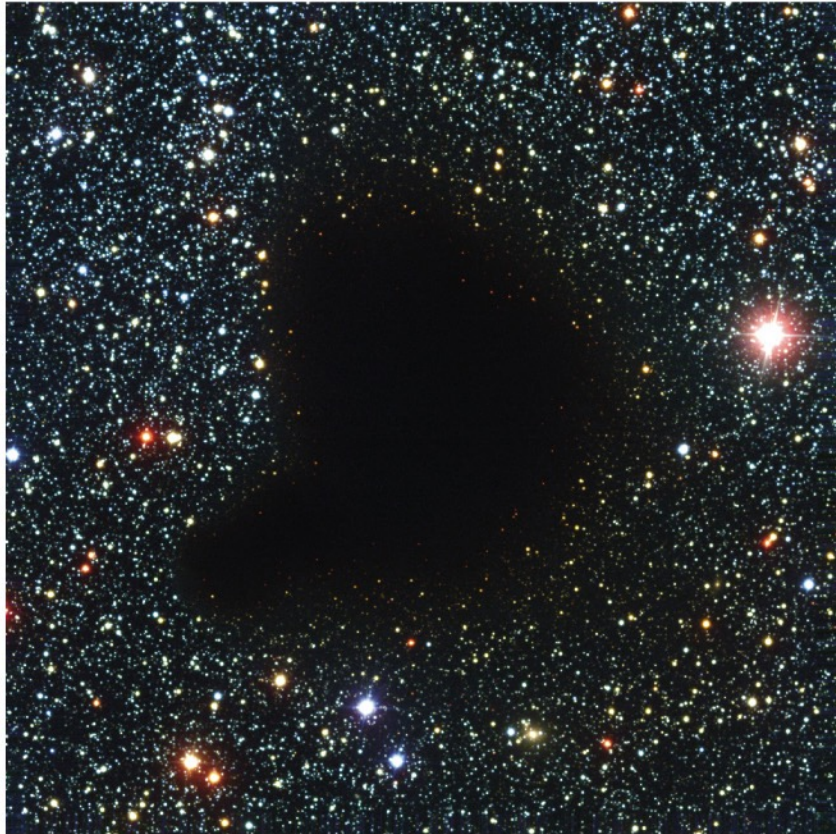
Différenciation d'un noyau cométaire



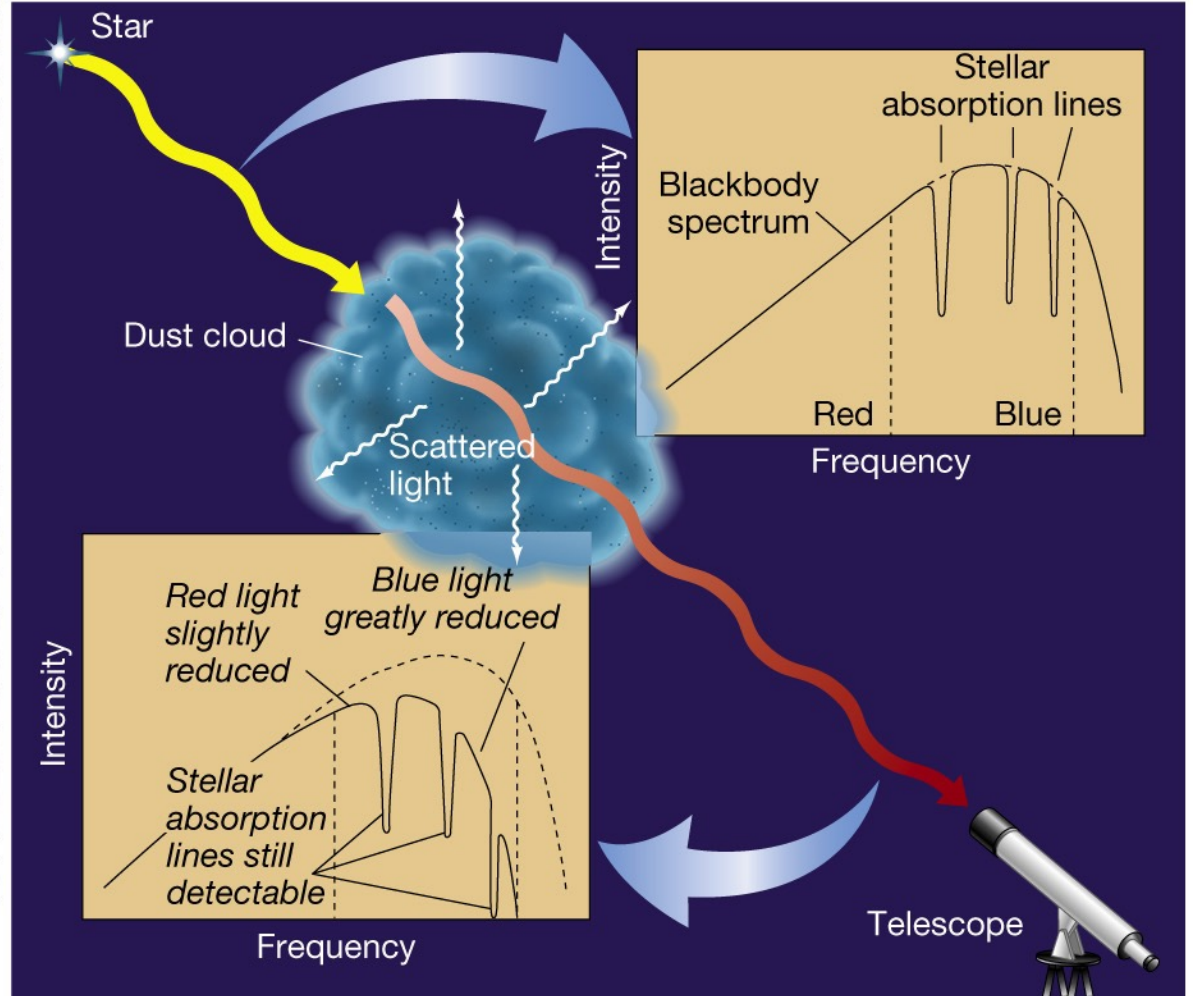


**Où
COMMENT SE FORMENT
LES GLACES COMÉTAIRES ?**

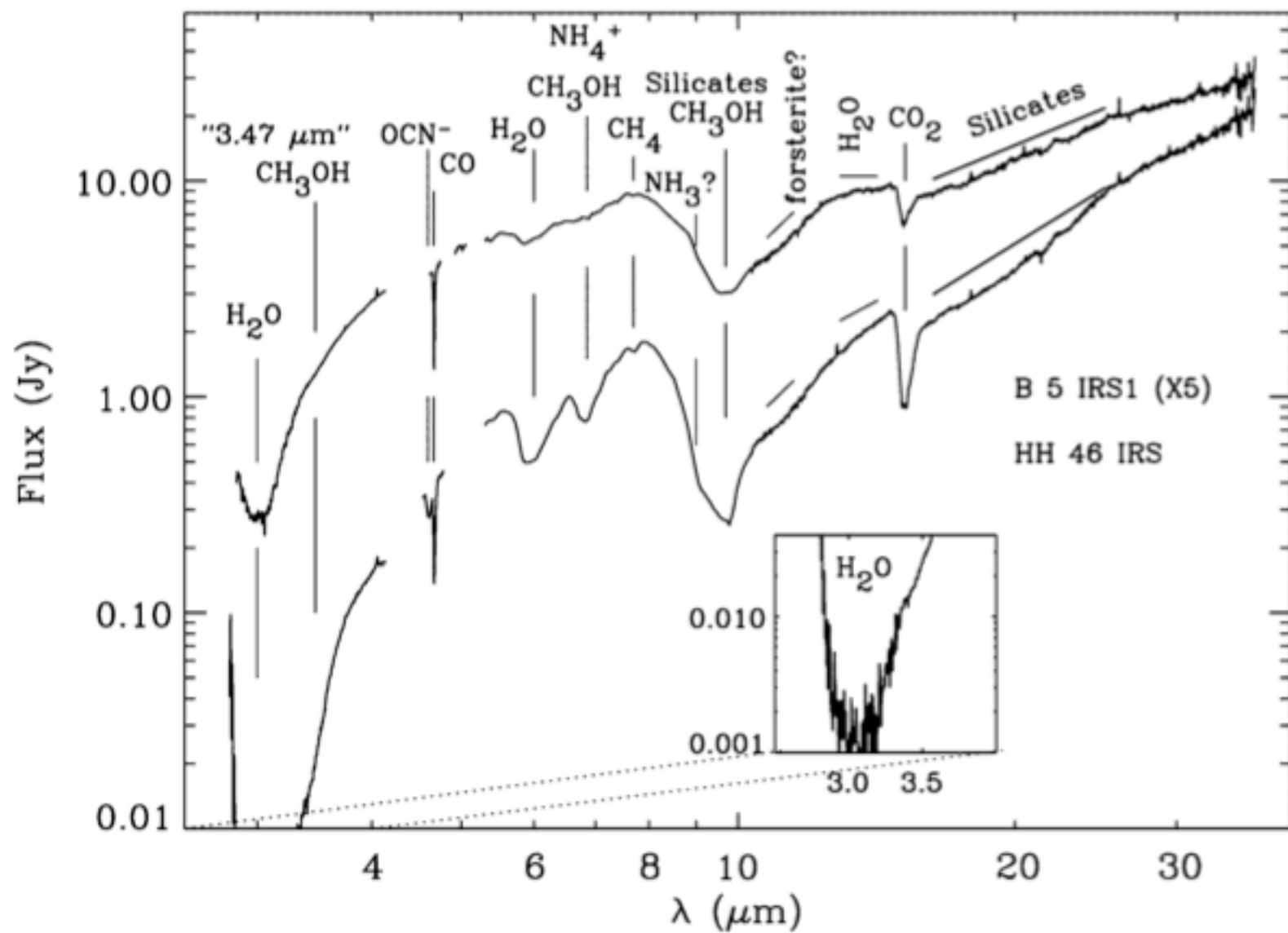




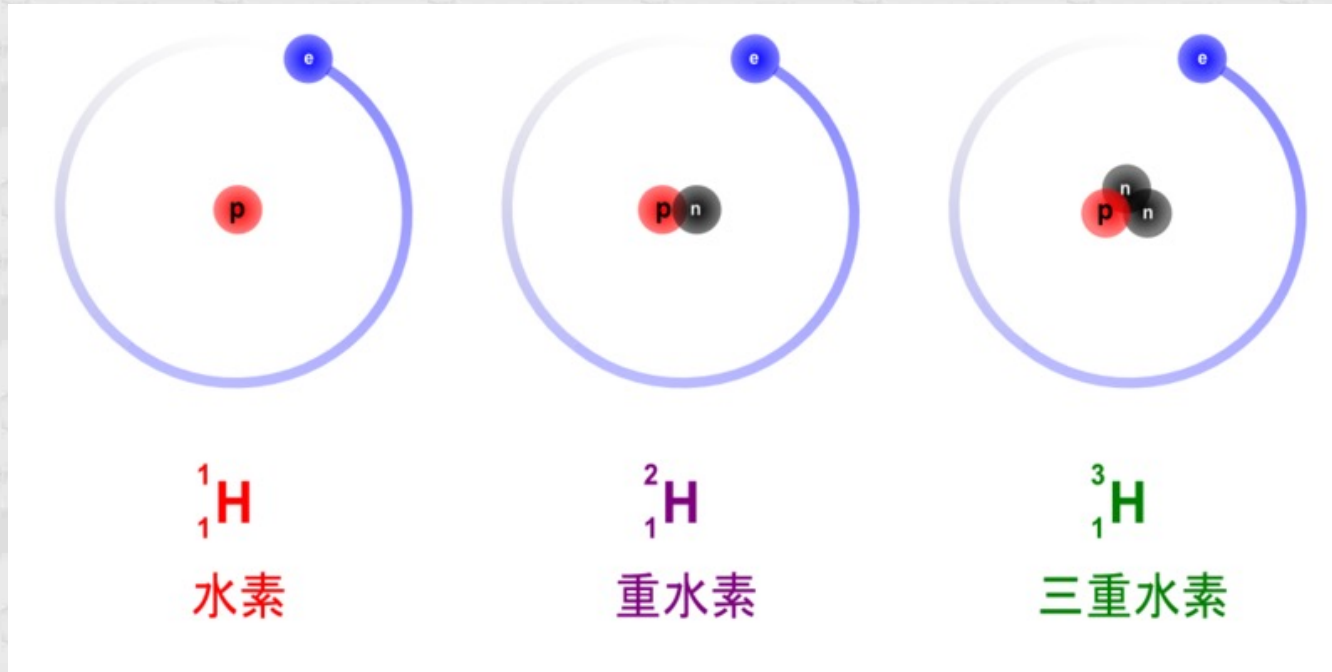
(a)



