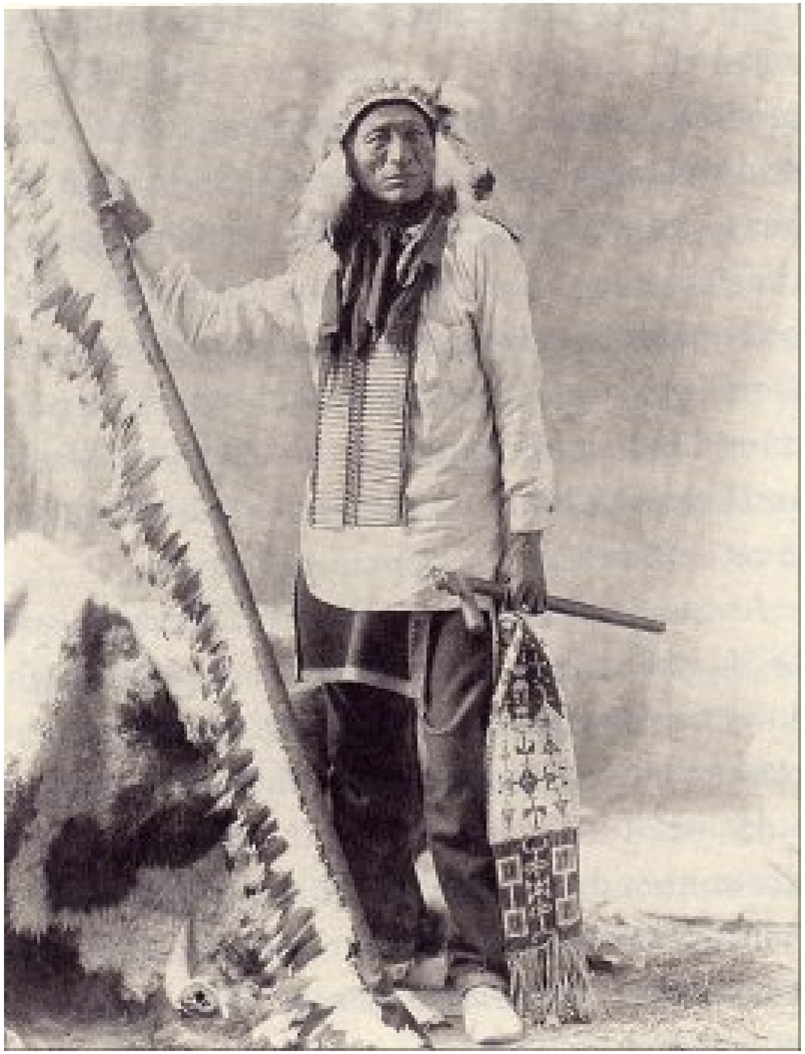
Iron Tail

M. Fulle (INAF - OATrieste)



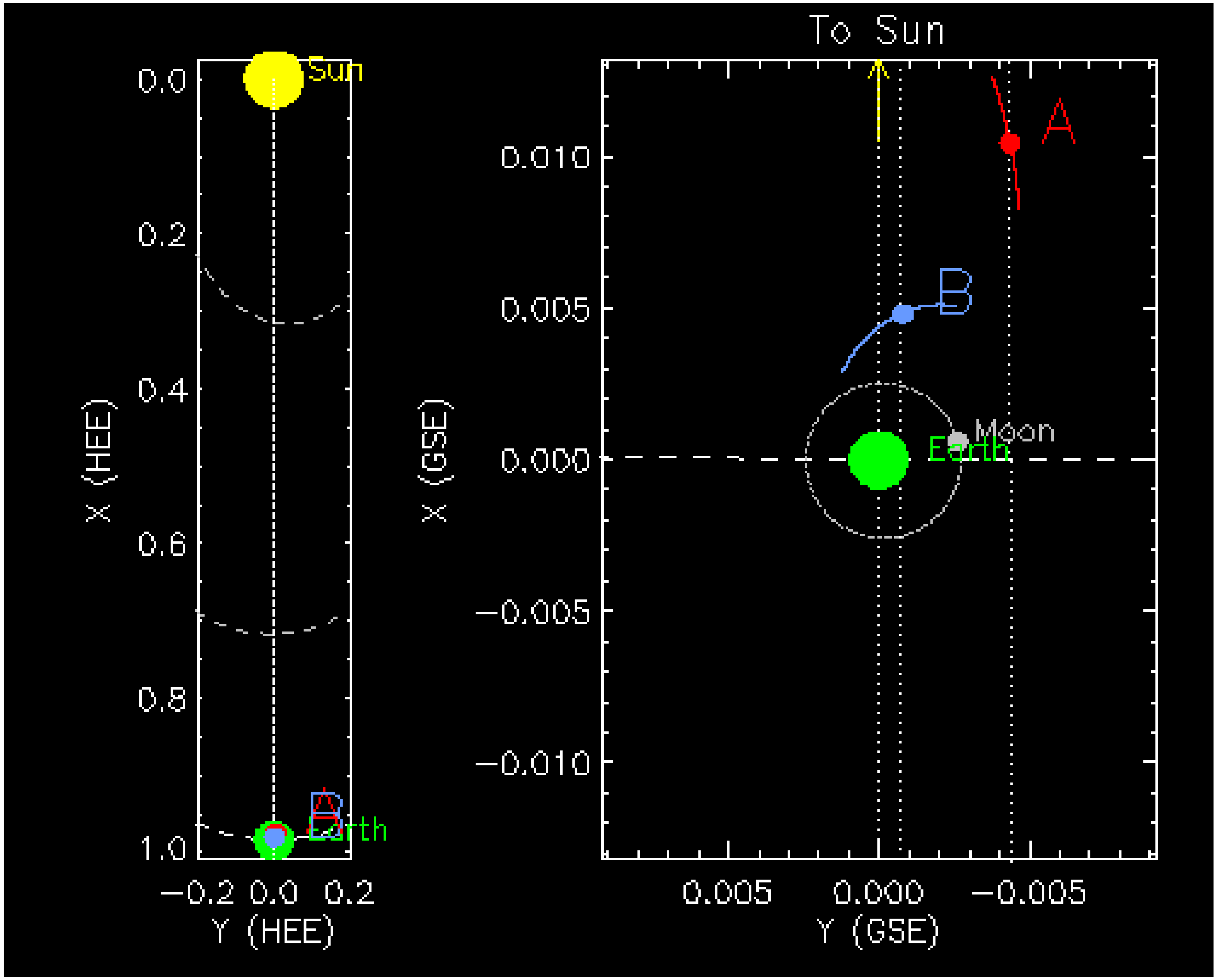
Sinte Maza (Iron Tail)

was an Oglala Sioux who fought alongside Sitting Bull at the Battle of the Little Big Horn (google)

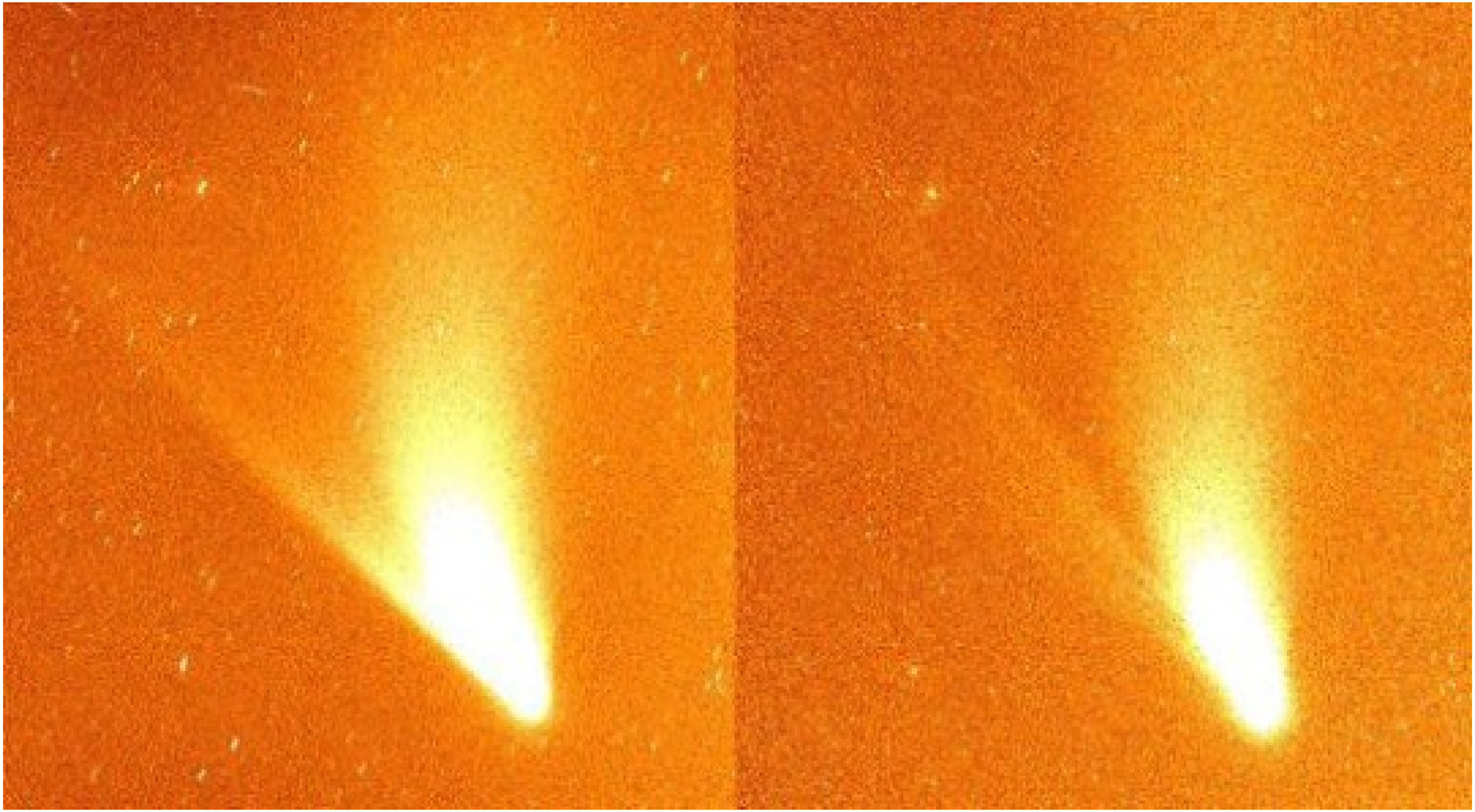
Stereo Spececraft

Two twin spacecrafts
are slowly drifting towards
L4-L5 points of Earth orbit
to get stereo images
of the solar corona
(plot position @q of
comet McNaught 2006P1)

