GIADA: shining a light on the monitoring of the comet dust production from the nucleus of 67P/Churyumov Gerasimenko

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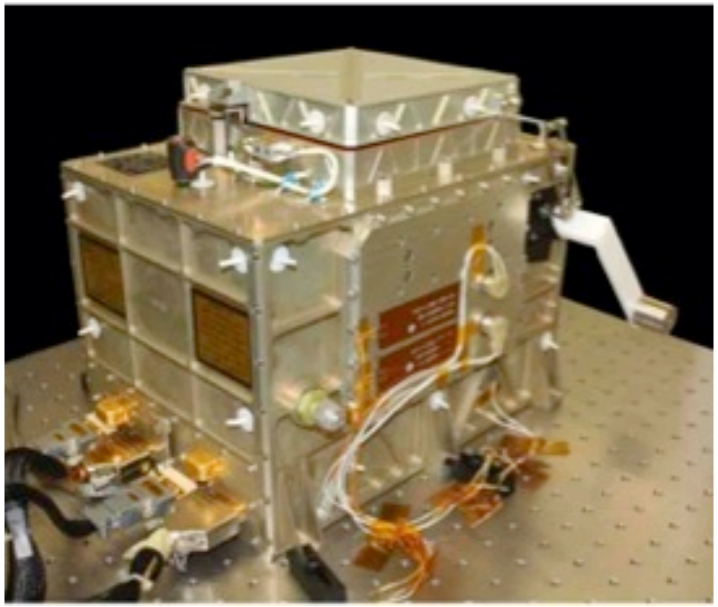