(b)



Le Deutérium : sonde de la chimie froide des nuages



-840 ‰

0 ‰

1000 ‰

1000 - 100000 ‰



Molécule	Comètes	IRAS 16293–2422	Cœur Chaud d'Orion	L134N
DCO ⁺ /HCO ⁺	-	0.0086 ^e	-	0.035 ^{n*} –0.18 ^r
N ₂ D ⁺ /N ₂ H ⁺	-	-	-	0.12 ^{n*} –0.35 ^r
HDO/H ₂ O	0.0003 ^{a,b,c}	≥ 0.01 ^e	0.0005–0.002 ^h	-
DCN/HCN	0.002 ^d	0.01 ^e	0.001 ^m –0.005 ⁱ	0.05 ⁿ
HDCO/H ₂ CO	-	0.15 ^f	0.14 ^g	0.068 ⁿ
CH ₂ DOH/CH ₃ OH	-	-	0.04 ^j	-
CH ₃ OD/CH ₃ OH	-	-	0.01–0.06 ^k	≤ 0.032 ⁿ
NH ₂ D/NH ₃	-	0.1 ^e	0.003 ^l	0.057 ⁿ –0.10 ^r
D ₂ CO/H ₂ CO	-	0.05 ^q	0.003 ^g	-
ND ₂ H/NH ₃	-	-	-	0.005 ^p

HDO/H₂O

0.03

Inner region

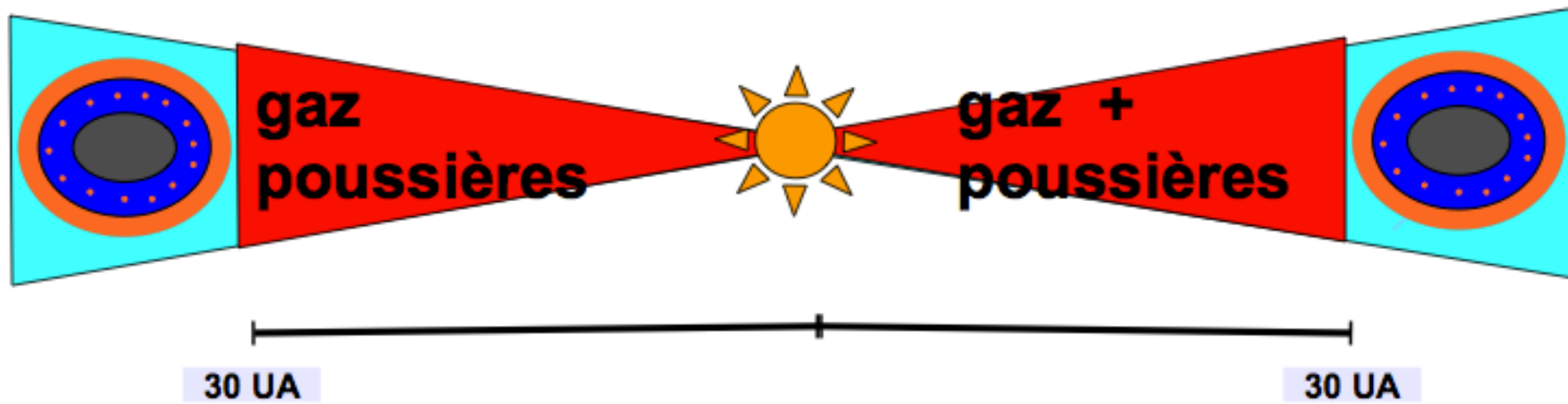
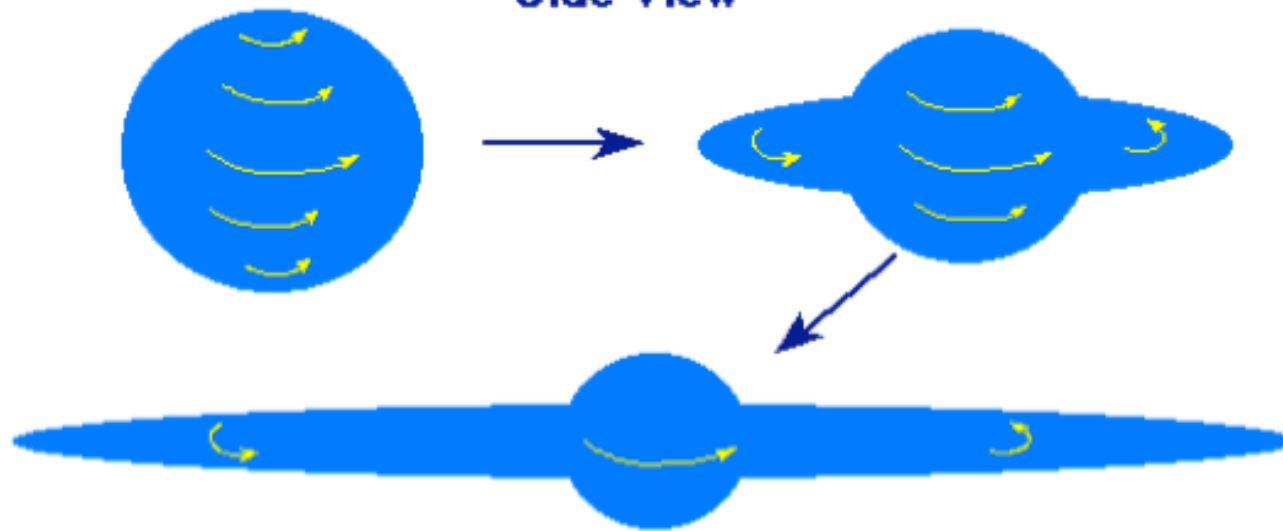
0.002

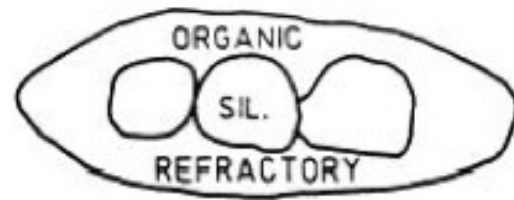
Outer region

Parise et al. 2005 A&A

D/H measured only in H₂O and HCN

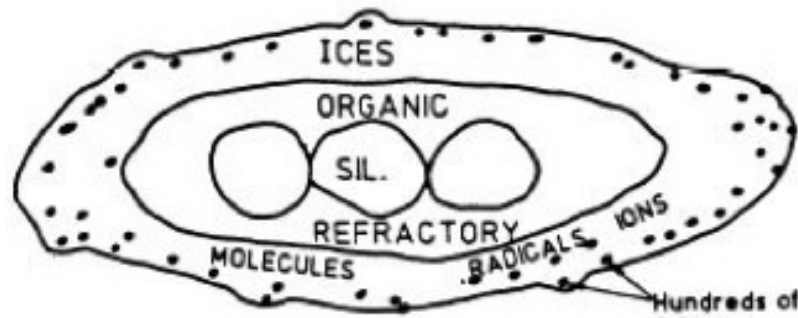
Side View





DIFFUSE CLOUD GRAIN.

0.25 μm



PRECOMETARY GRAIN

Hundreds of
0.01 μm
particles

0.5 μm



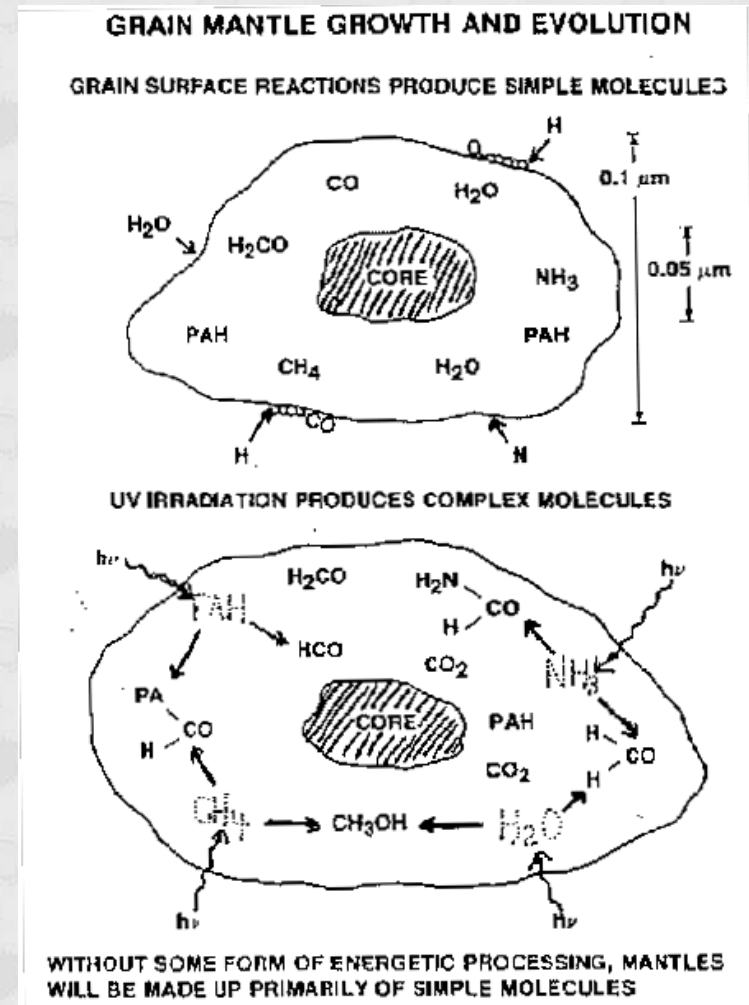
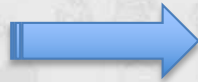
0.25 μm