Each spacecraft has
wide angle cameras
pointing between
Sun & Earth

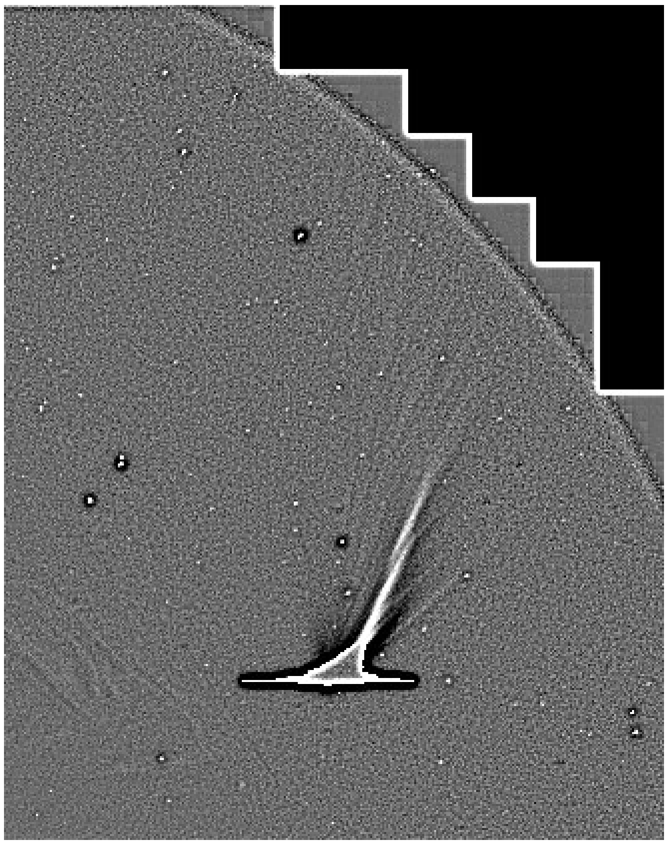


Antecedent: sodium tail of comet C/1995O1 Hale-Bopp (left panel)

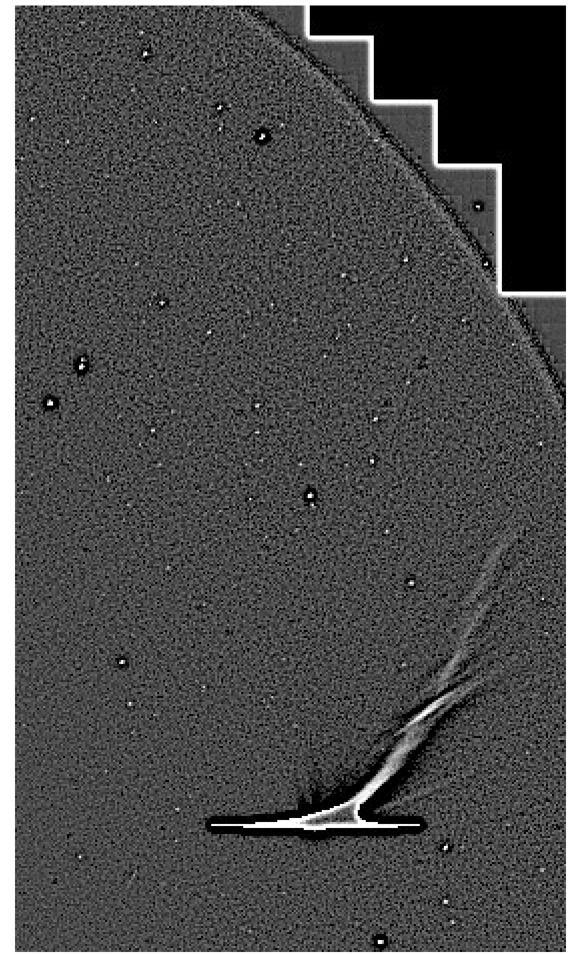


All starts in 2003..........

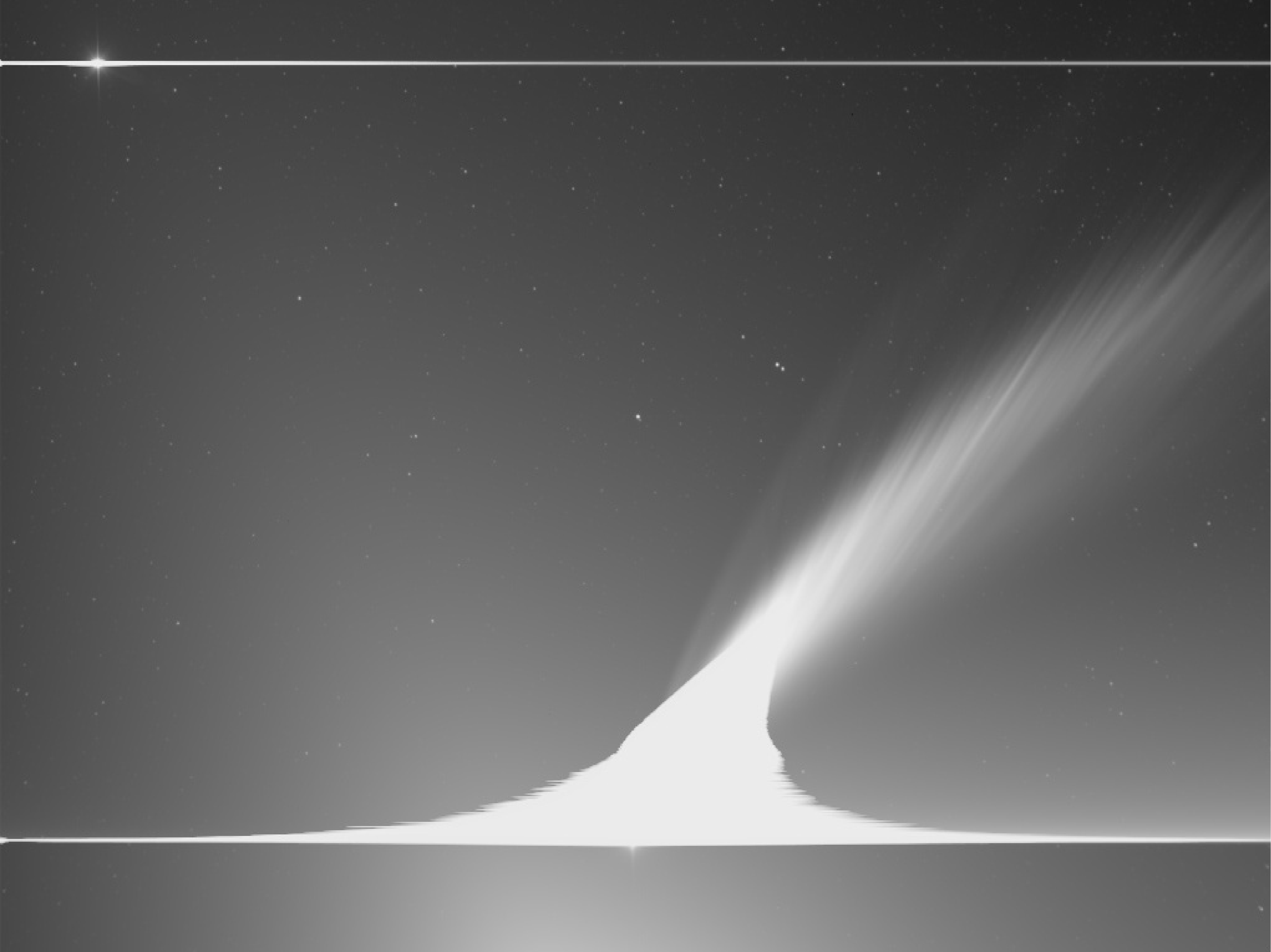
SOHO images of C/2002V1 NEAT (unsharp masking by G.A.Milani)