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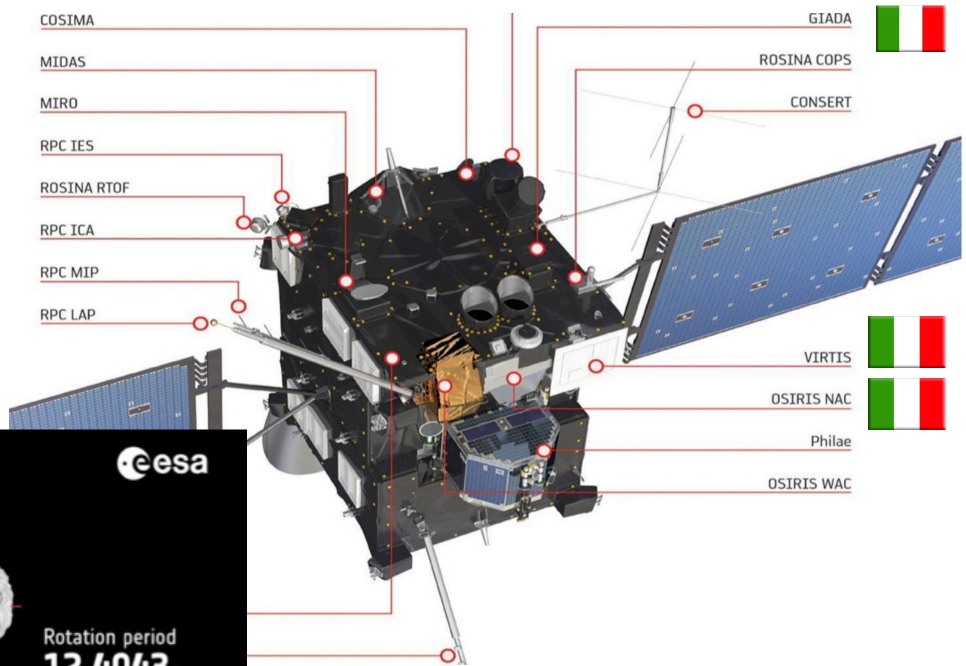
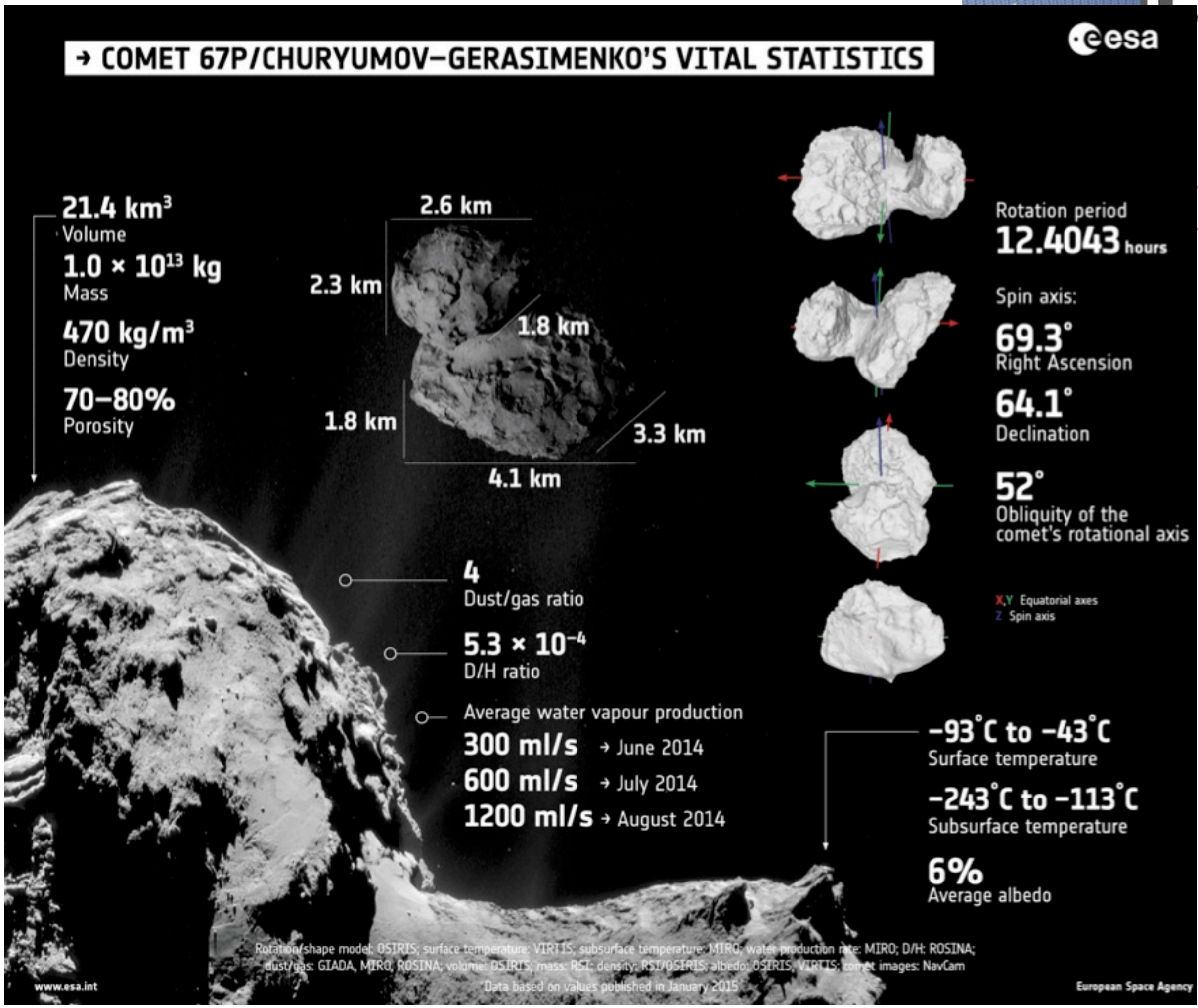
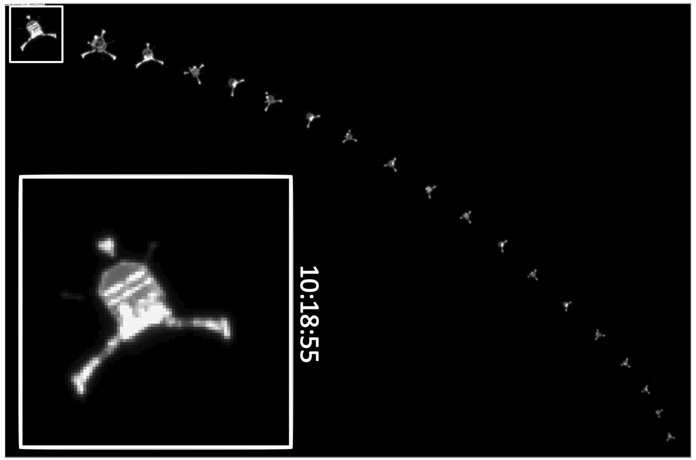
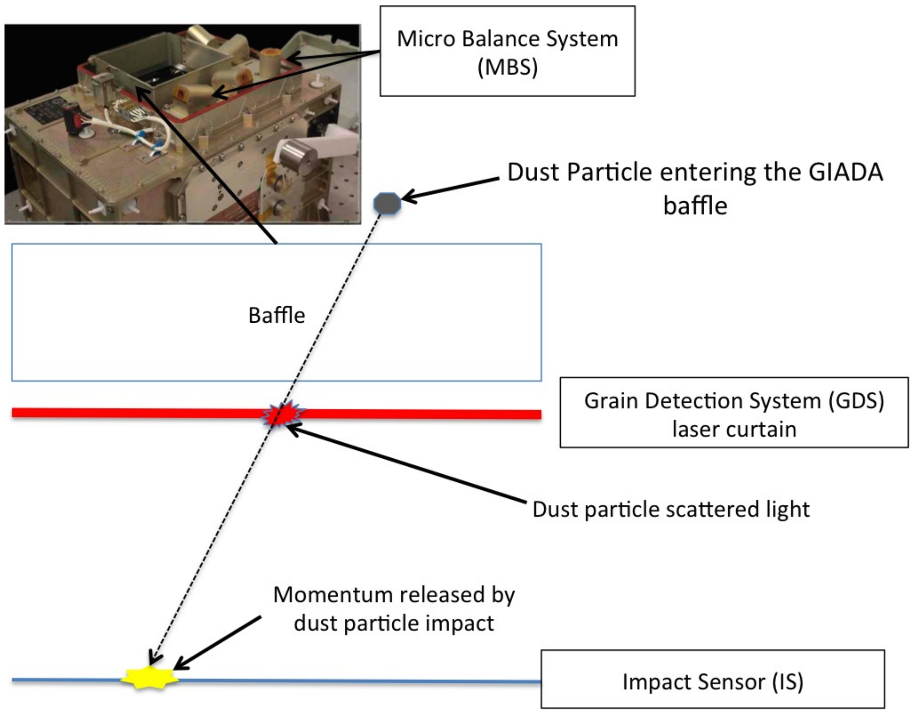
Rosetta & 67P/C-G