Comète

=

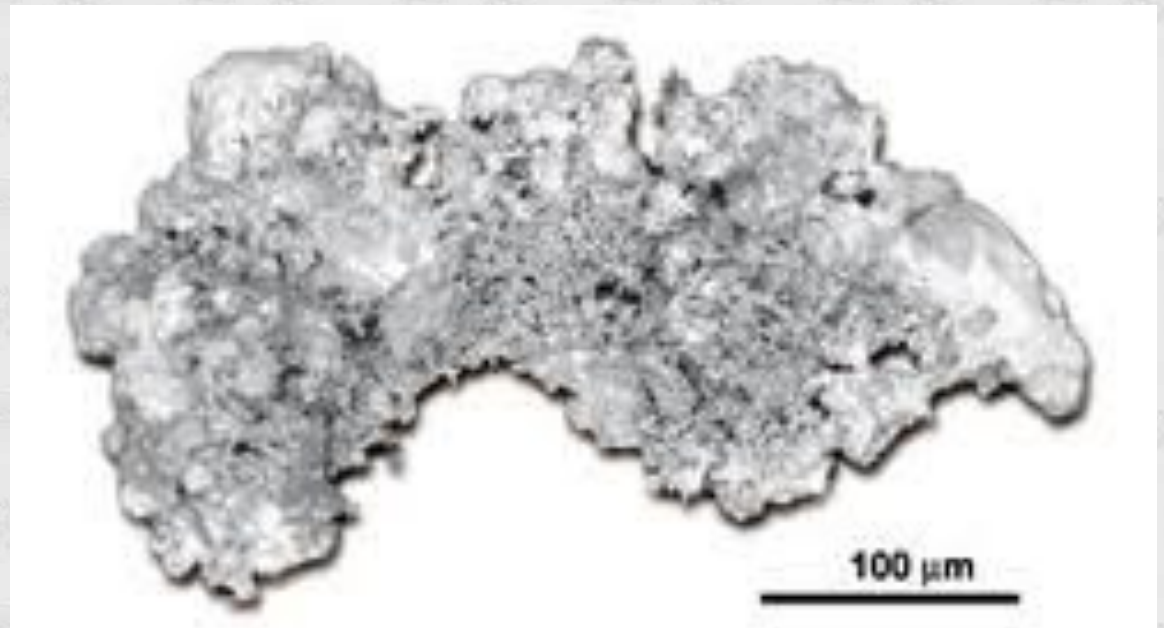
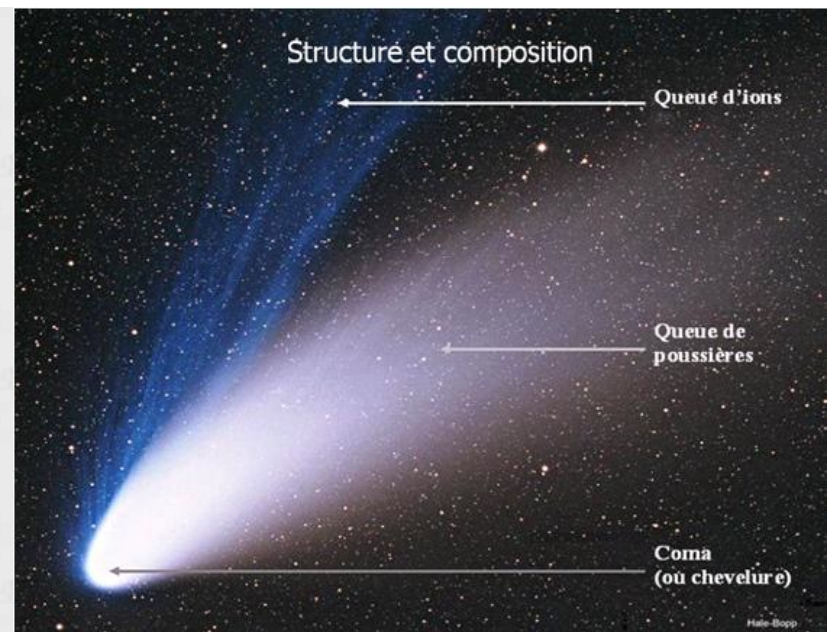
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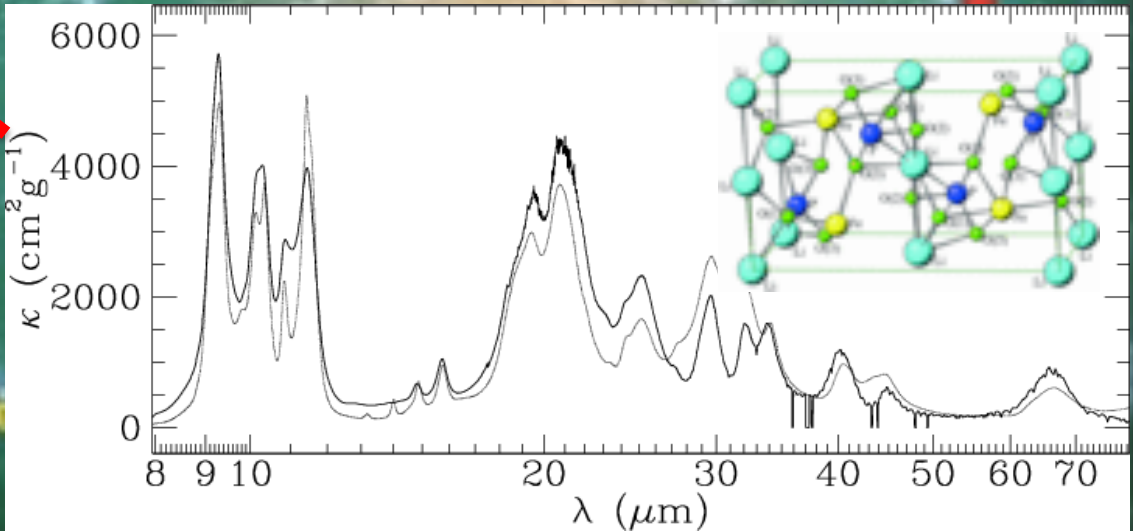
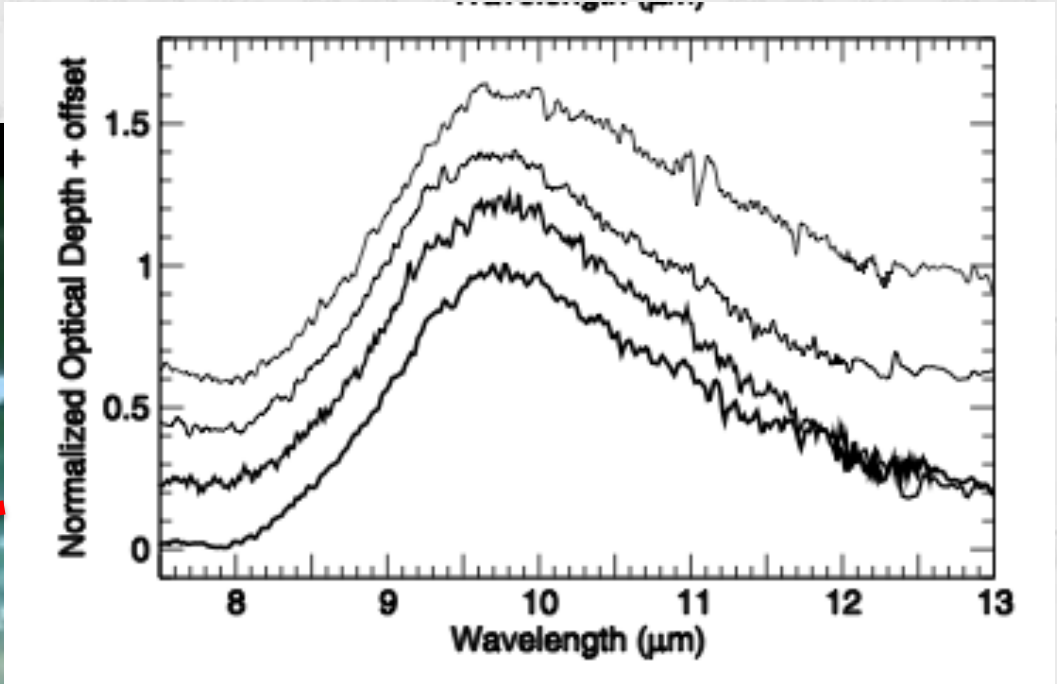
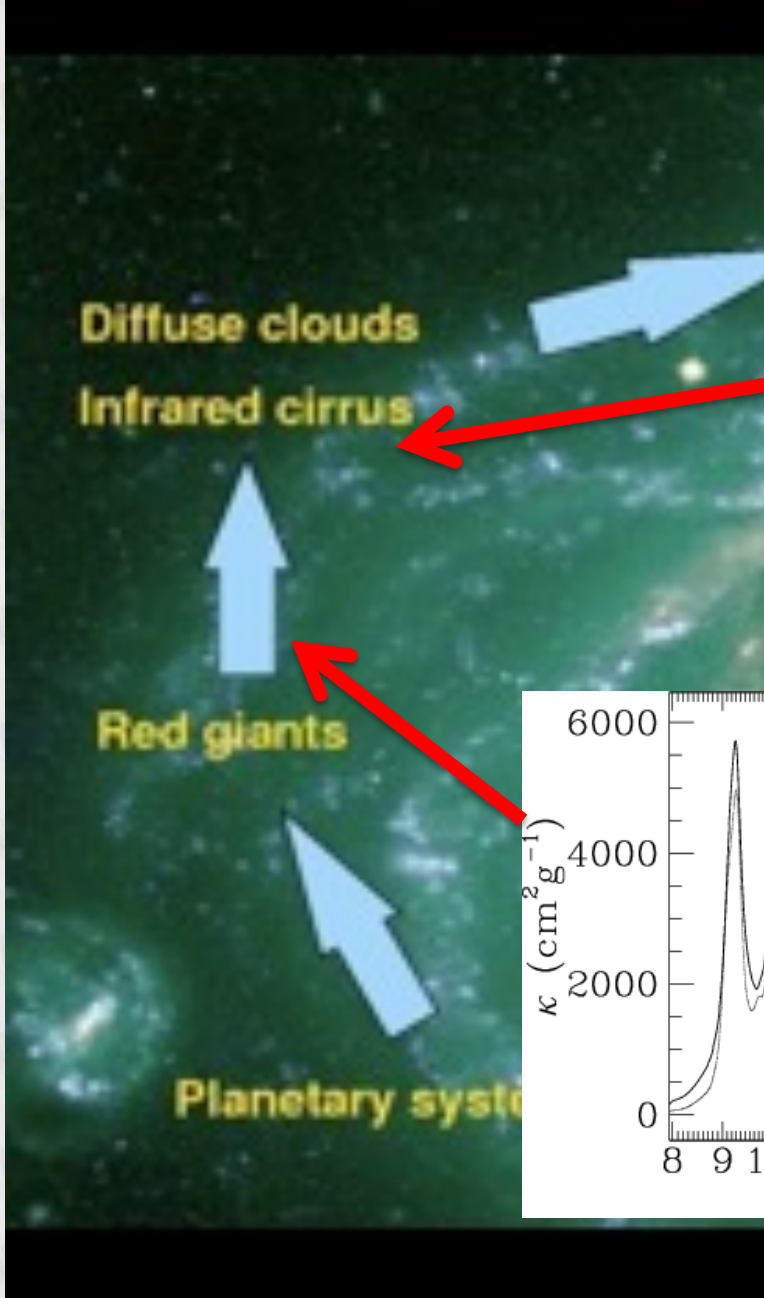
Condensat du Milieu Interstellaire

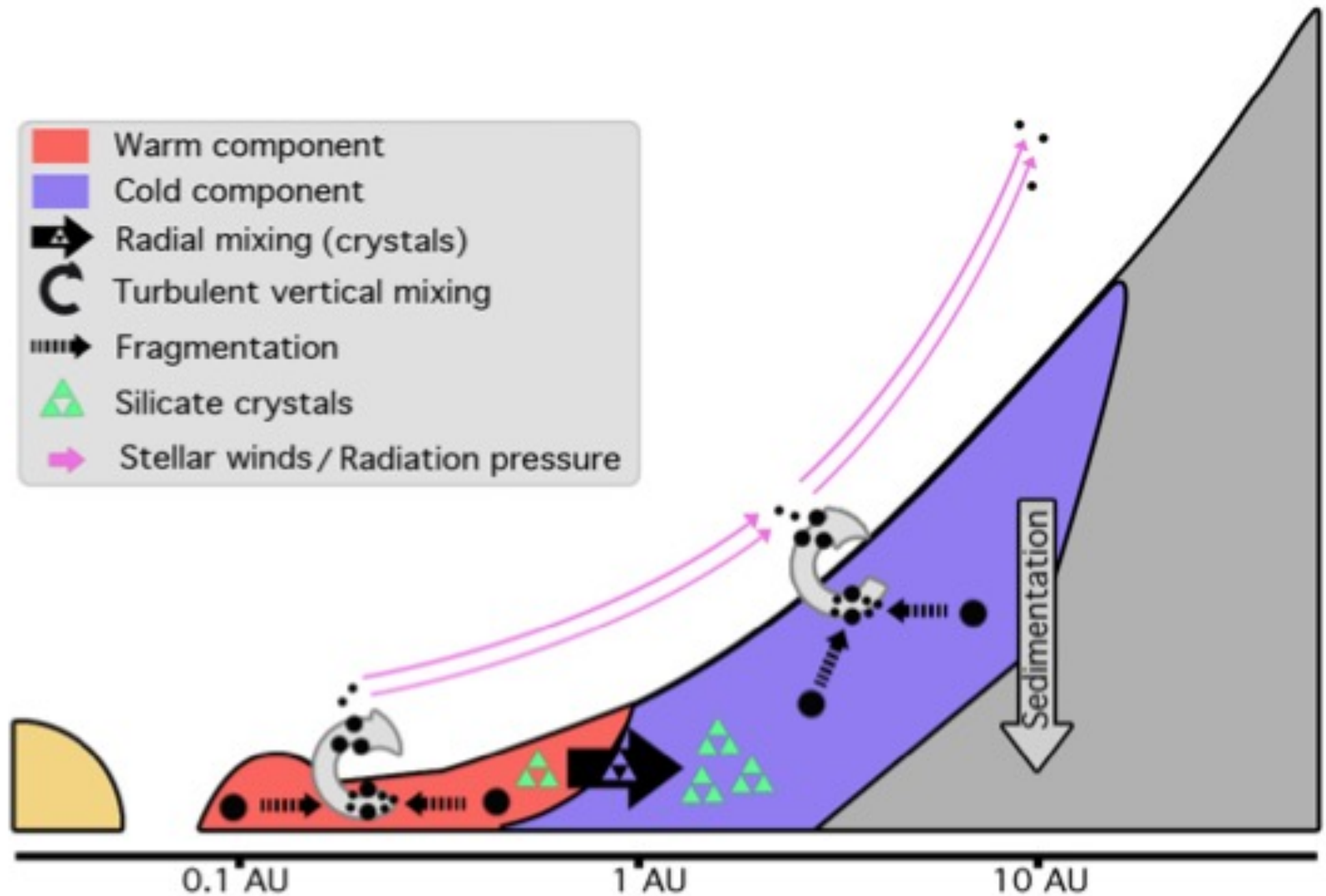


Les Matériaux Réfractaires des Comètes

C'est à dire les poussières....