17 feb 2003 6hUT



18 feb 2003 19hUT

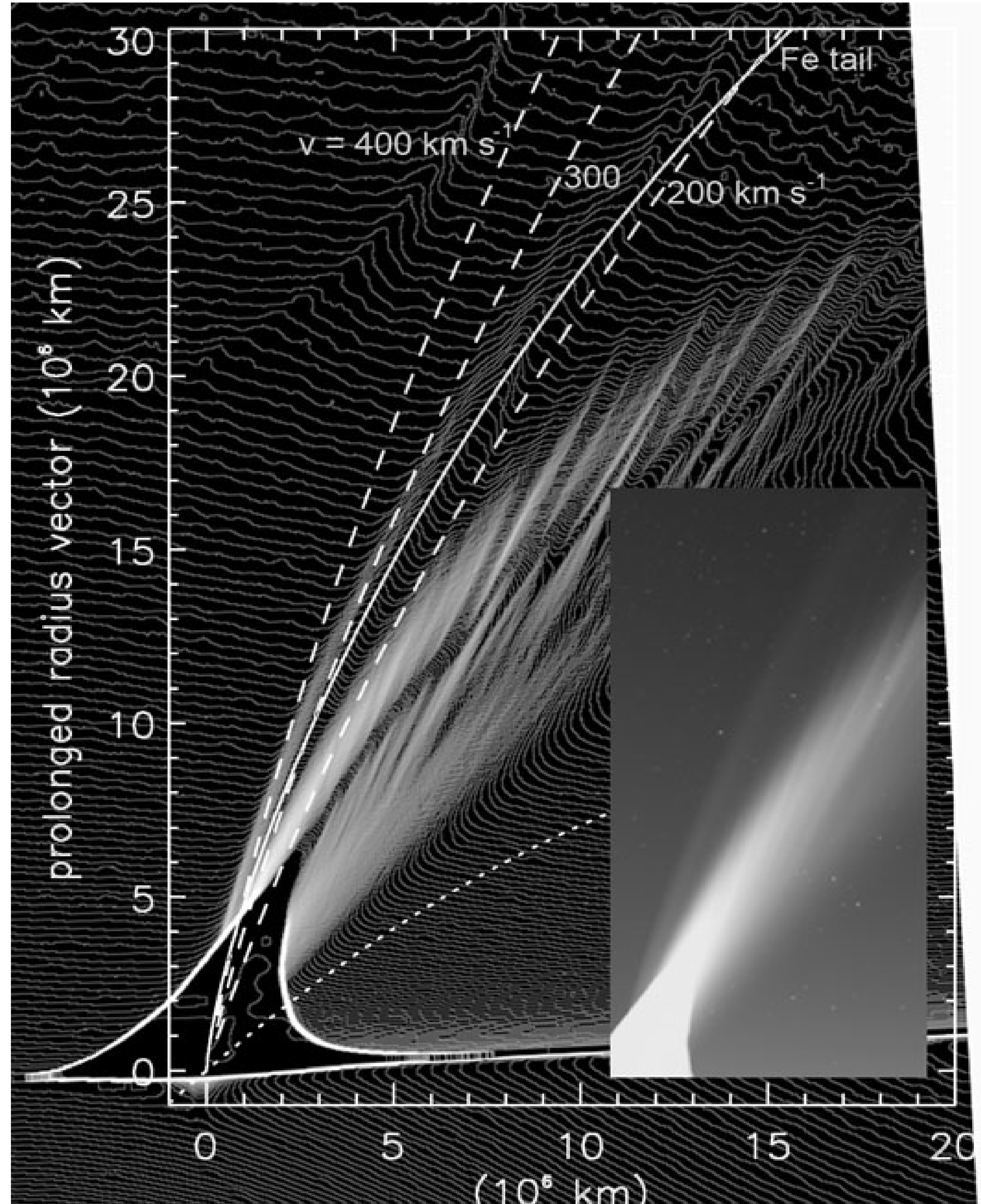


C/2006P1 filament
is not a dust tail:
1. no plausible dynamics
2. no gap explanation

C/2006P1 tail is NOT
an ion tail (poor fit)

The lifetime of water
ions @ 0.2 AU = 1 hr
(of CO^+ ions = 2 hr)

All ions have been
photodissociated before
they exit the diamagnetic
cavity about 10^5 km wide



Atom dynamics.......

The motion of a neutral atom depends on the solar gravity (sun-pointing) and on the momentum transfer of solar photons (anti-sun-pointing)

$$F_{grav} = \frac{G\ m_{at}\ M_{\odot}}{N_{Av}\ r^2} \qquad\qquad F_{rad} = \frac{(1AU)^2}{r^2} \sum_i \frac{h\ \nu_i}{c}\ g_i$$

Total anti-sun-pointing force acting on the atom:

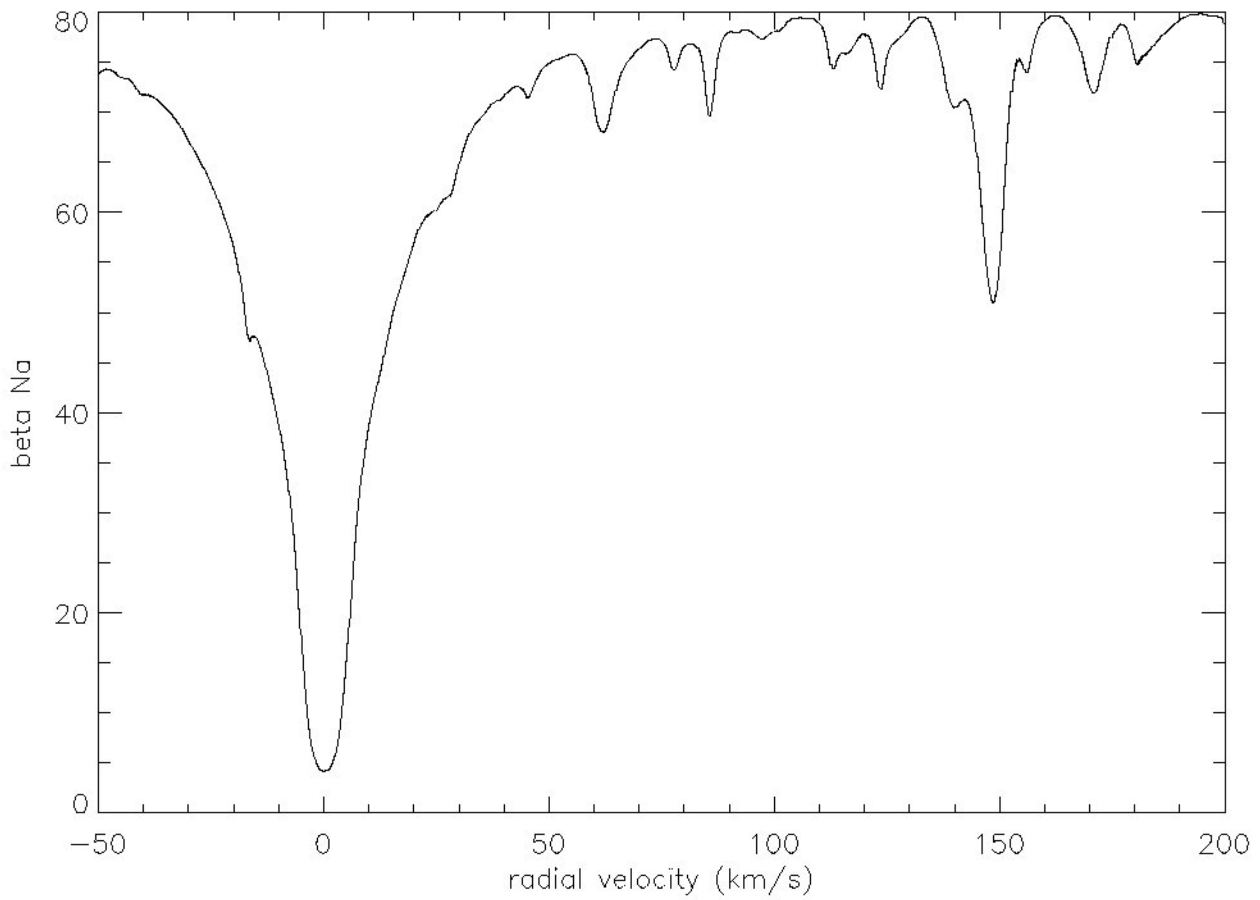
$$F_{tot} = (\beta - 1)\ F_{grav} \qquad\qquad \beta = \frac{h\ (1AU)^2\ N_{Av} \sum_i \frac{g_i}{\lambda_i}}{G\ m_{at}\ M_{\odot}}$$

Total spectral power emitted by the atoms: $$E = \frac{c\ G\ m_{at}\ M_{\odot}\ \beta}{(1AU)^2\ N_{Av}}$$