GIADA description



3 subsystems to characterize dynamics of individual particles and the dust flux:

1)Micro-Balances System (MBS): 5 QCMs, cumulative dust flux of particles < 10 μm.

2)Grain Detection System (GDS): individual particle mass (with IS), speed and cross section;

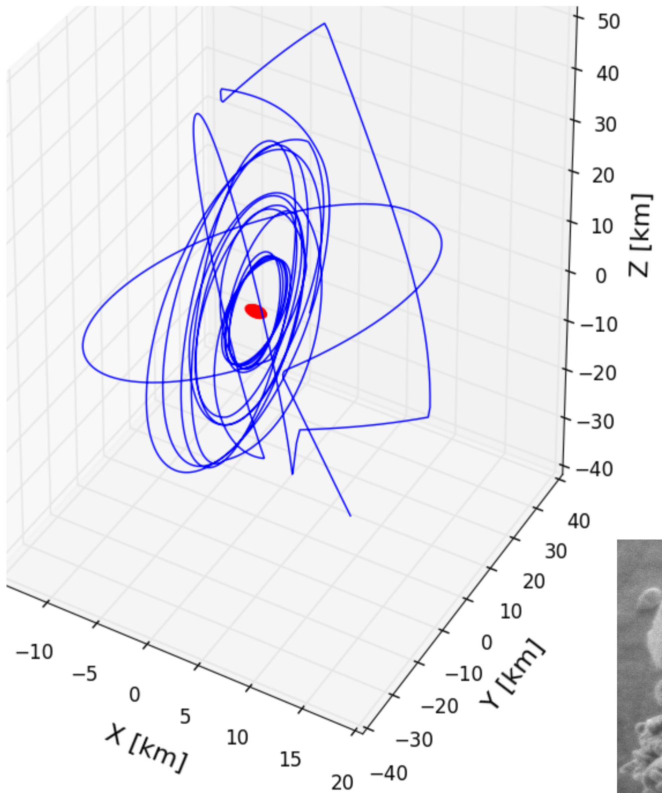
3)Impact Sensor (IS): particle momentum from the impact on a Al plate connected to 5 PZTs;

Speed	0.3 – 300 [m s^{-1}]	(GDS+IS)
Momentum (*)	1 x 10^{-10} – 4 x 10^{-4} [kg m s^{-1}]	(IS)
Dust mass Fluence	1.9 x 10^{-9} – 2.9 x 10^{-4} [g cm^{-2}]	(MBS)

Particle Equivalent Diameter	High Albedo 60 μm – 200 μm (Kaolinite)
	Low Albedo 150 μm - 800 μm (Amorph. Carbon)

Mass	2.2 x 10^{-12} – 4 x 10^{-4} [kg]
Flux	6 x 10^{-12} [g cm^{-2} s^{-1}]

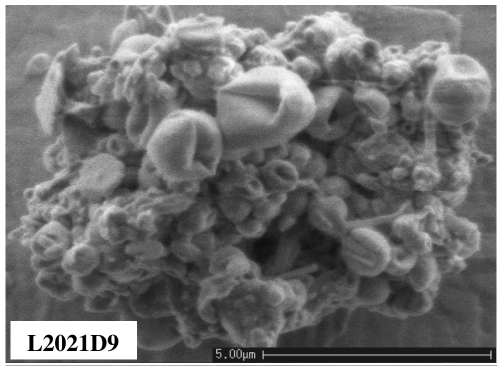
GIADA can constrain the particle density