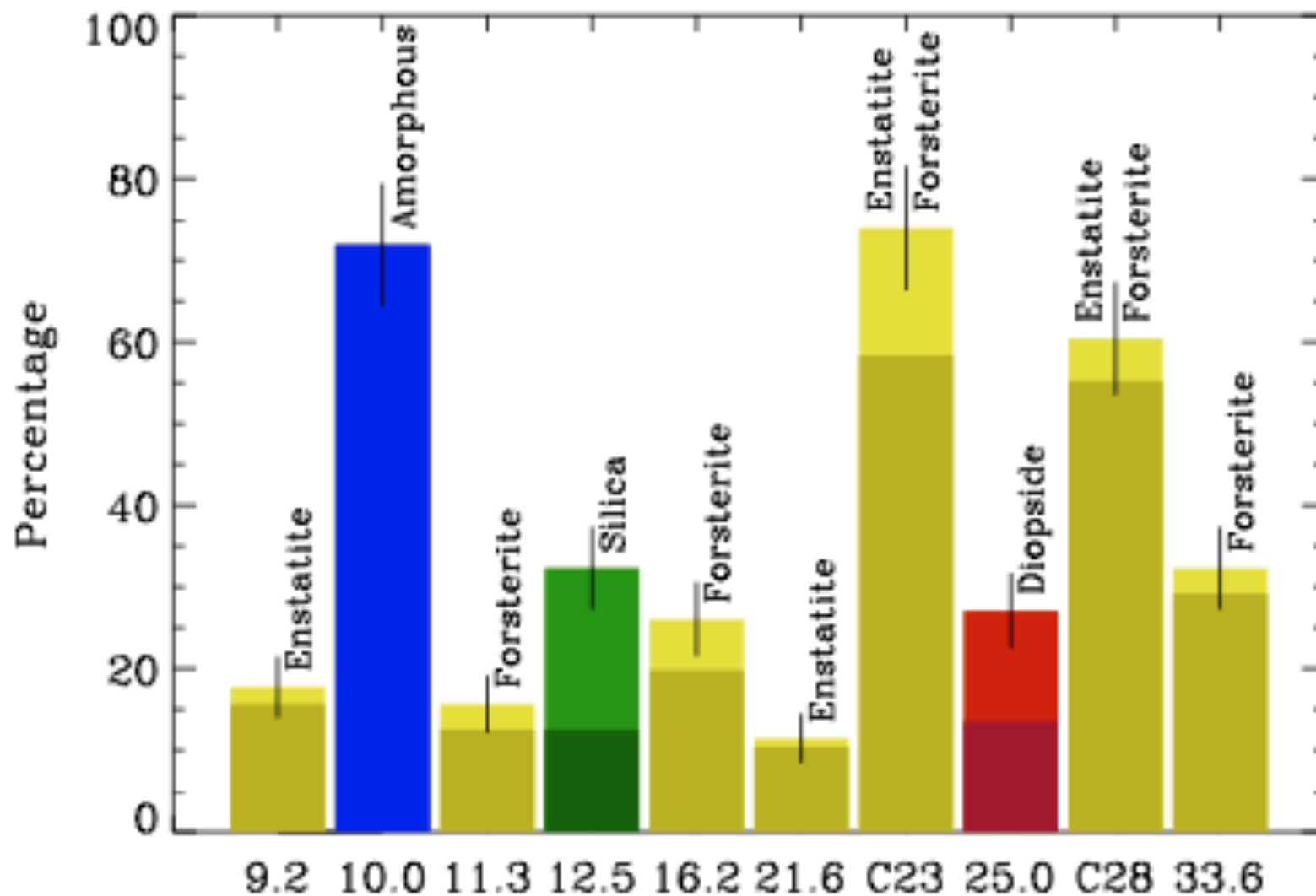
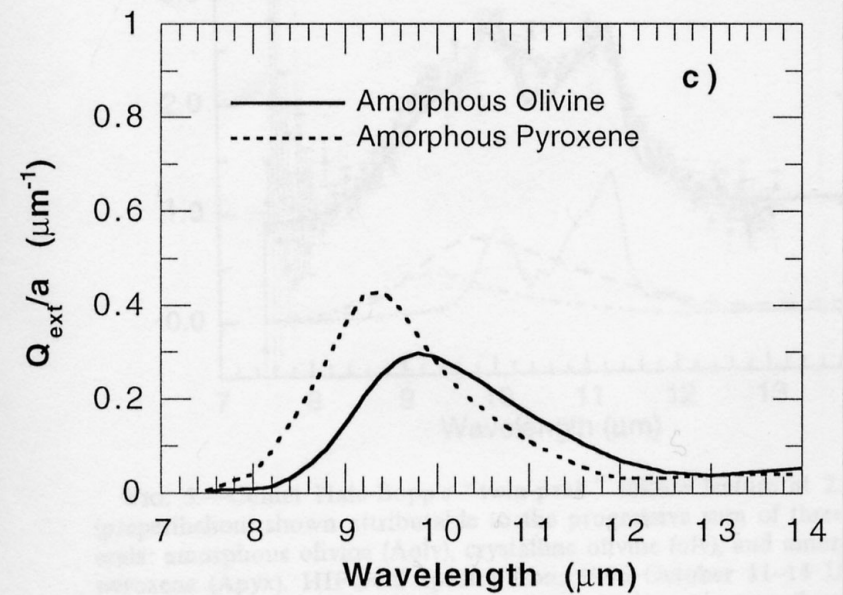
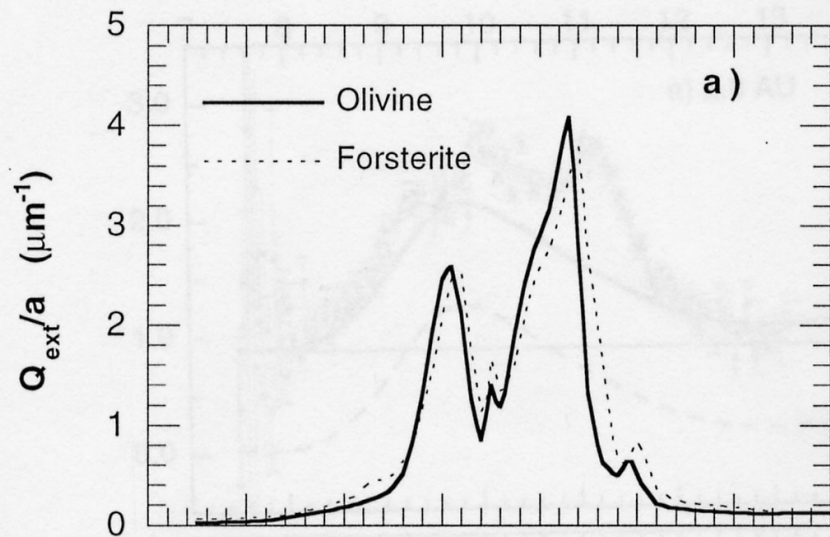
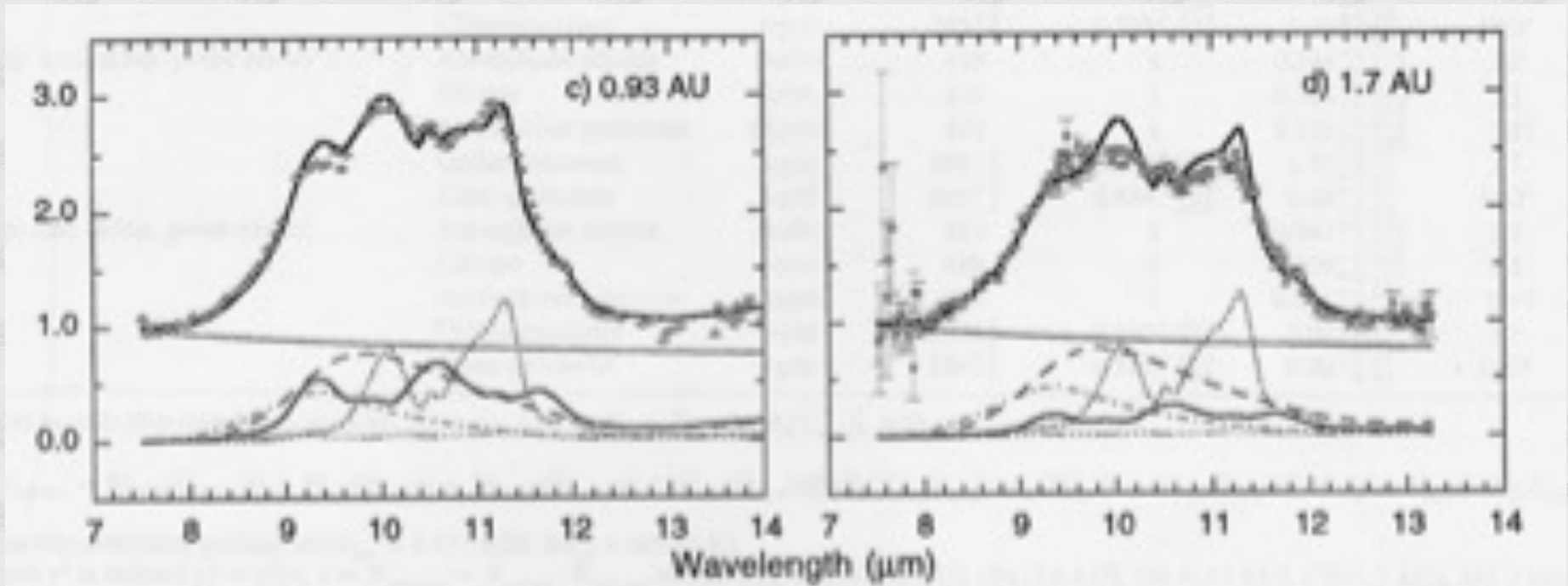


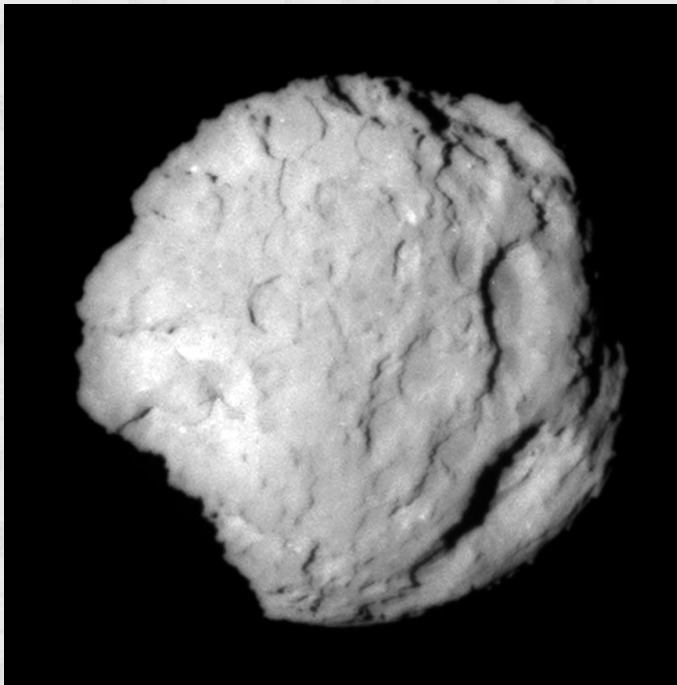
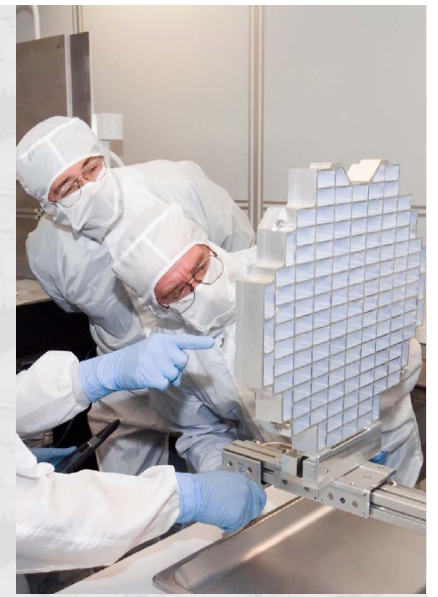
Fig. 3. Detection statistics for crystalline silicate features (yellow and red bars) for the $10.0 \mu\text{m}$ amorphous silicate feature (blue) and for silica at $12.5 \mu\text{m}$ (green). Darker color bars are positive detections ($SNR > 20$), and lighter color bars stand for tentative detections ($SNR \leq 20$). The uncertainties are those due to Poisson statistics.