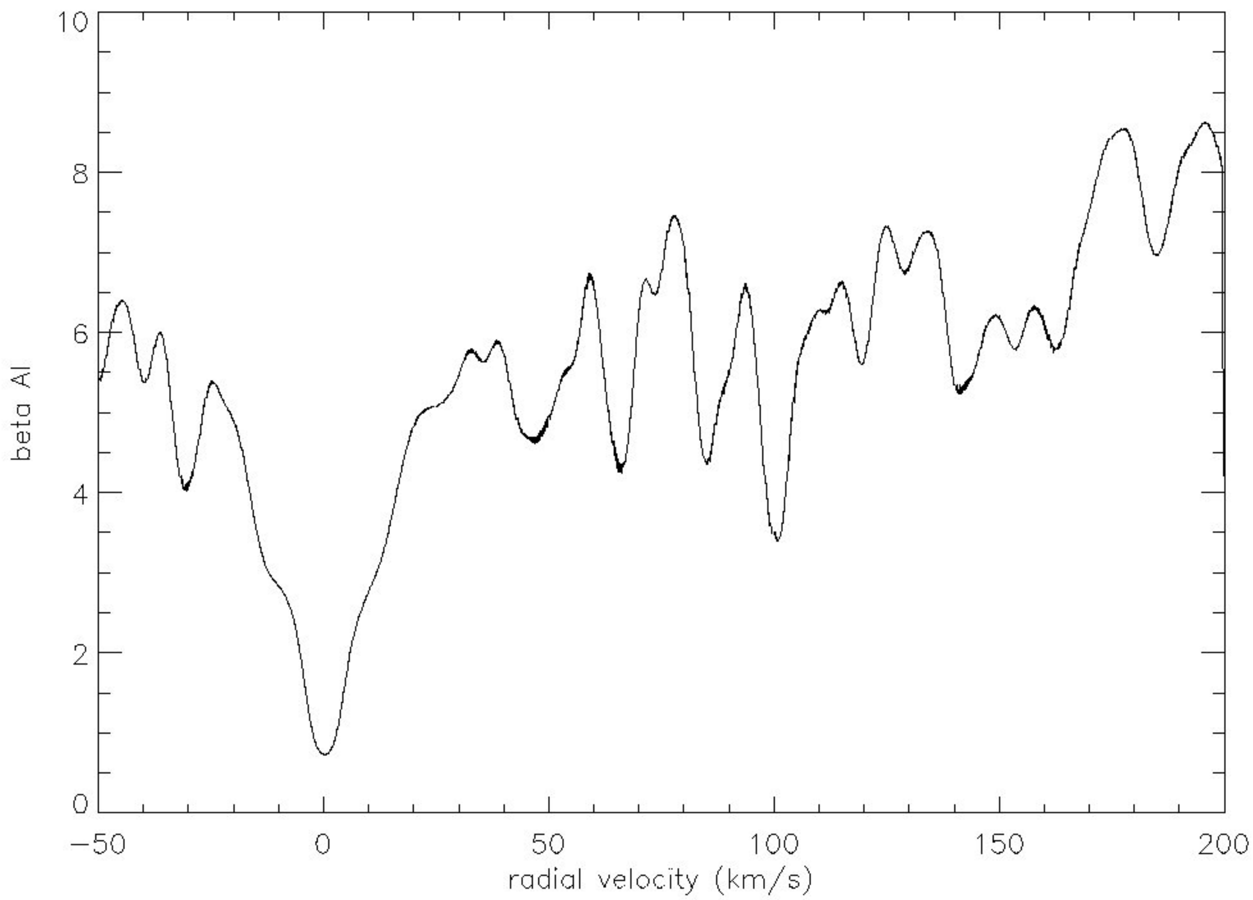
If r is the sun-comet vector of absolute value |*r* |, atom's motion becomes

$$\ddot{r} = G\ M_{\odot}\ \left[\beta\left(\frac{r\ \dot{r}}{|r|}\right) - 1\right] \frac{r}{|r|^3}$$

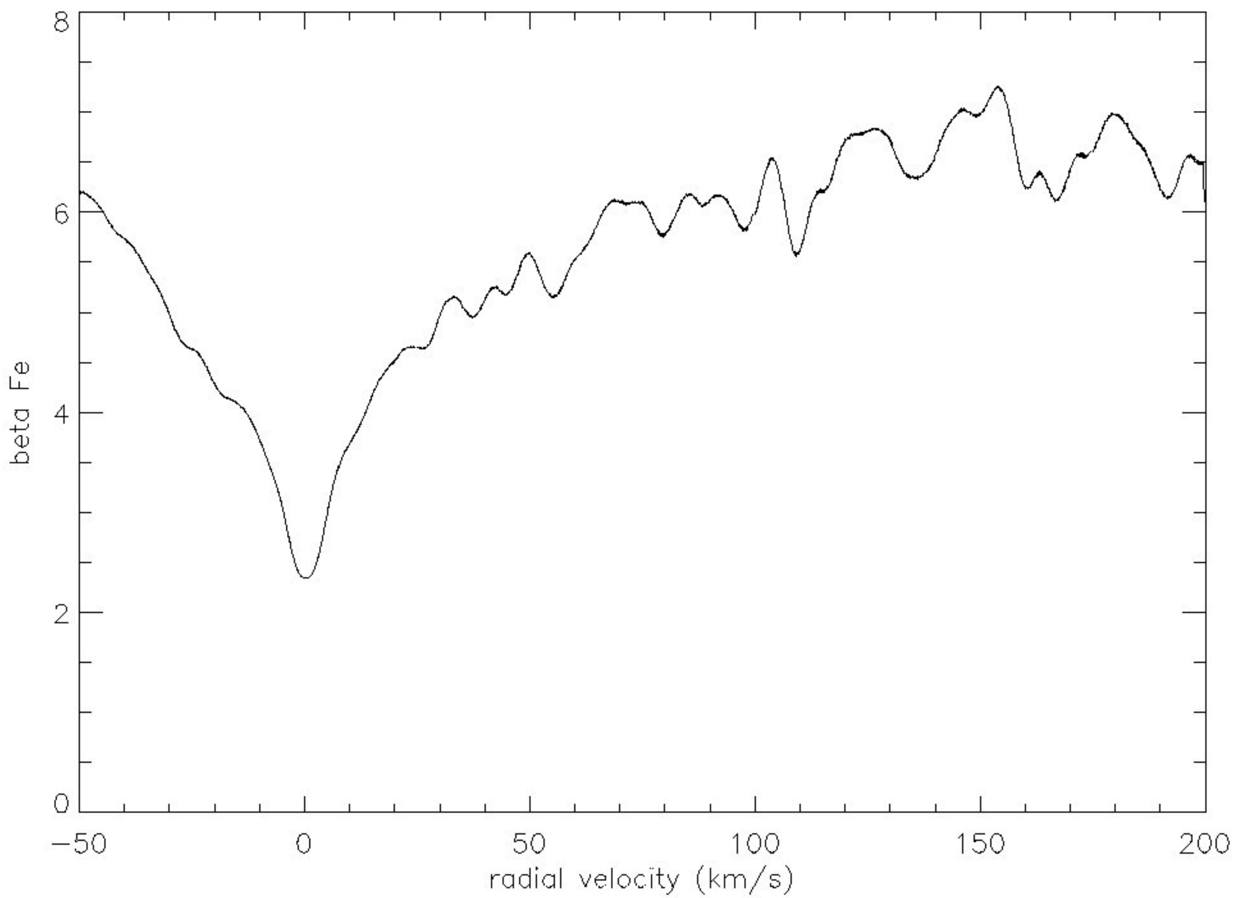
Sodium (32 resonant transitions)



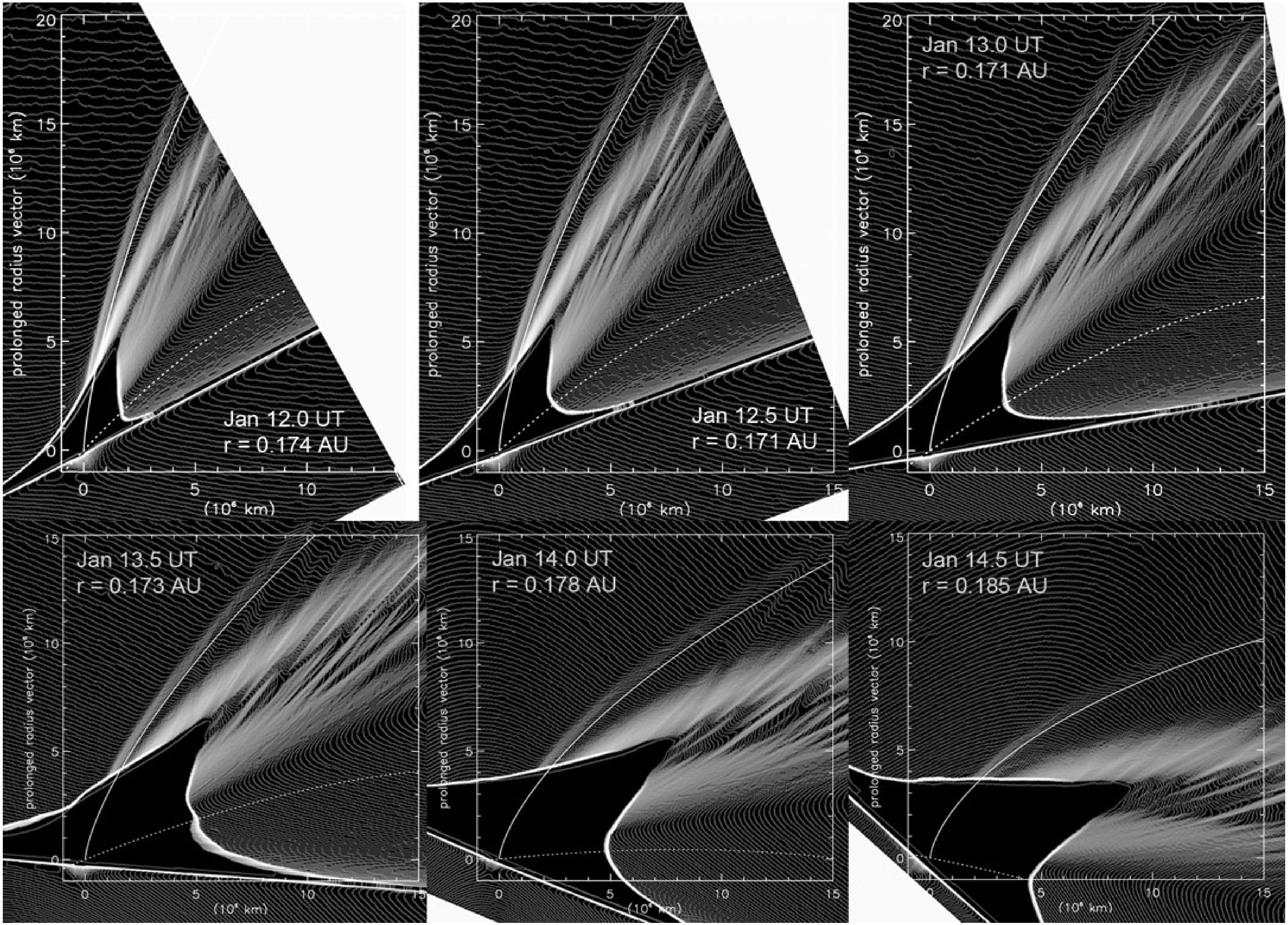
Alluminium (43 resonant transitions)