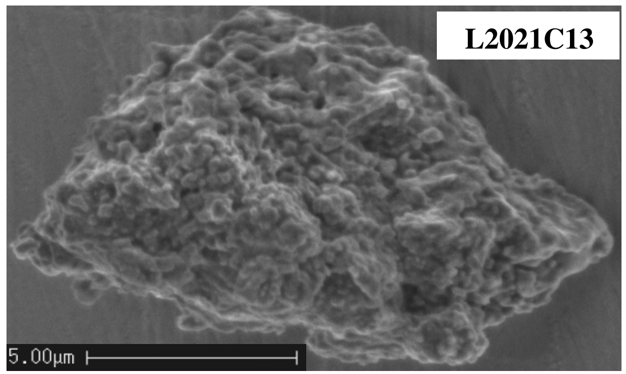


GIADA @ bound orbits

Compact particles (Rotundi et al., Science, 2015)
Fluffy particles (Fulle et al., ApJL, 2015)
Fluffy & Compact particles (Della Corte et al., A&A, 2015)

GIADA classified two types of dust particles



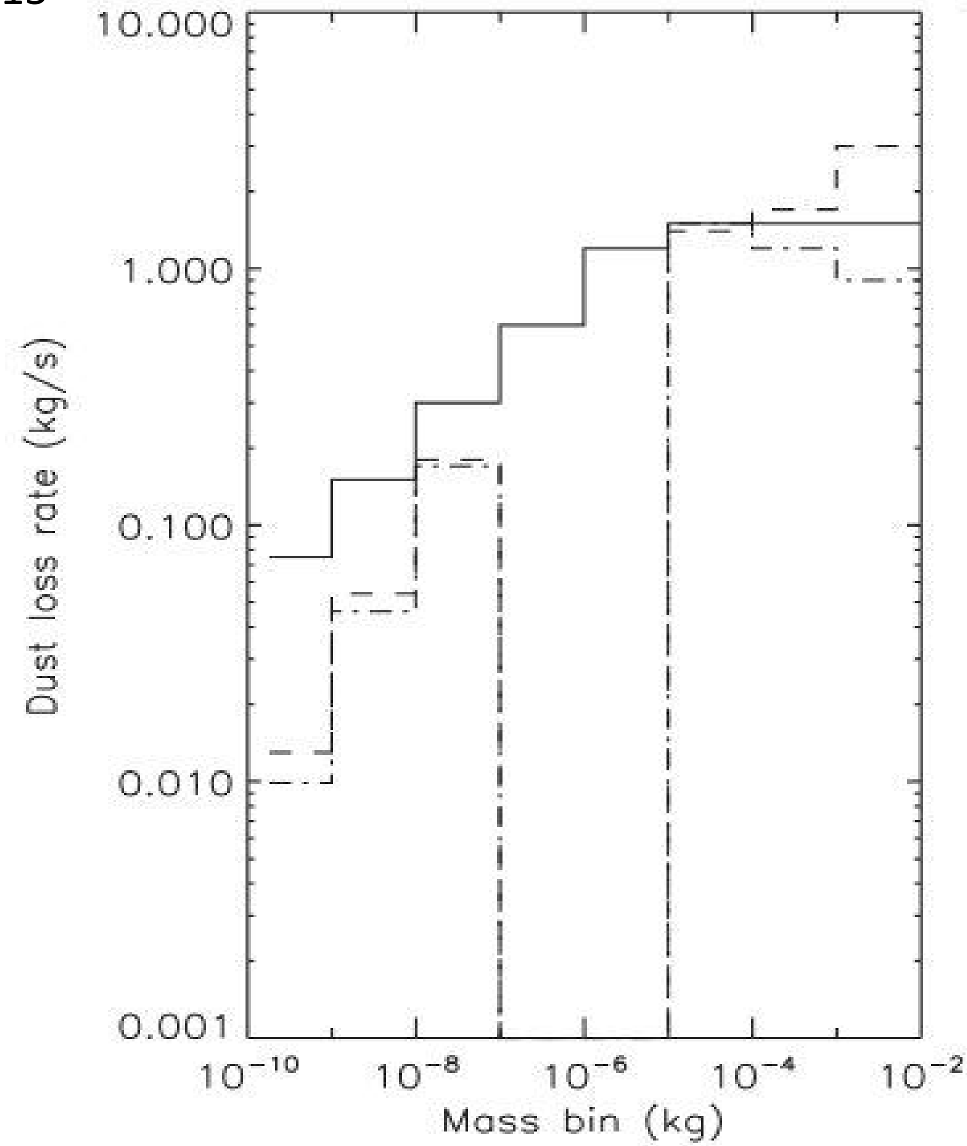


- **Fluffy:** porous aggregates with low momentum (< 10^{-10} kg m s^{-1}) and low density (< 1 kg m^3);
- **Compact:** momentum > 10^{-10} kg m s^{-1}, high density (800 - 3000 kg m^3);

Particle type	$N°$ of particles	Speed [m s^{-1}]	Mass [kg]	Momentum [kg m s^{-1}]	Size* [μm]
Fluffy	1056	<9	...	...	$180 \div 800$
Compact	202	$0.3 \div 12.2$	$1.9 \times 10^{-10} \div 4.2 \times 10^{-7}$	$1 \times 10^{-10} \div 3.9 \times 10^{-7}$	$80 \div 800$