Silicates cométaires cristallins (ISO 1997)



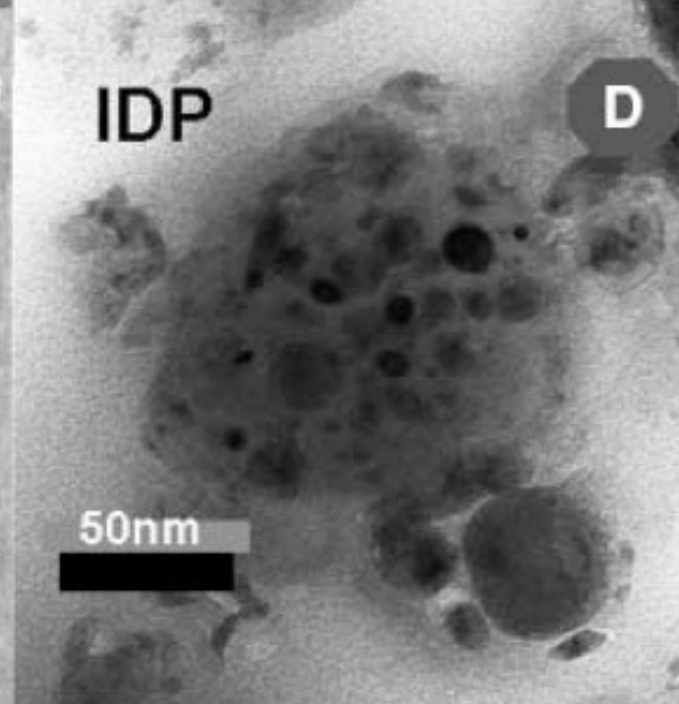
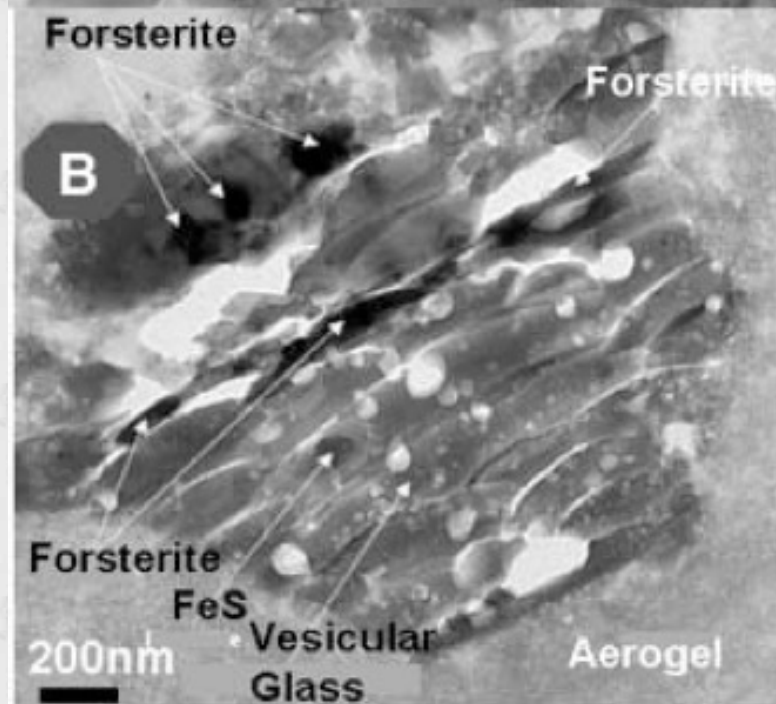
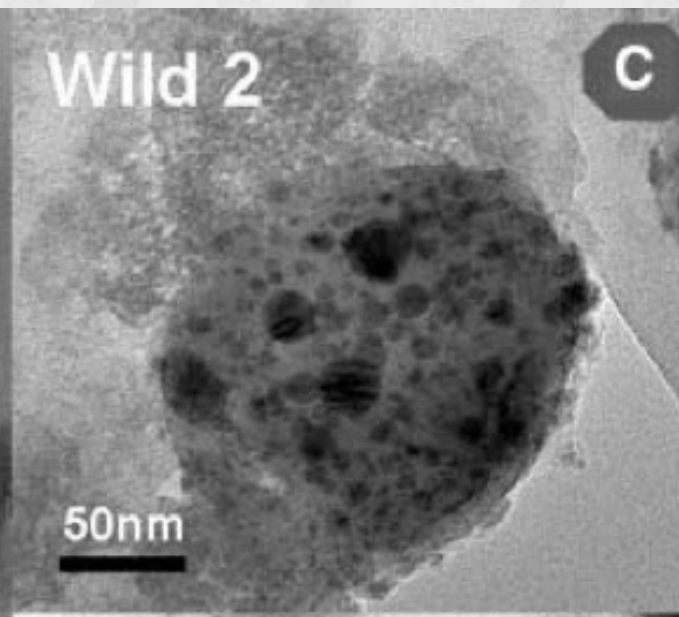
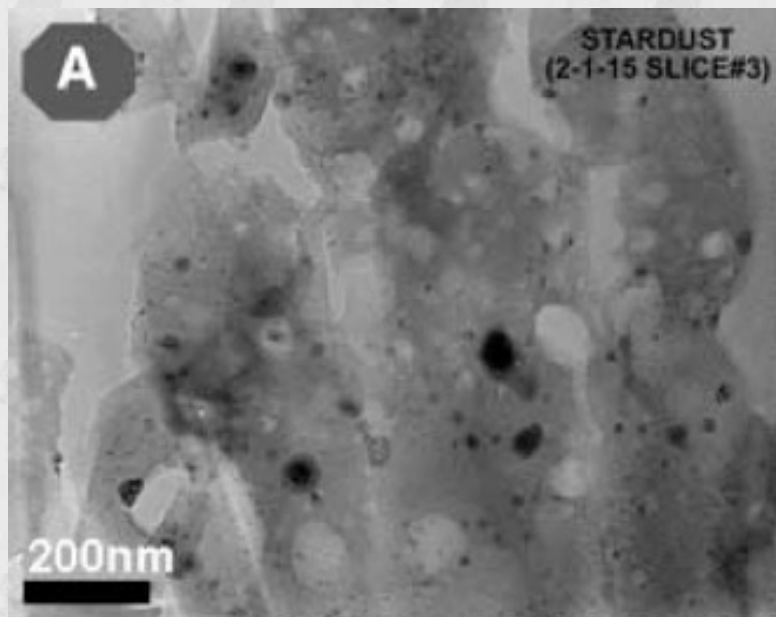
Stardust : retour d'échantillon cométaire

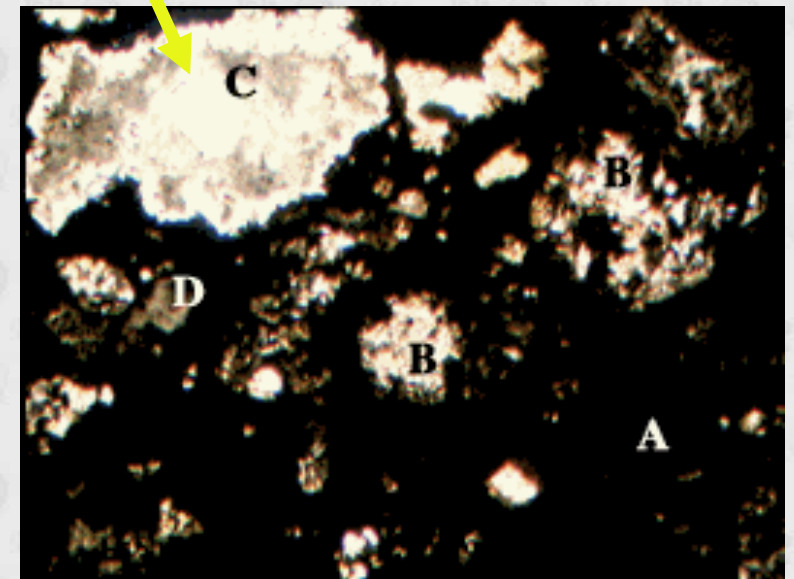
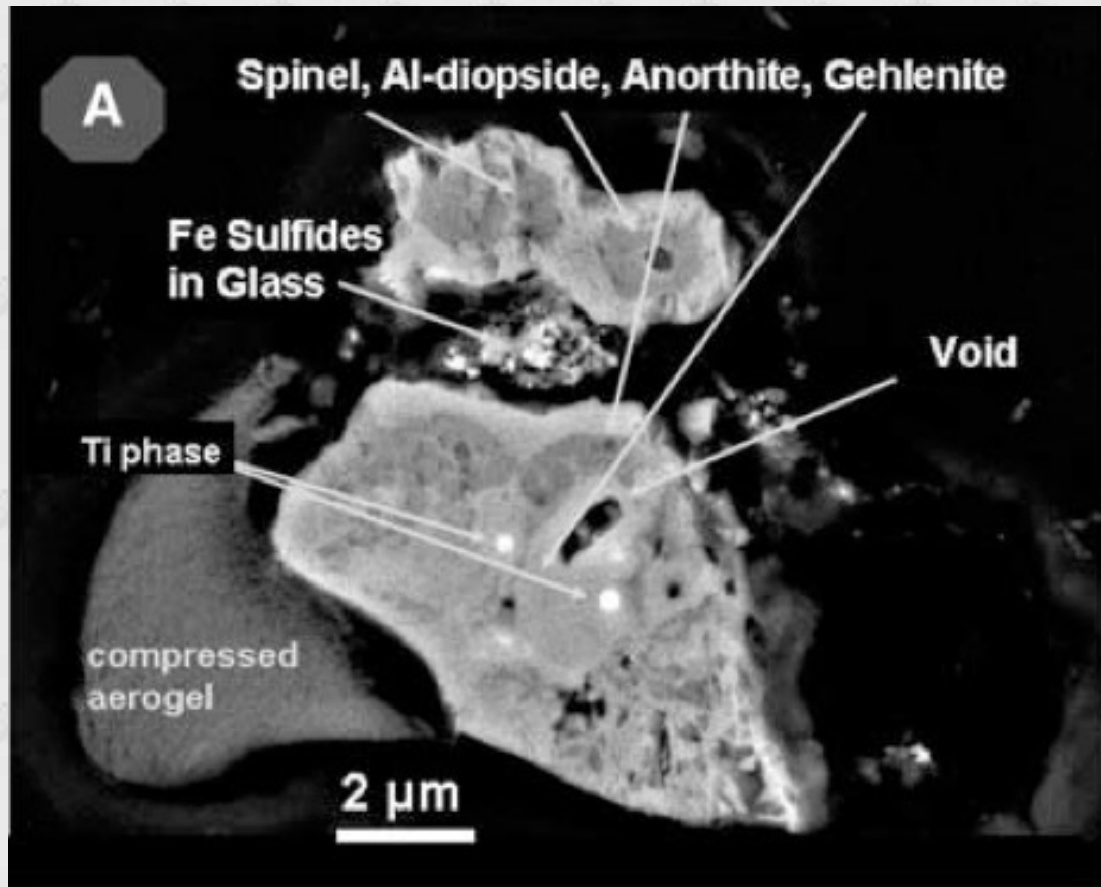
Wild 2 (STARDUST) – Comète de Kuiper
(perturbée par Jupiter en 1974)