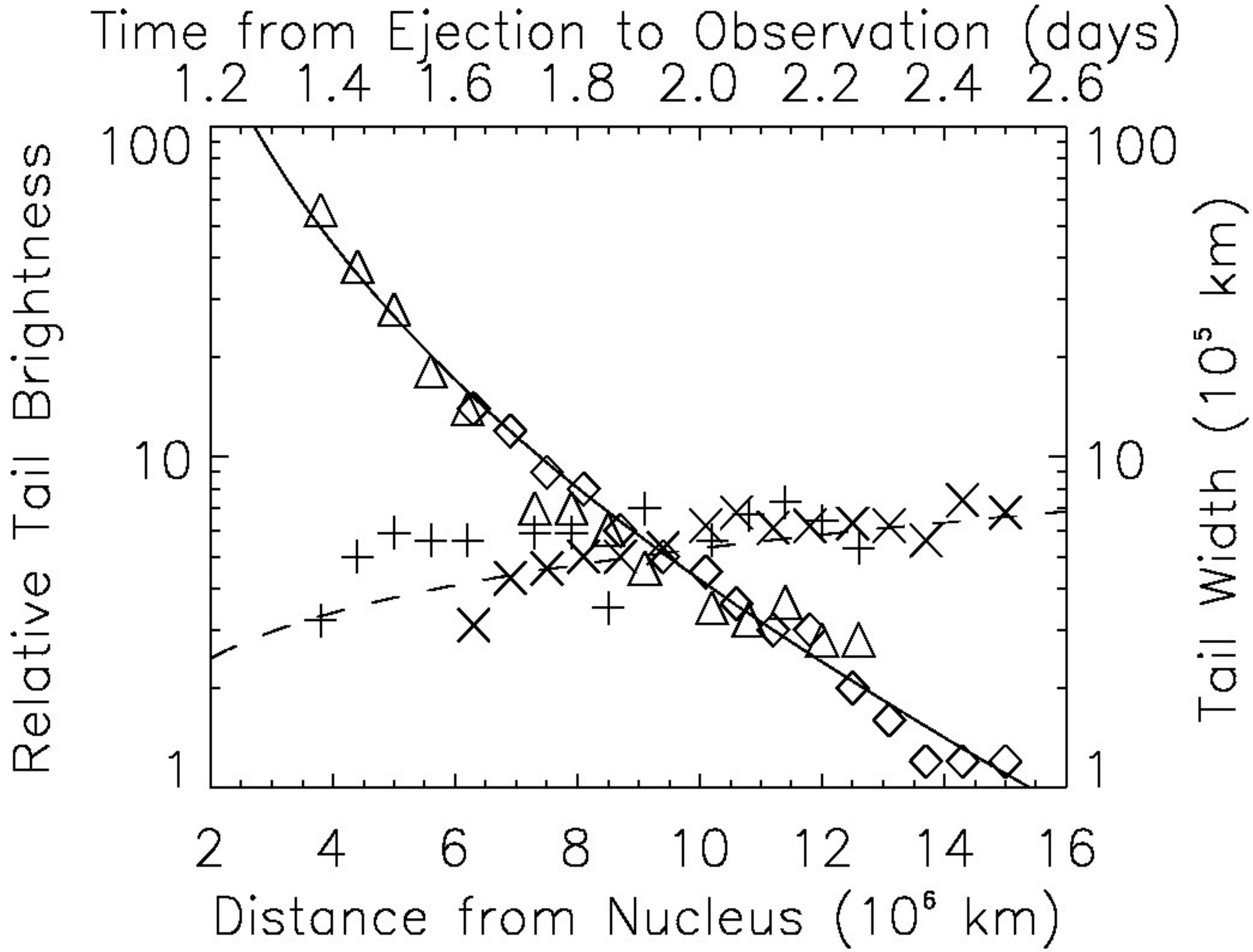


Iron (229 resonant transitions)



Neutral Iron Tail fits all STEREO observations





Observed Lifetime = 180 hr @ 1 AU

atom column density =
10^{14} m $^{-2}$ @ x = 1.5 10^{7} km

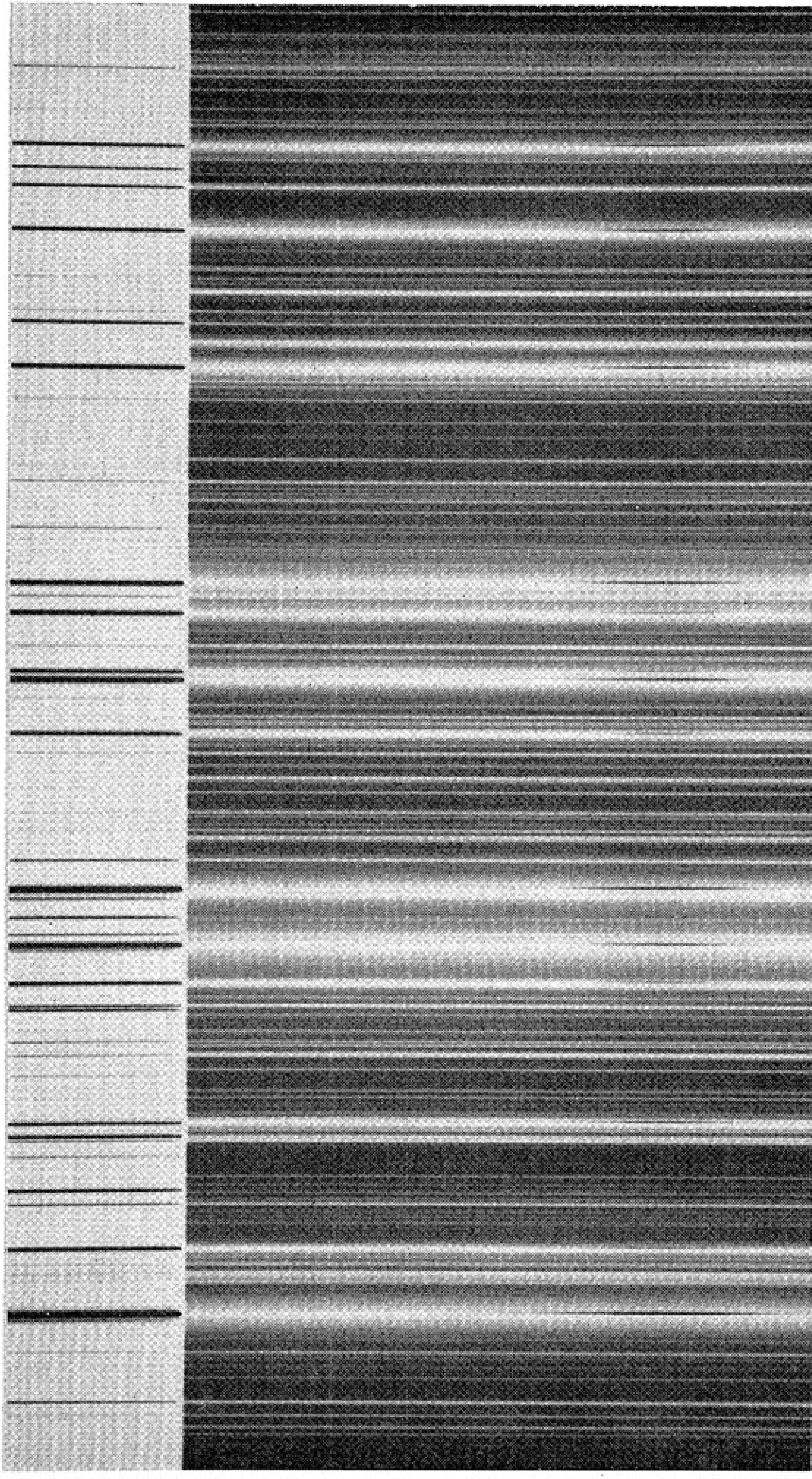
V_{rad} = 1.5 km/s, Q_{Fe} = 10^{30} s $^{-1}$

$$\delta(x) = \frac{Q_{Fe}\ \exp - \frac{t_{obs} - t(x)}{\tau}}{2\ V_{rad}\ [t_{obs} - t(x)]\ \dot{x}_{sky}}$$