Compact Particles

Rotundi et al., Science, 2015



Mass distribution:

- GIADA data constrained the 3 lower mass bin, OSIRIS the 3 upper mass bins.
- Low masses are "missing": size distribution is shallower than predicted (see MIDAS)
- GIADA constrained particles bulk density 800 – 3000 kg/m^3
- Dust/gas ratio => 4 ± 2

Fluffy Particles

THE ASTROPHYSICAL JOURNAL LETTERS, 802:L12 (5pp), 2015 March 20 doi:10.1088/2041-8205/802/1/L12

DENSITY AND CHARGE OF PRISTINE FLUFFY PARTICLES FROM COMET 67P/CHURYUMOV–GERASIMENKO

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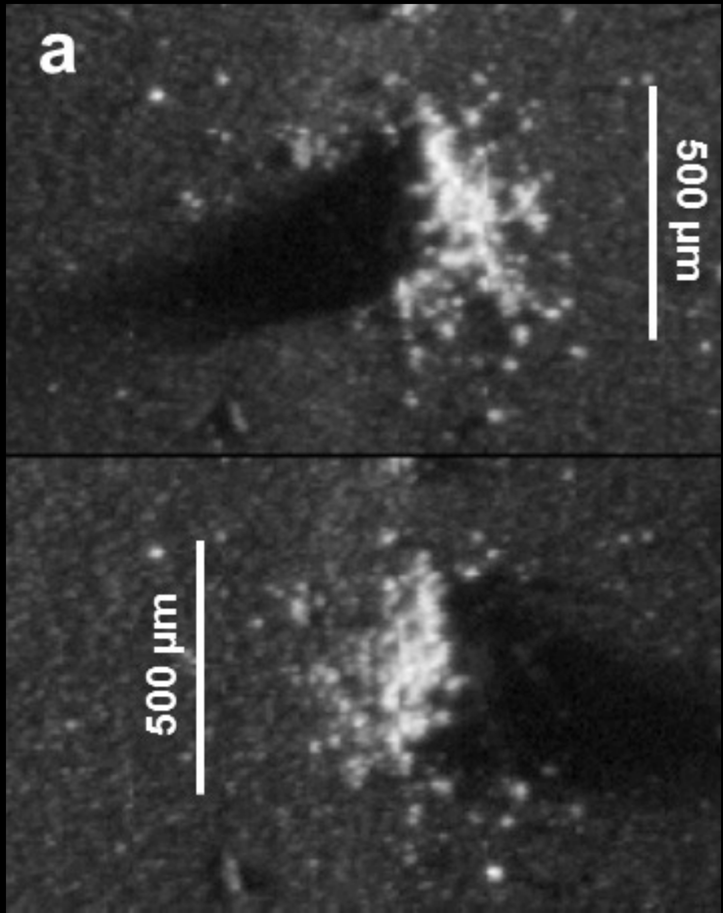
(i) While compact particles, ranging in size from 0.03 to 1 mm, are probably witnessing the presence of **materials that underwent processing within the solar nebula;** fluffy particles, ranging in size from 0.2 to 2.5 mm, are aggregates of sub-micron grains which **may be a record of a primitive component**, probably linked to interstellar dust.

(ii) Fluffy particles are charged, fragmented, and decelerated by the spacecraft negative potential (RPC). The density of such optically thick aggregates is consistent with the low bulk density of the nucleus (0,47 g cm^{-3}).

(iii)The dynamics of fluffy particles constrain their equivalent bulk density to $<1 kgm^{-3}$.