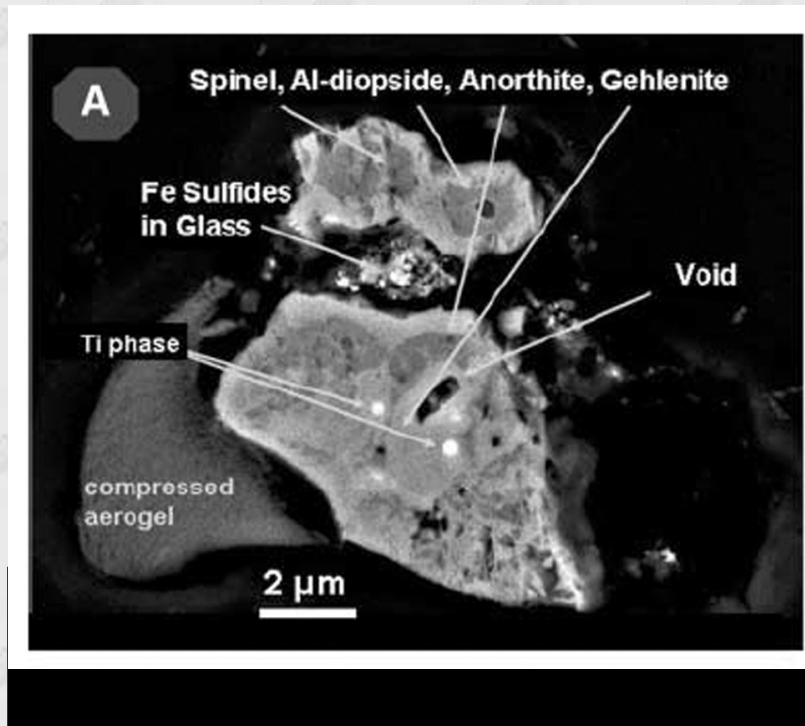
Impacts à 6 km/s



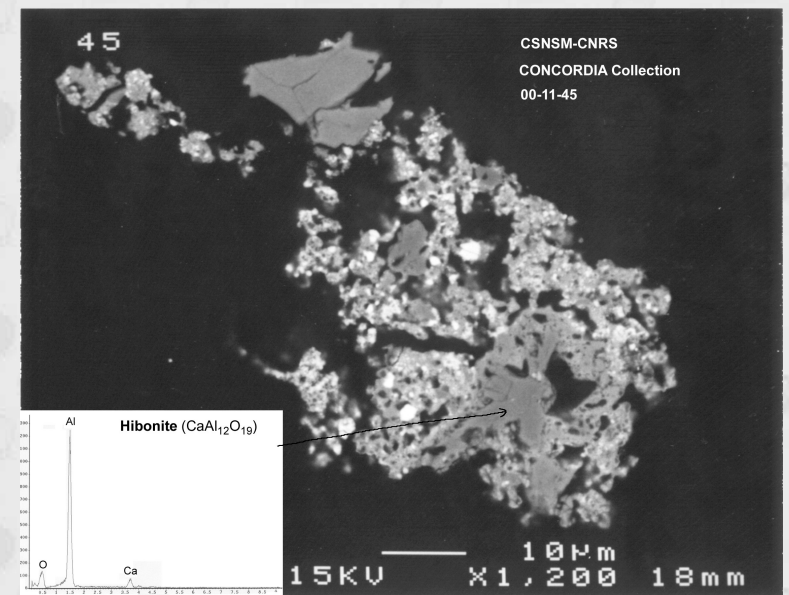
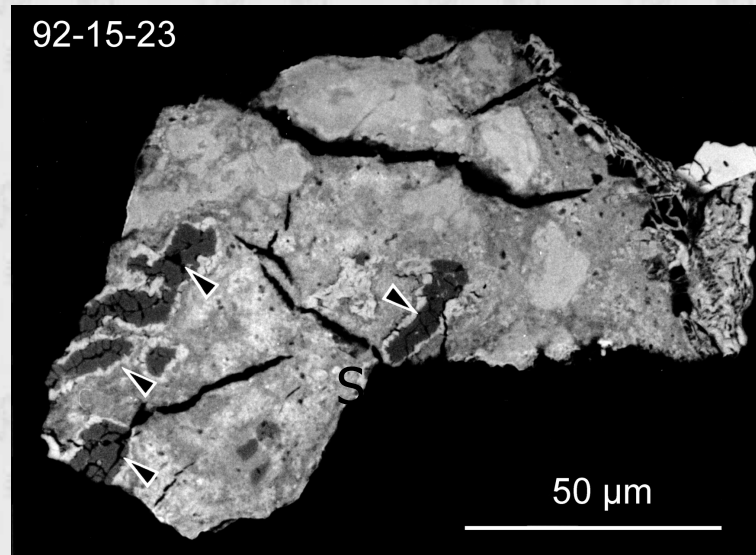




STARDUST



Micrométéorites

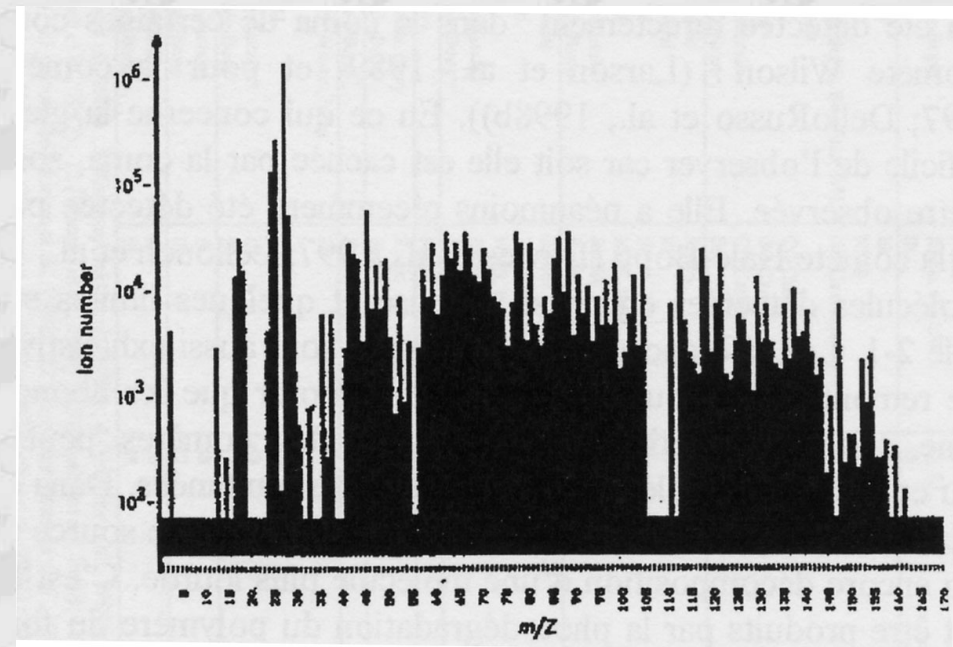
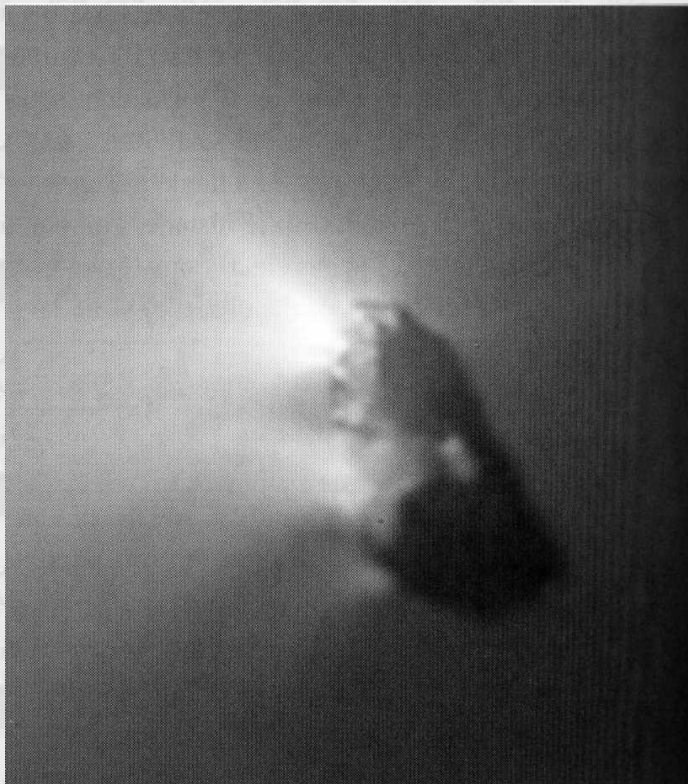
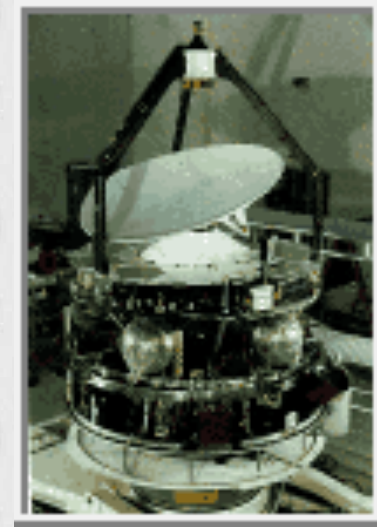


Les minéraux sont principalement non primitifs !

- **Une grande proportion de silicates cristallins**
- **Formés à haute température**
- **Coexistent avec des glaces = basse température**

Des poussières carbonées très complexes...

Survol GIOTTO/VEGA : Halley (1985)

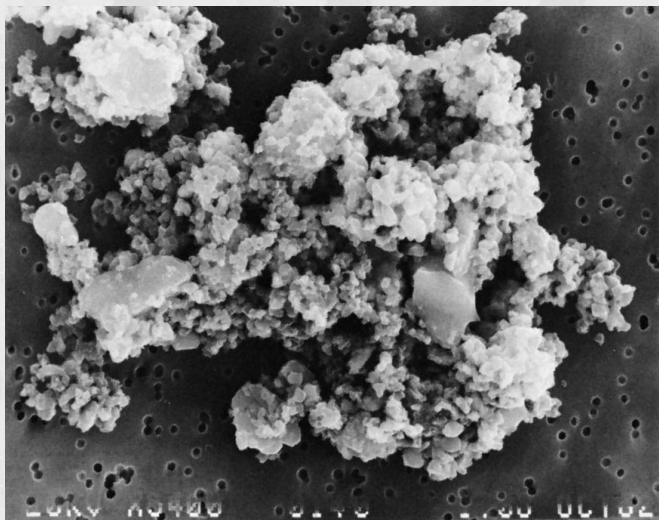
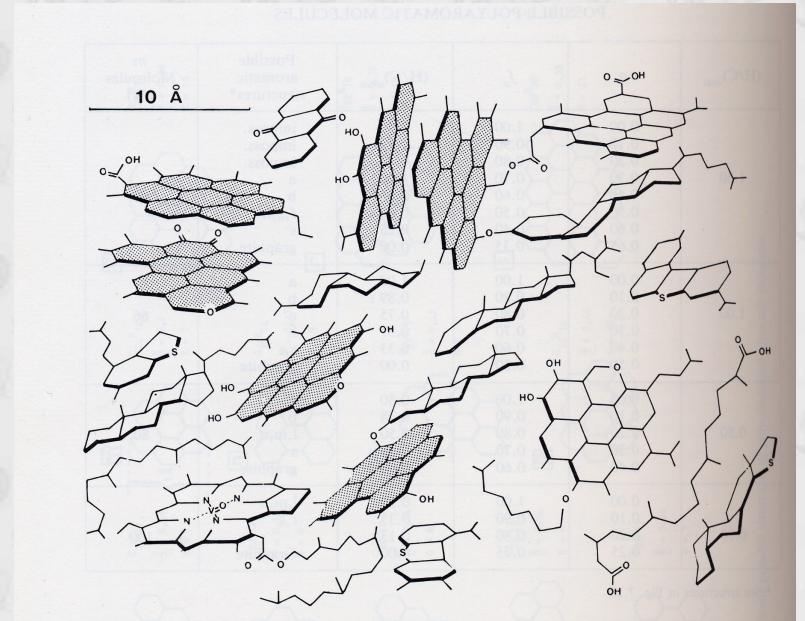
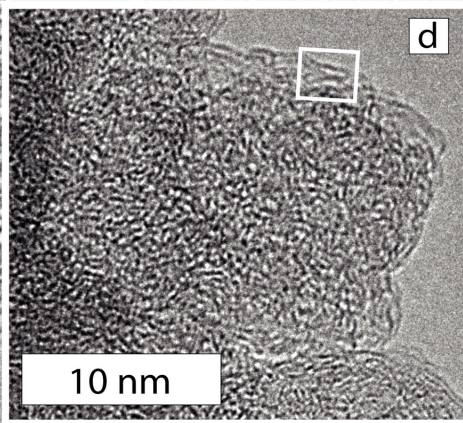
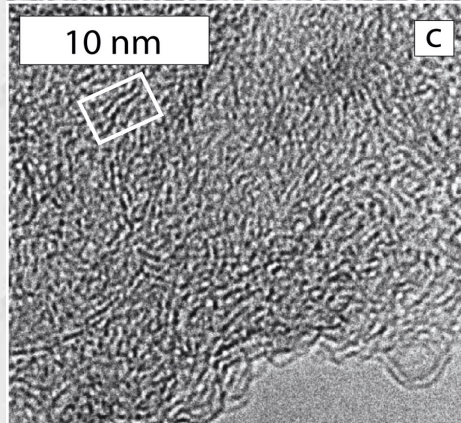
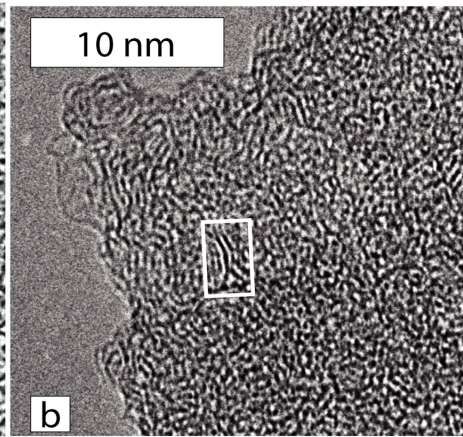
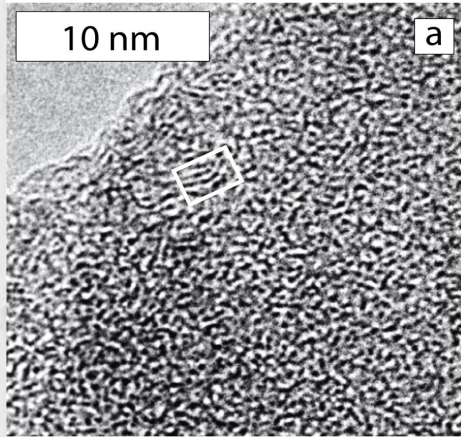