TABLE 1

COMPUTED EQUIVALENT CONSTANT β AND PHOTOIONIZATION LIFETIMES

		Photoionization Lifetime (s) at 1 AU	
Atom	Equivalent β	Huebner et al. (1992)	This Letter
H	0.20 ± 0.15	1.4×10^{7}	7.8×10^{6}
C	$(1.15 \pm 0.05) \times 10^{-3}$	2.4×10^{6}	1.1×10^{6}
N	$(5 \pm 1) \times 10^{-5}$	5.4×10^{6}	2.0×10^{6}
O	$(4 \pm 2) \times 10^{-5}$	4.7×10^{6}	2.0×10^{6}
Na	75 ± 5	6.2×10^{4}	1.9×10^{5}
Mg	1.3 ± 0.3	...	2.1×10^{6}
Al	5 ± 2	...	1.4×10^{3}
Si	$(7 \pm 1) \times 10^{-2}$	...	4.4×10^{4}
S	$(6 \pm 1) \times 10^{-4}$	9.4×10^{5}	4.2×10^{5}
Ar	$(4 \pm 1) \times 10^{-8}$	3.3×10^{6}	1.4×10^{6}
K	56 ± 2	4.3×10^{4}	...
Ca	40 ± 10	...	1.4×10^{4}
Fe	6.0 ± 0.5	...	5.1×10^{5}

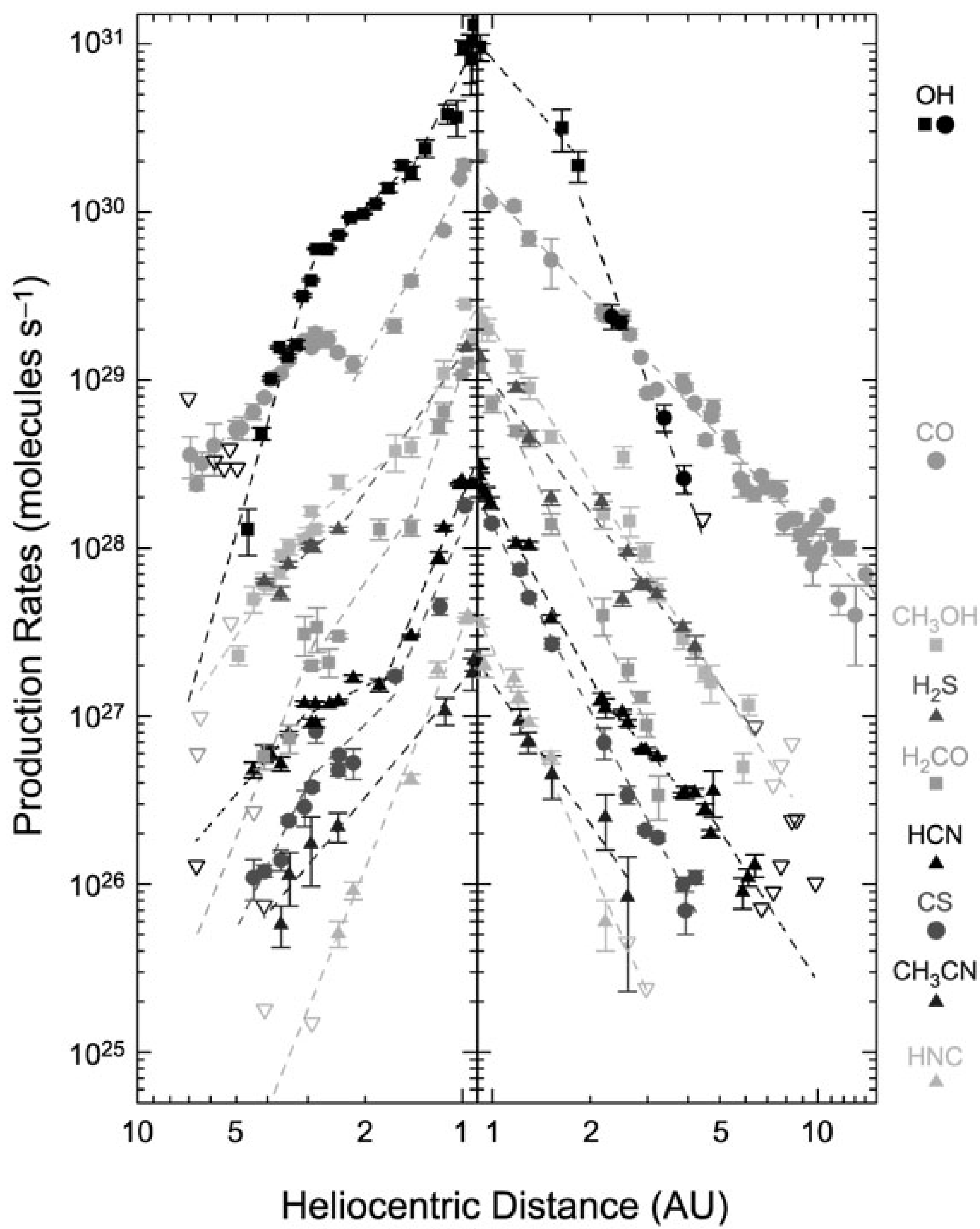

3743 Fe I
3737 Fe I
3727 Fe I
3719 Fe I

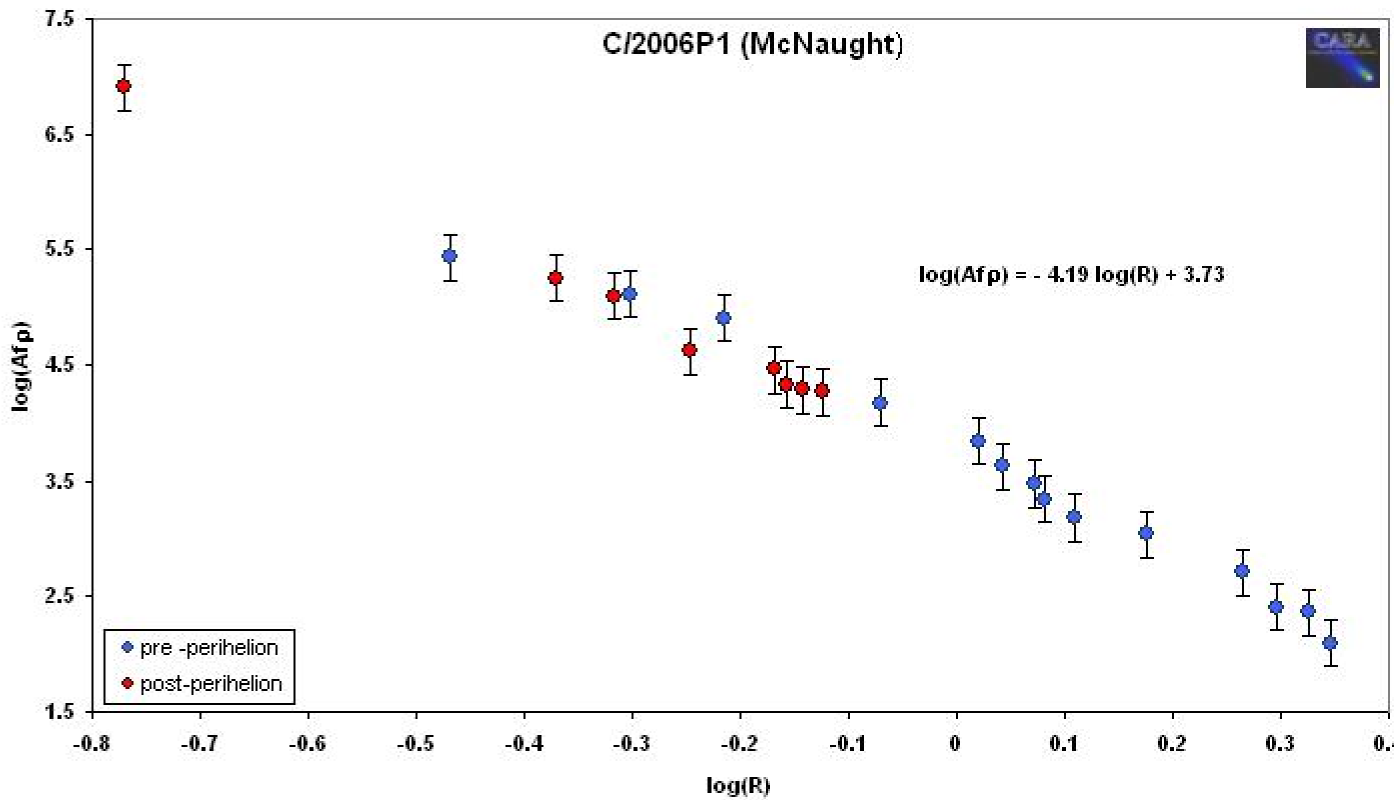
Is the observed iron loss rate consistent with data on comet nuclei ?

Let's start with Comet Hale-Bopp...