COSIMA

From the shadow particle height is derived: about 100 micron



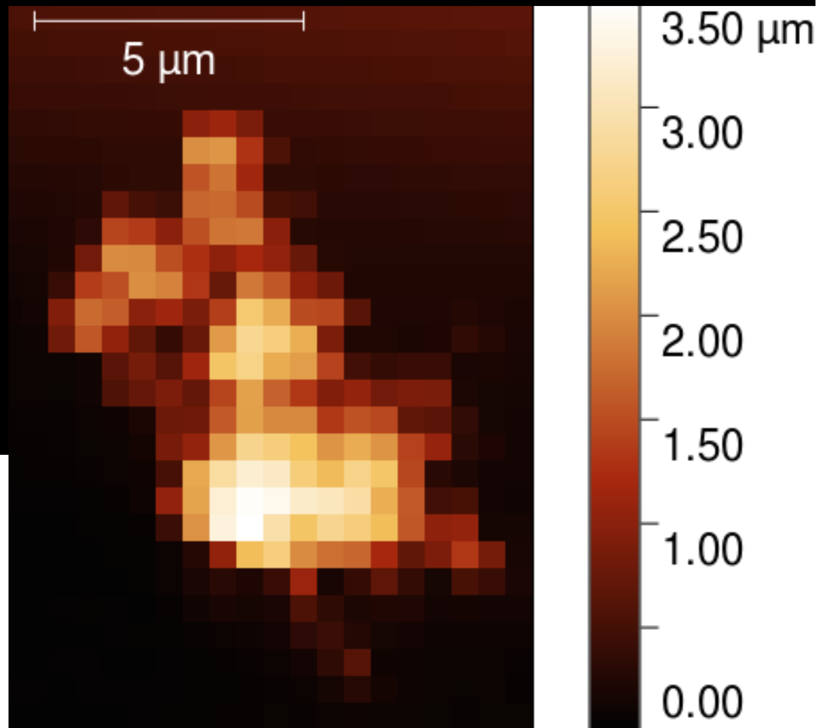
The mass spectra of the surface of the COSIMA grains collected beyond 3 AU show a high abundance of Na. Preliminary values are as high as 0.8, normalized to Mg = 1. For comparison, the Na abundances (Mg = 1) for comet 81P/Wild-2 are 0.13 (collected in aerogel) and 0.2 (collected on aluminium foil), 0.1 ± 0.06 for comet 1P/Halley28, and 0.55 for CI chondrites.

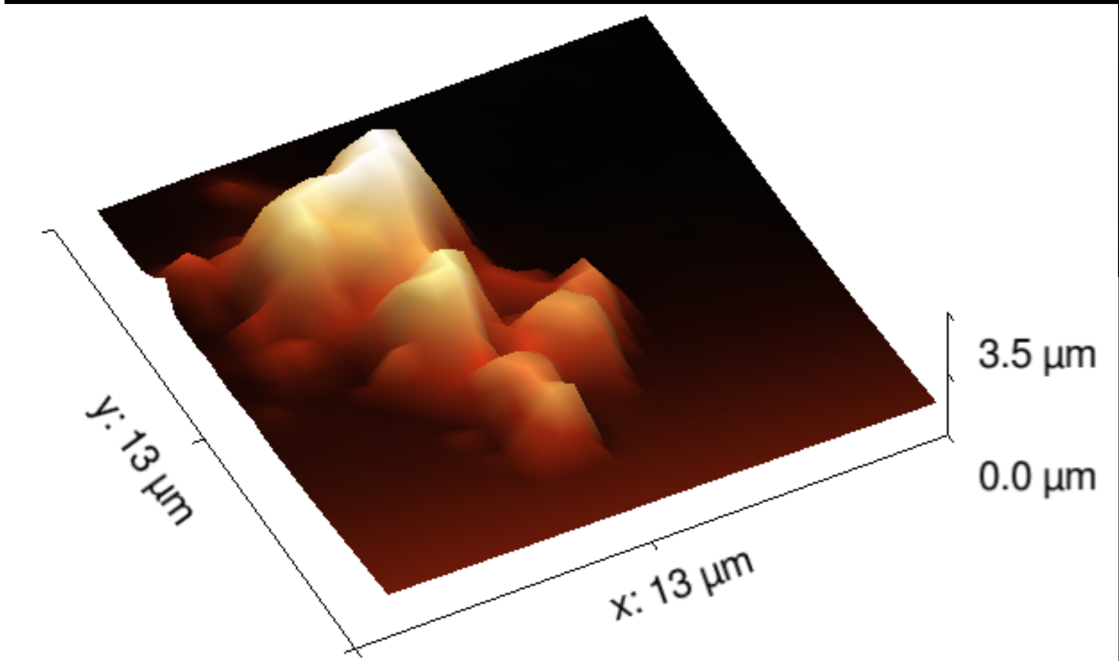
High Na abundance, combined with the fluffiness of the particles, supports the hypothesis that they represent the parent population of interplanetary dust particles in meteor streams of cometary origin.

Schulz et al., 2015, Nature

The extremely low bulk densities estimated (< 1 kg/m^3) lead to very porous "COSIMA particle building blocks"

MIDAS and the porosity at small scale!