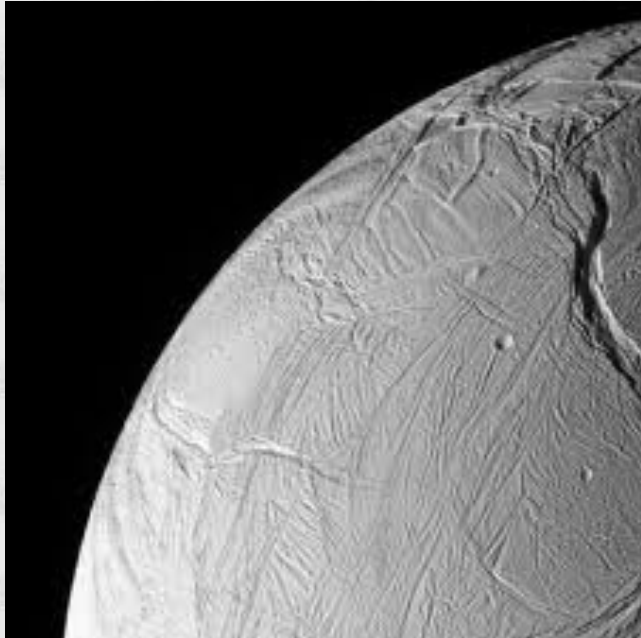
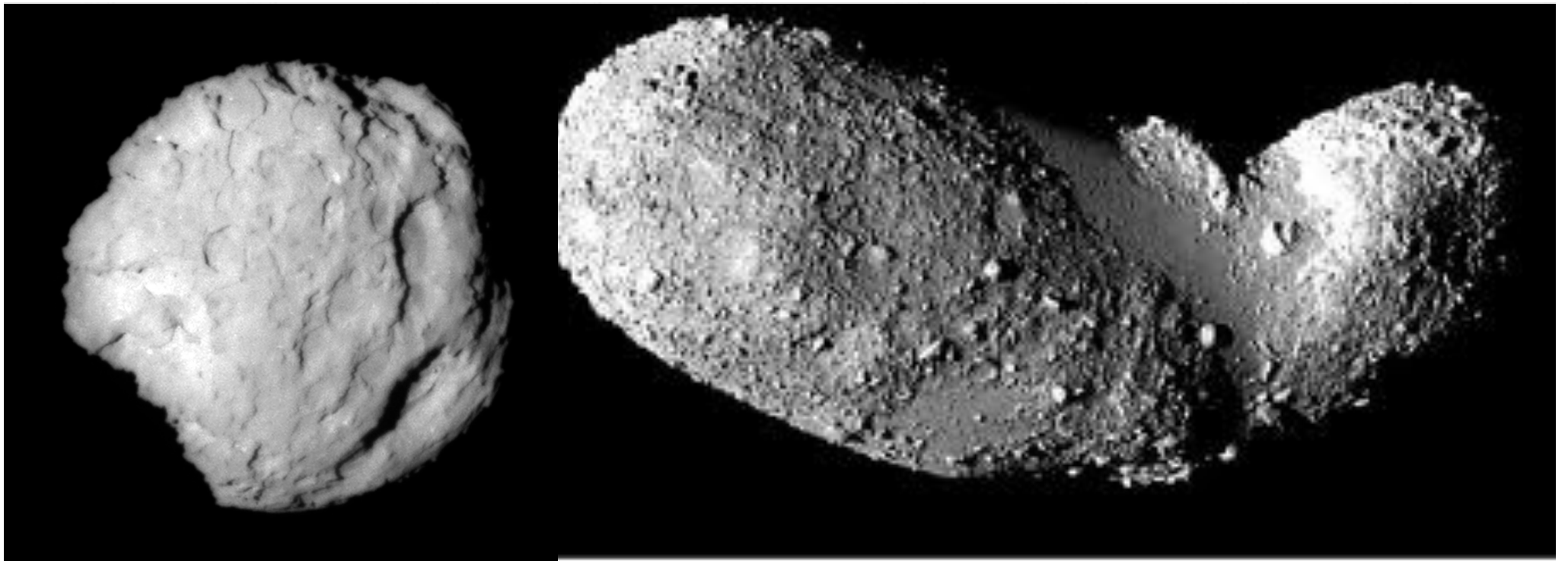
$m \sim 10^{-16} - 10^{-11} \text{ g}$

$R \sim 20 \text{ nm} - 1 \mu\text{m}$

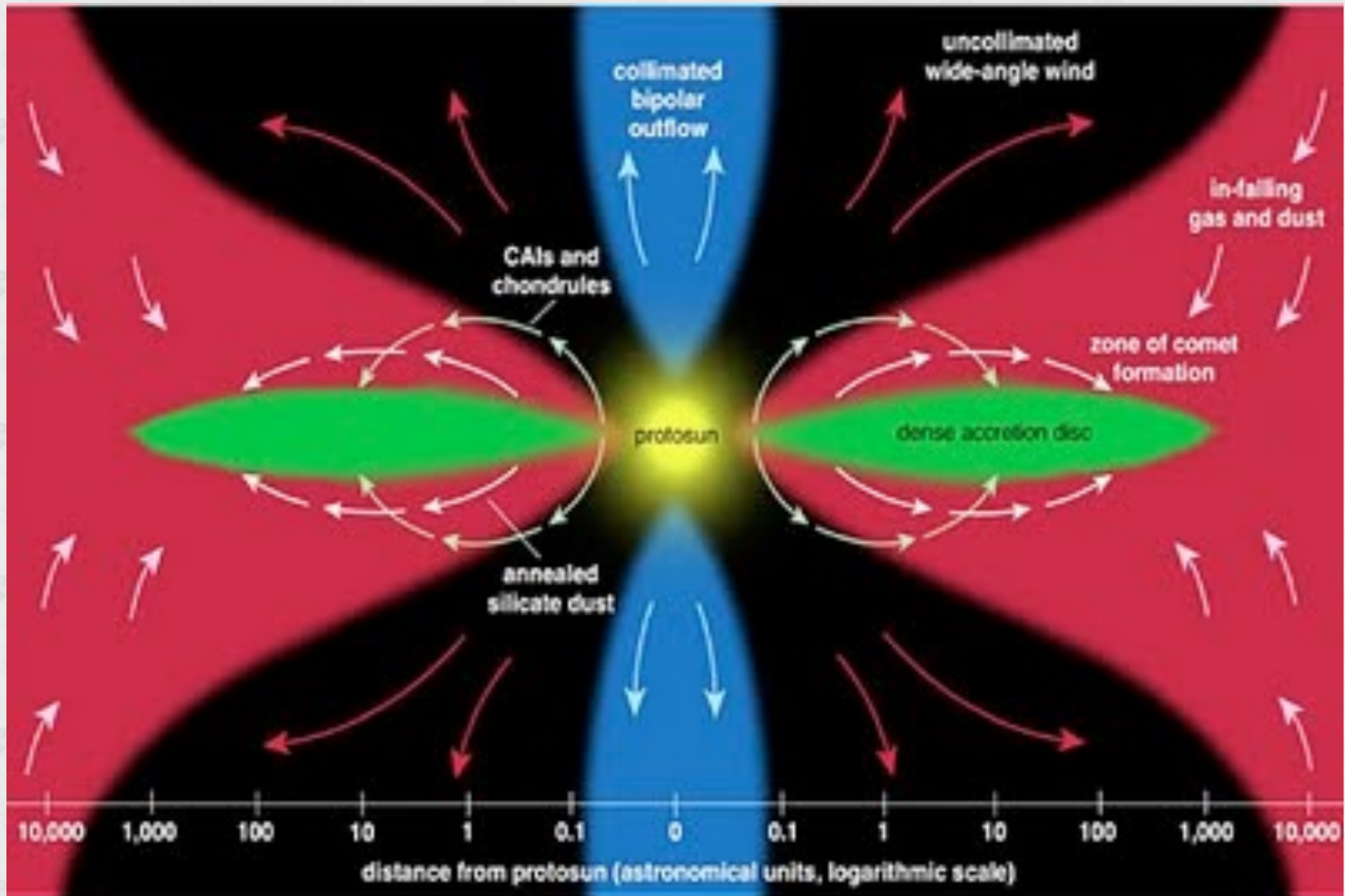


Nous ne
pouvons pas
afficher l'image.





Un disque protosolaire très remuant



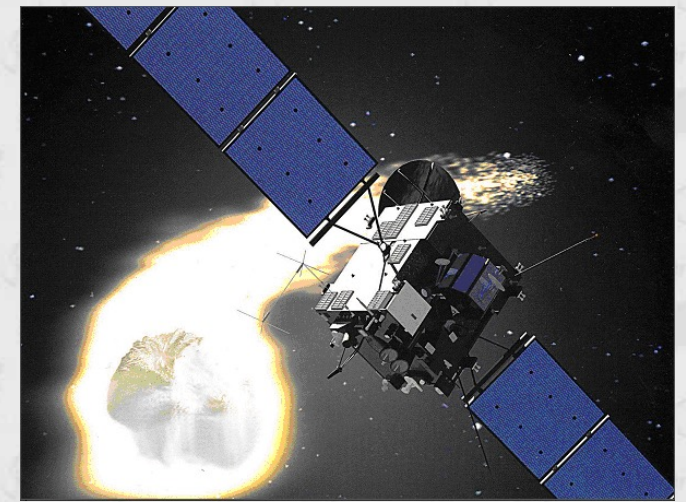
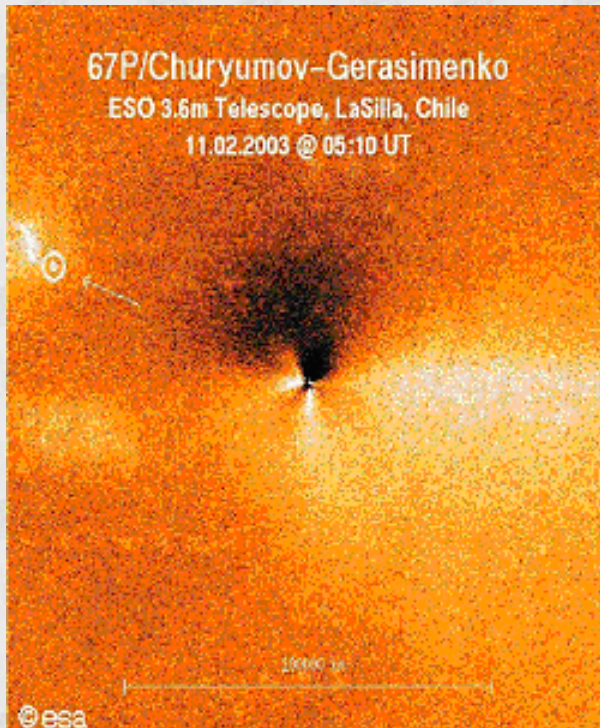
(from Nuth, J. A., 2001, *American Scientist*, v. 89, p.230.)