@ 1 AU, a surface of pure water ice ejects $Q_{H2O} = 10^{22}\ s^{-1}\ m^{-2}$

After we assume a “typical” dust to gas ratio DGR = 10, we obtain a nucleus of surface $10^{10}\ m^2$, i.e. R = 30 km

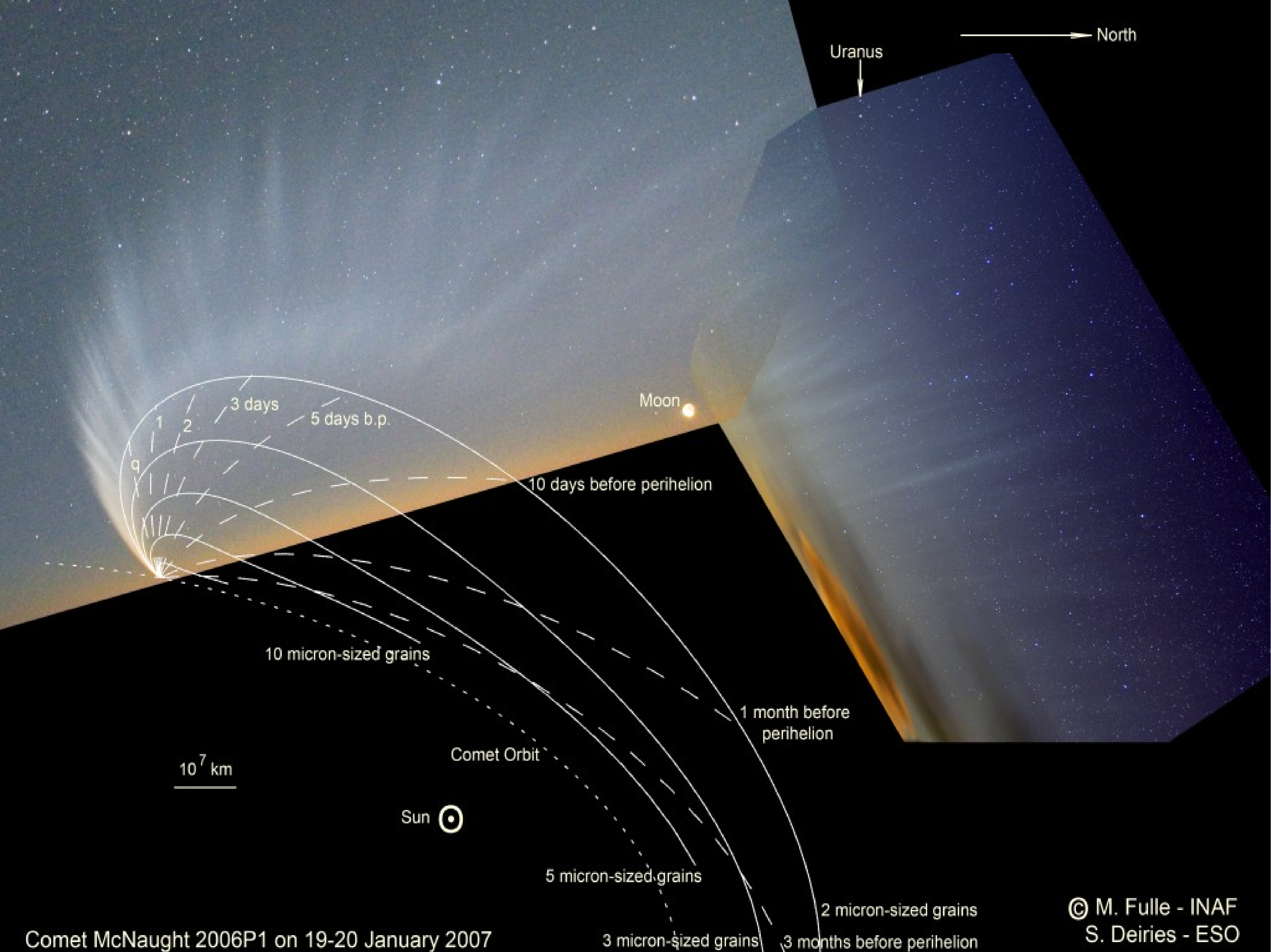




@ q, McNaught dust loss rate 10 times bigger than Hale-Bopp's. HOWEVER, @ 0.17 AU ice ejects 30 times more water than @ 1 AU, so that R = 10 km

Hale-Bopp's water loss rate @ q: $Q_{H2O} = 10^{6}$ kg/s, so that DGR = 10 implies $Q_{dust} = 10^{7}$ kg/s. Then McNaught dust loss rate @q becomes $Q_{dust} = 10^{8}$ kg/s. C/2006P1 has lost a dust “cube” of 3km edge in a week (a shell 25m thick)

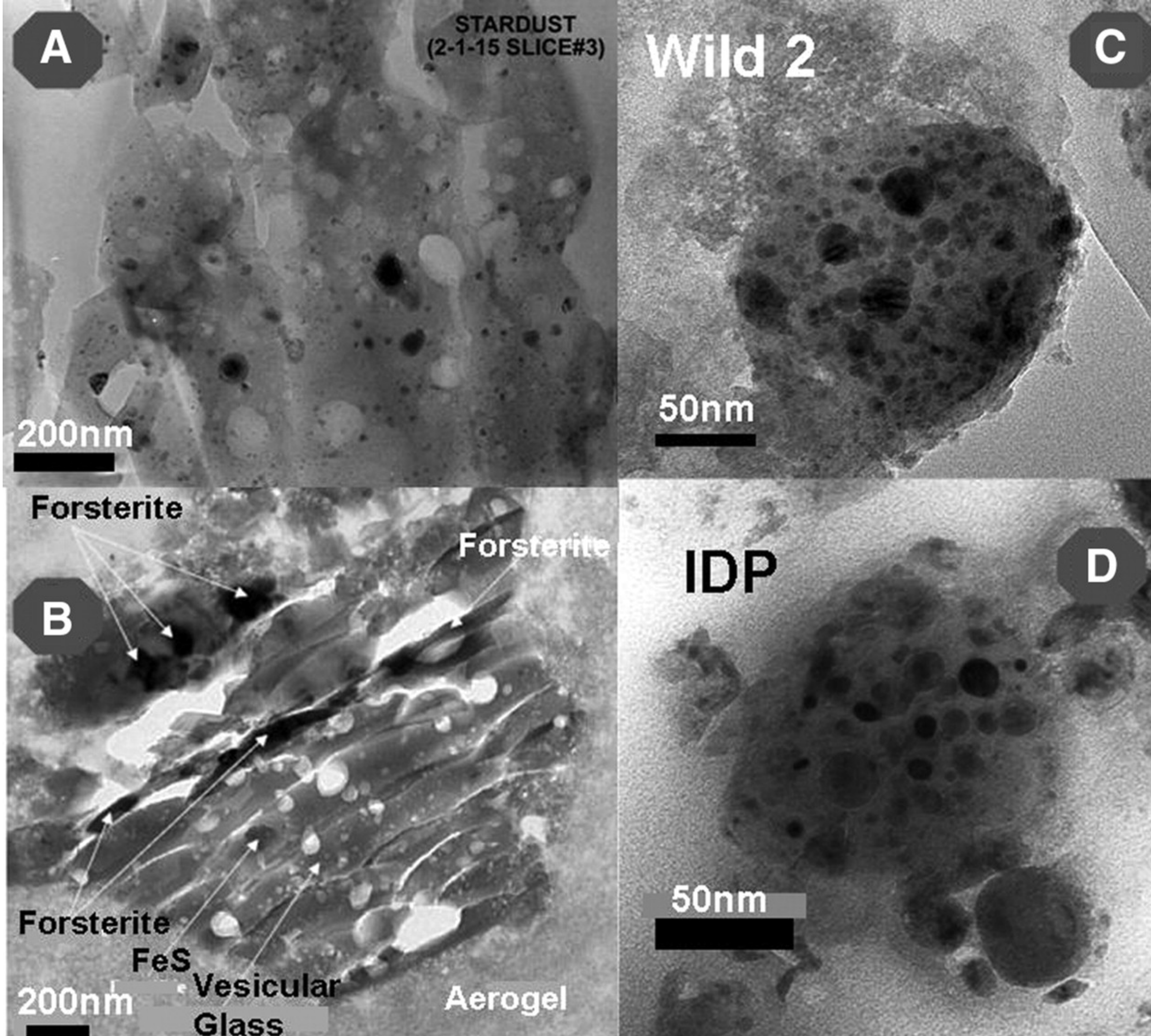
@ q, McNaught ejected $Q_{H2O} = 10^{32}\ s^{-1}$, so that $Q_{Fe} = 0.1\%\ Q_{dust}$


North
Uranus
Moon
3 days
1
2
5 days b.p.
q
10 days before perihelion
10 micron-sized grains
1 month before
perihelion
Comet Orbit
10^7 km
Sun
5 micron-sized grains
2 micron-sized grains
3 micron-sized grains
3 months before perihelion
© M. Fulle - INAF
S. Deiries - ESO
Comet McNaught 2006P1 on 19-20 January 2007