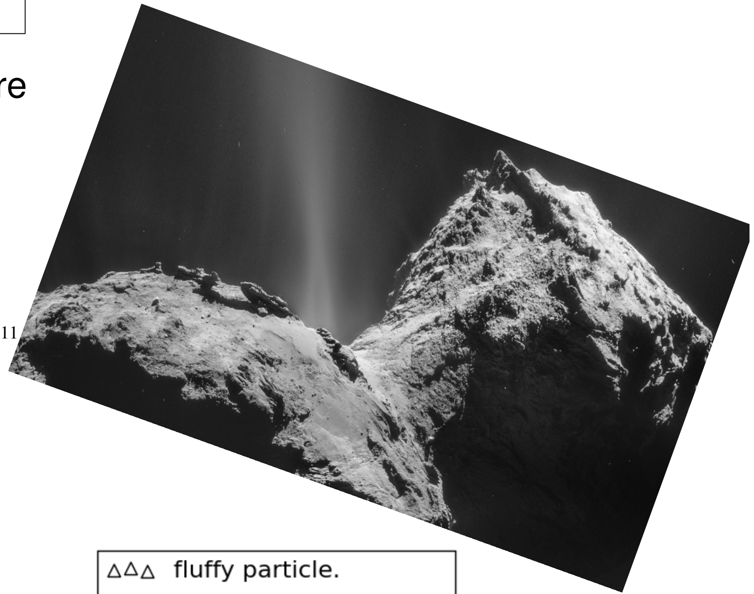


Astronomy & Astrophysics manuscript no. aa26208-15
August 19, 2015

Rosetta mission results pre-perihelion

Special feature

GIADA: shining a light on the monitoring of the comet dust production from the nucleus of 67P/Churyumov Gerasimenko



V. Della Corte[1], A. Rotundi[1,2], M. Fulle[3], E. Gruen[4], P. Weissman[5], R. Sordini[1], M. Ferrari[1], S. Ivanovski[1], F. Lucarelli[2], M. Accolla[6], V. Zakharov[7], E. Mazzotta Epifani[8,9], J. J. Lopez-Moreno[10], J. Rodriguez[10], L. Colangeli[11], P. Palumbo[2,1], E. Bussoletti[2], J. F. Crifo[12], F. Esposito[8], S. F. Green[13], P. L. Lamy[14], J. A. M. McDonnell[13,15,16], V. Mennella[8], A. Molina[17], R. Morales[10], F. Moreno[10], J. L. Ortiz[10], E. Palomba[1], J. M. Perrin[12,18], F. J. M. Rietmeijer[19], R. Rodrigo[20,21], J. C. Zarnecki[21], M. Cosi[22], F. Giovane[23], B. Gustafson[24], M. L. Herranz[10], J. M. Jeronimo[10], M. R. Leese[13], A. C. Lopez-Jimenez[10], and N. Altobelli[25]

(Affiliations can be found after the references)