VERS UNE COMÈTE

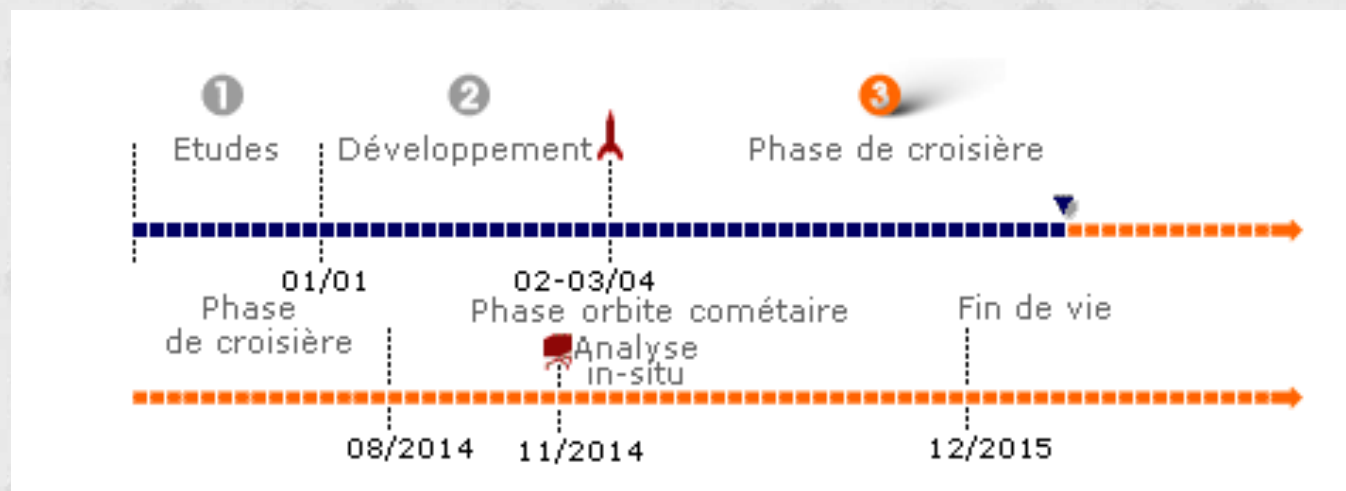
LE FUTUR C'EST DEMAIN :

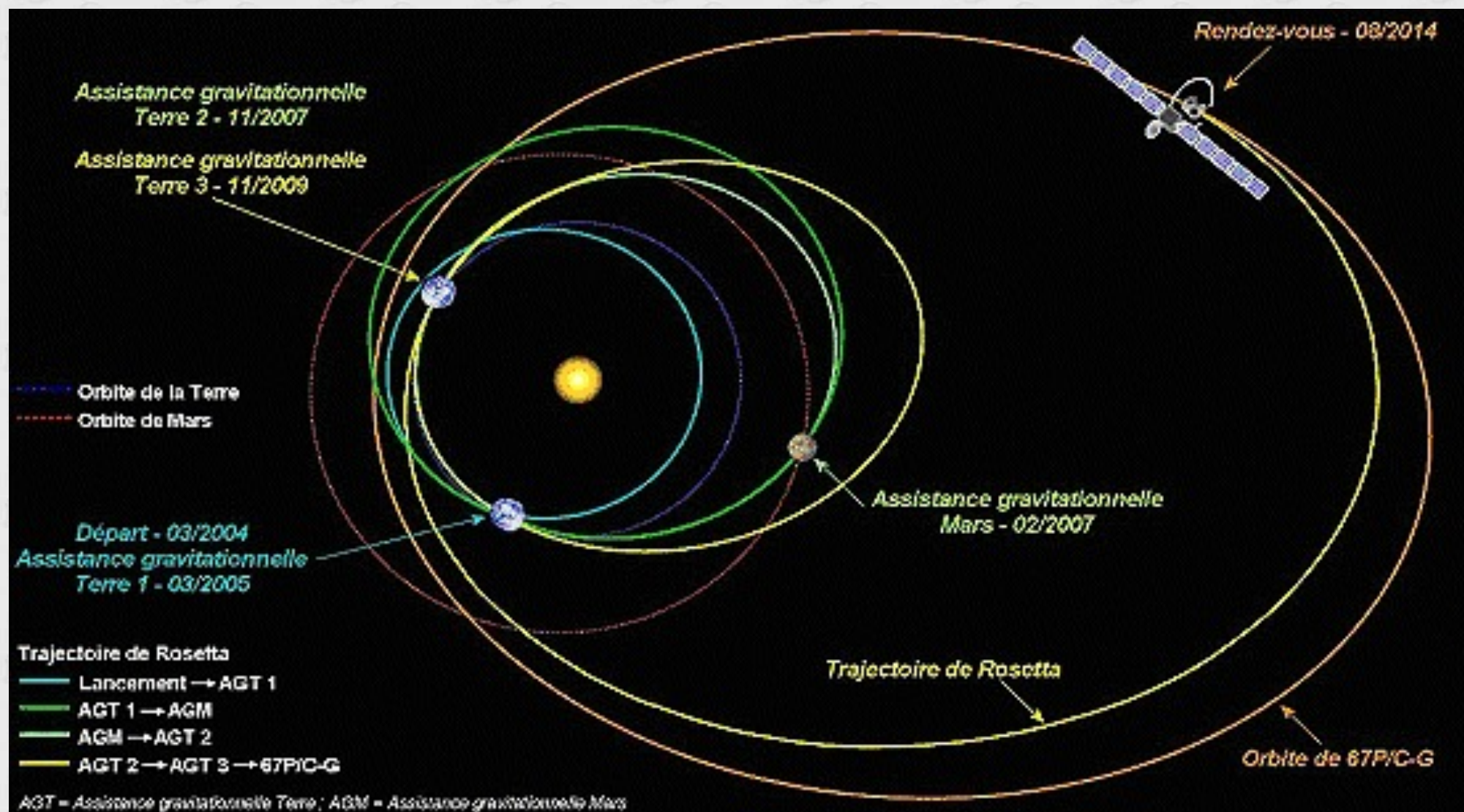
LA MISSION ROSETTA (ESA)

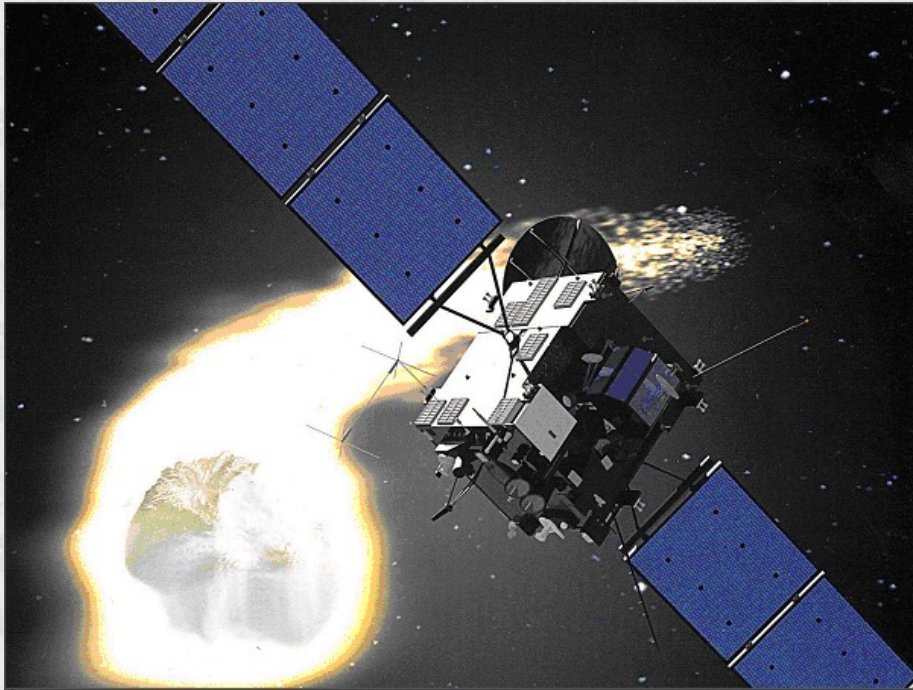
La mission ROSETTA



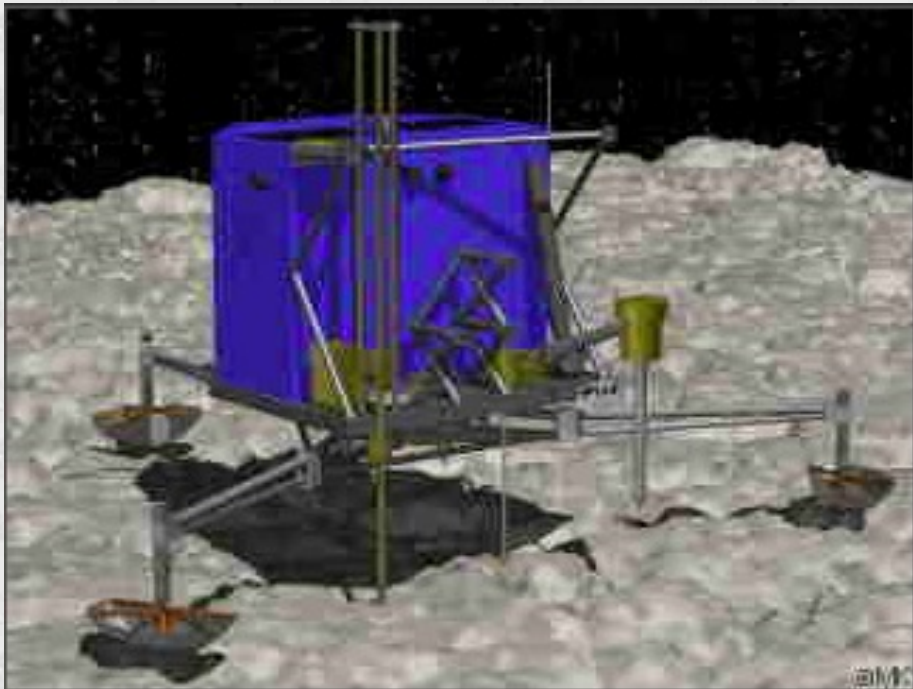
- ▶ Découverte en 1969
- ▶ Période héliocentrique : 6,59 ans
- ▶ Aphélie (distance au plus loin du soleil) : 5,73 Unités Astronomiques*
- ▶ Périhélie (distance au plus près du soleil) : 1,3 Unité Astronomique*
- ▶ Rayon moyen environ 2000 m (si albédo de 4%)
- ▶ Période de rotation environ 12,3 h
- ▶ Direction de l'axe de rotation : inconnu







Orbiteur



Lander

Rosetta Orbiter Instruments		
	Instrument	Principal Investigator
ALICE	Ultraviolet Imaging Spectrometer	Alan Stern, NASA Science Mission Directorate, Washington, DC, USA
CONSERT	C omet N ucleus S ounding E xperiment by R adio wave T ransmission	Wlodek Kofman, Planetology Laboratory, Grenoble, France
COSIMA	C ometary S econdary I on M ass A nalyser	Martin Hilchenbach, Max-Planck-Institute for Solar System Research, Katlenburg-Lindau, Germany
GIADA	G rain I mpact A nalyser and D ust A ccumulator	Luigi Colangeli, Capodimonte Observatory, Naples, Italy
MIDAS	M icro- I maging D ust A nalysis S ystem	Willibald Riedler, Space Research Institute Graz, Austria
MIRO	M icrowave I nstrument for the R osetta O rbiter	Samuel Gulkis, Jet Propulsion Laboratory, Pasadena, California, USA
OSIRIS	O ptical, S pectroscopic, and I nfrared R emote I maging S ystem	Horst Uwe Keller, Max-Planck-Institute for Solar System Research, Katlenburg-Lindau, Germany
ROSINA	R osetta O rbiter S pectrometer for I on and N eutral A nalysis	Hans Balsiger, University of Bern, Switzerland

RPC	Rosetta Plasma Consortium	
	ICA	Ion Composition Analyser Rickard Lundin, Swedish Institute of Space Physics, Kiruna, Sweden
	IES	Ion and Electron Sensor James Burch, Southwest Research Institute, San Antonio, Texas
	LAP	Langmuir Probe Anders Eriksson, Swedish Institute of Space Physics, Uppsala, Sweden
	MAG	Fluxgate Magnetometer Karl-Heinz Glassmeier, Technical University of Braunschweig, Germany
	MIP	Mutual Impedance Probe Jean Gabriel Trotignon, Environmental Physics and Chemistry Laboratory, Orléans, France
	PIU	Plasma Interface Unit Christopher Carr, Imperial College of Science, Technology and Medicine, London, United Kingdom
RSI	Radio Science Investigation Martin Pätzold, University of Cologne, Cologne, Germany	
VIRTIS	Visible and Infrared Thermal Imaging Spectrometer Angioletta Coradini, Institute of Space Astrophysics, Rome, Italy	

INSTRUMENT	PURPOSE	PRINCIPAL INVESTIGATOR
APXS	Alpha-p-X-ray spectrometer	G. Klingelhöfer Johannes-Gutenberg Univ., Mainz, Germany
CIVA	Panoramic and microscopic imaging system	J-P. Bibring Institut d'Astrophysique Spatiale, Université Paris Sud, Orsay, France
CONCERT	Radio sounding, nucleus tomography	W. Kofman Laboratoire de Planetologie, Grenoble, France
COSAC	Evolved gas analyser - elemental and molecular composition	F. Goesmann Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, Germany
MODULUS Ptolemy	Evolved gas analyser - isotopic composition	I. Wright Open University, Milton Keynes, UK
MUPUS	Measurements of surface and subsurface properties	T. Spohn German Aerospace Center (DLR), Cologne, Germany
ROLIS	Imaging	S. Mottola DLR, Berlin, Germany

ROMAP	Magnetometer and plasma monitor	H-U. Auster Technische Universität, Braunschweig, Germany I. Apathy KFKI, Budapest, Hungary
SD2	Drilling and sample retrieval	A. Ercoli-Finzi Politecnico of Milan, Italy
SESAME	Surface electrical, acoustic and dust impact monitoring	K. Seidensticker German Aerospace Center (DLR), Cologne, Germany I. Apathy KFKI, Budapest, Hungary