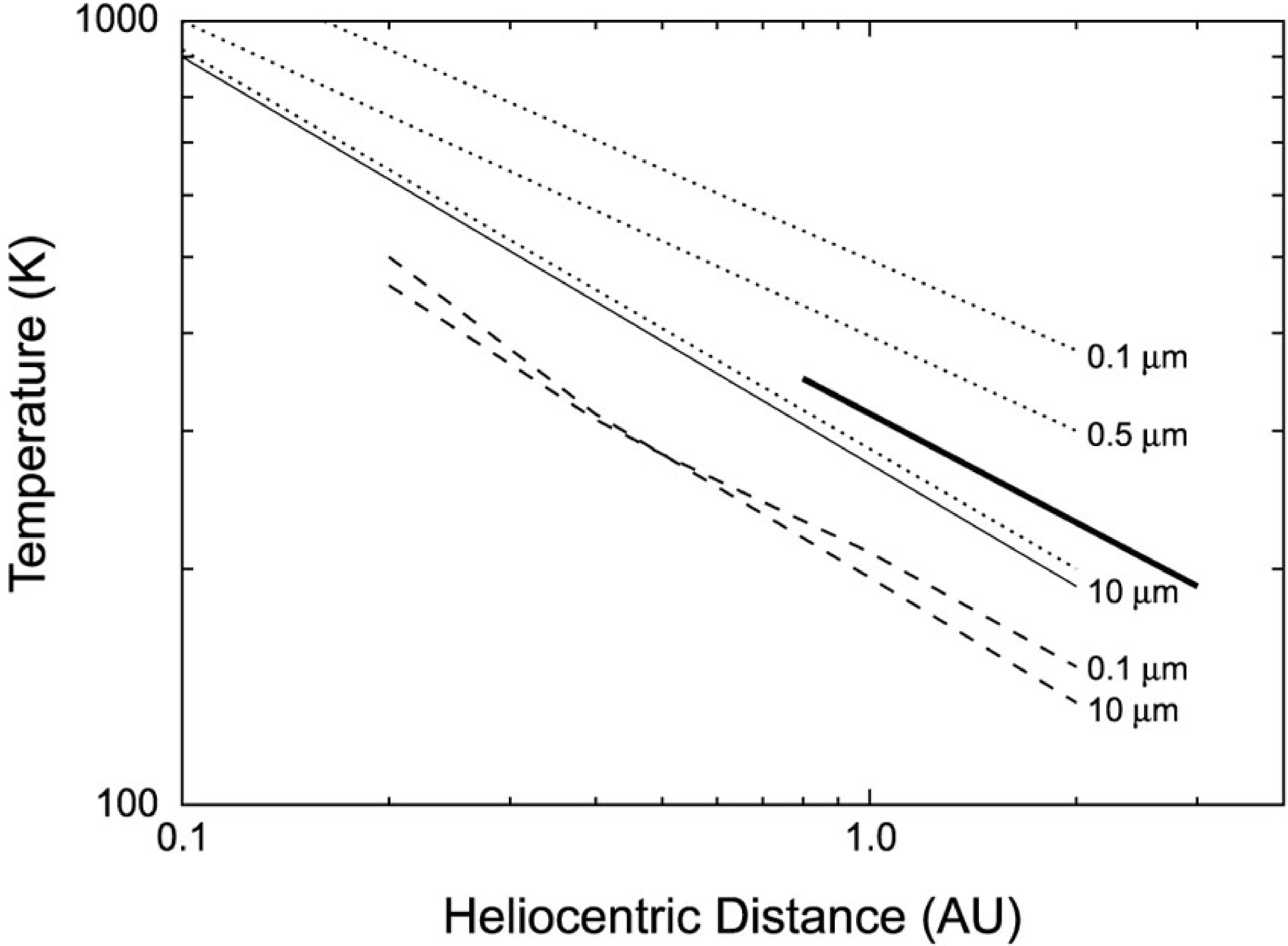
According to Stardust data, almost all Fe is going into the Fe Tail

Table 1. Quantitative energy-dispersive x-ray spectral analyses (atomic %) of two GEMS-like objects embedded in the aerogel of track 35 (GEMS 1 and 2) compared with actual GEMS in a chondritic IDP and CI chondrite (CI) abundances.

Element (atom %)	GEMS-like 1 (60 nm in diameter)	GEMS-like 2 (100 nm in diameter)		GEMs in IDPs (*6*)			CI (*39, 40*)
O	64.95	65.8	65.7	75.3	61.9	56.2	49.7
Mg	6.3	3.5	4.6	1.2	2.9	22.3	10.3
Si	26.4	28.4	26.0	19.1	16.9	13.3	11.5
S	1.75	1.65	2.7	1.2	6.1	3.2	5.7
Ca	0.1	0.1	0.15	Nd	0.15	nd	0.3
Cr	trace	trace	trace	0.2	0.3	0.1	0.3
Mn	0.1	0.1	0.15	0.1	nd	nd	0.2
Fe	0.3	0.2	0.5	2.2	11.1	4.2	20.0
Ni	0.1	0.1	0.2	0.4	nd	0.1	1.1
Al	nd	nd	nd	0.5	0.8	0.6	0.9


A
STARDUST
(2-1-15 SLICE#3)
200nm
Wild 2
C
50nm
Forsterite
B
Forsterite
Forsterite
FeS
Vesicular
Glass
200nm
Aerogel
IDP
D
50nm

Problem: Sublimation does not work, requiring T > 1200K



Coma chemistry seems a much more efficient Fe source

Pollack (1984) shows that all metallic Fe from supernovae goes into troilite

$Fe + H_2S \text{-->} FeS + H_2$ when T goes below 680K at almost every P

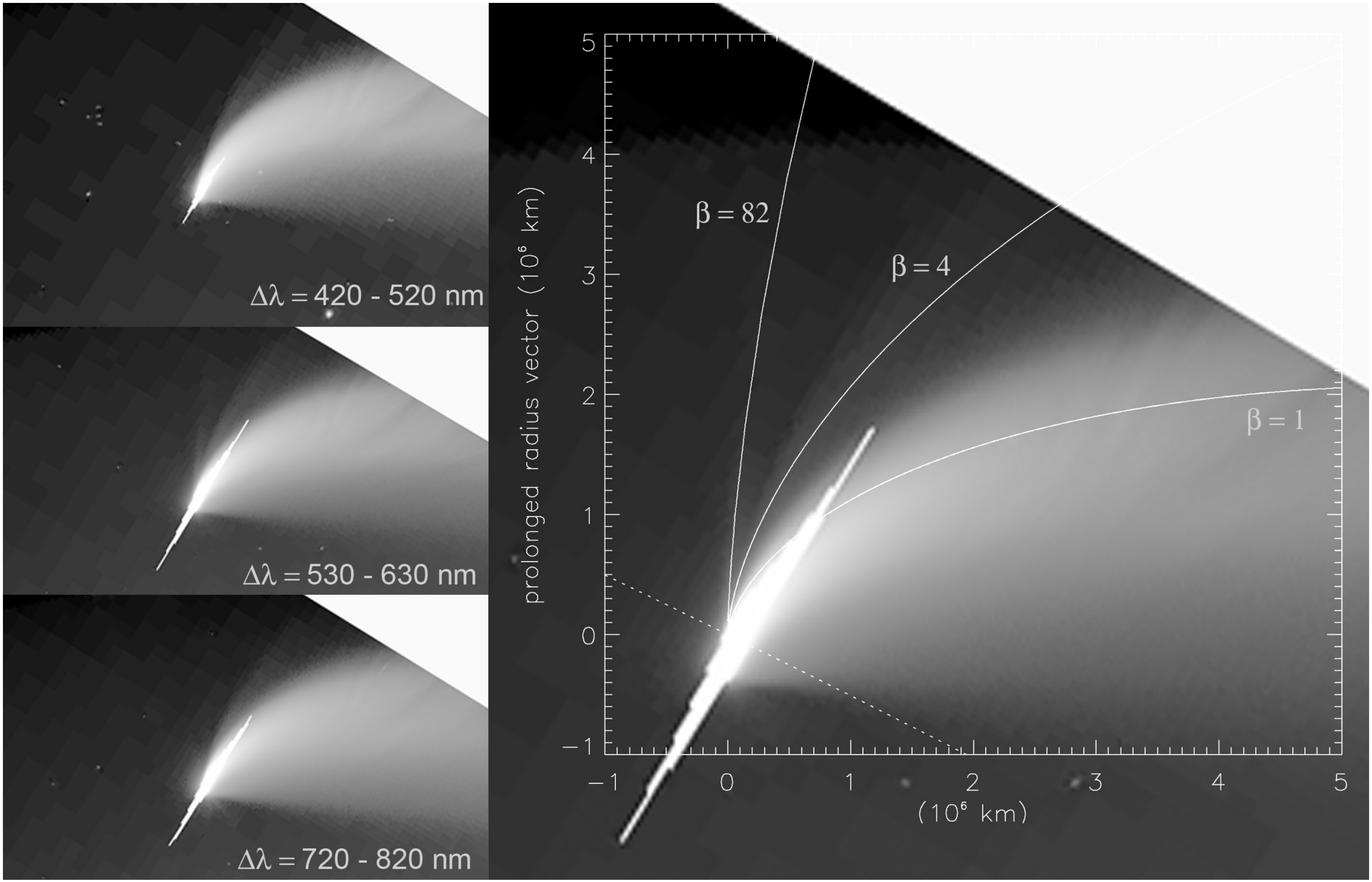
Since in comae we have NOT H_2 , is the possible reaction
$H_2O + FeS + C \text{-->} Fe + H_2S + CO$ when T goes above 680K ?

10% of all H_2S and 1% of all CO from such a reaction ?

In Earth, this reaction works in serpentinite with liquid water
Which T in coma pressure ??   Chemistry specialists at work....

Meanwhile...............

SOHO observes both the “white” Fe tail, and the “yellow” Na tail (15 Jan 2007 01h-02hUT)



And comet NEAT in 2003 ? (SOHO image of 19 feb 12hUT)