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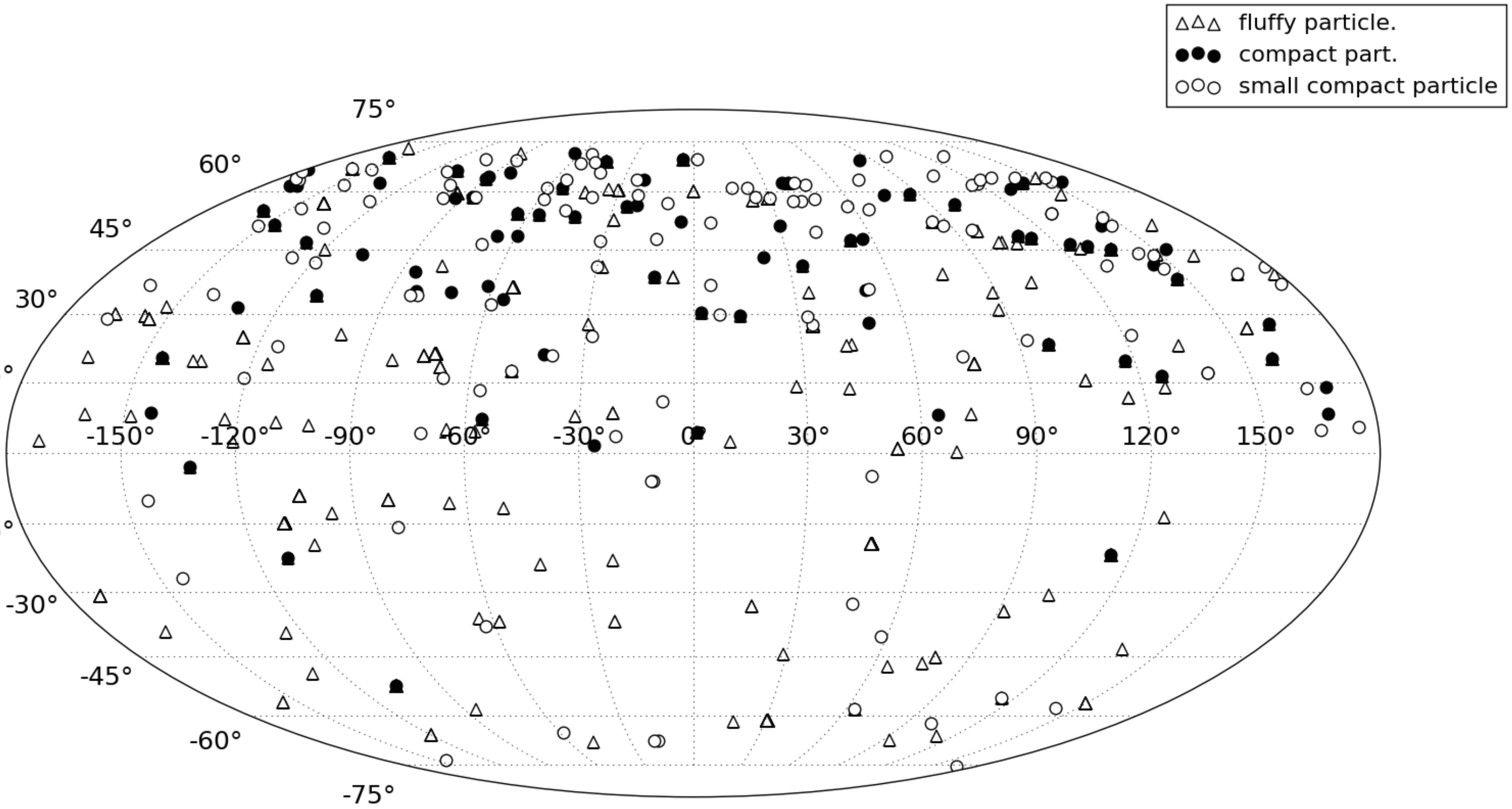
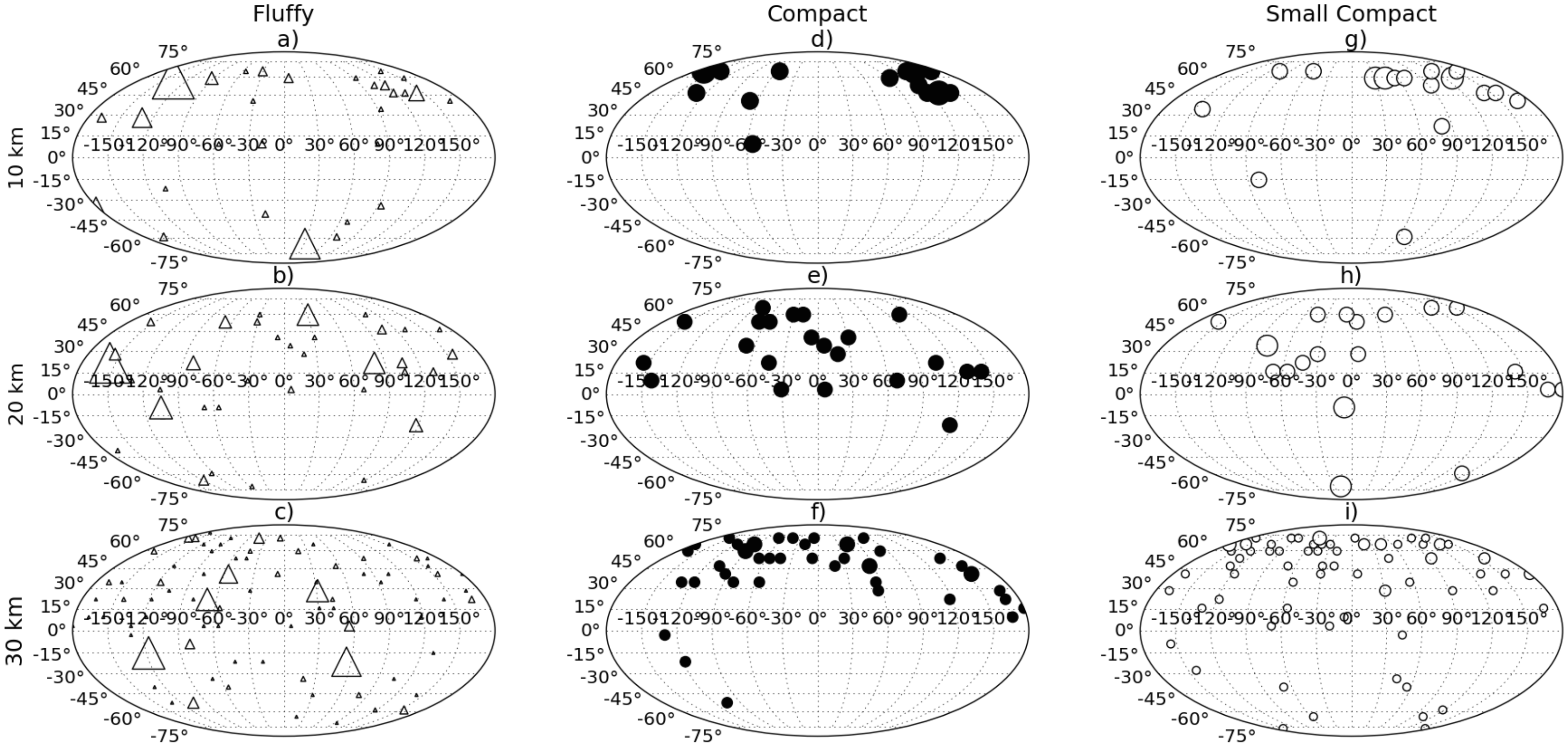


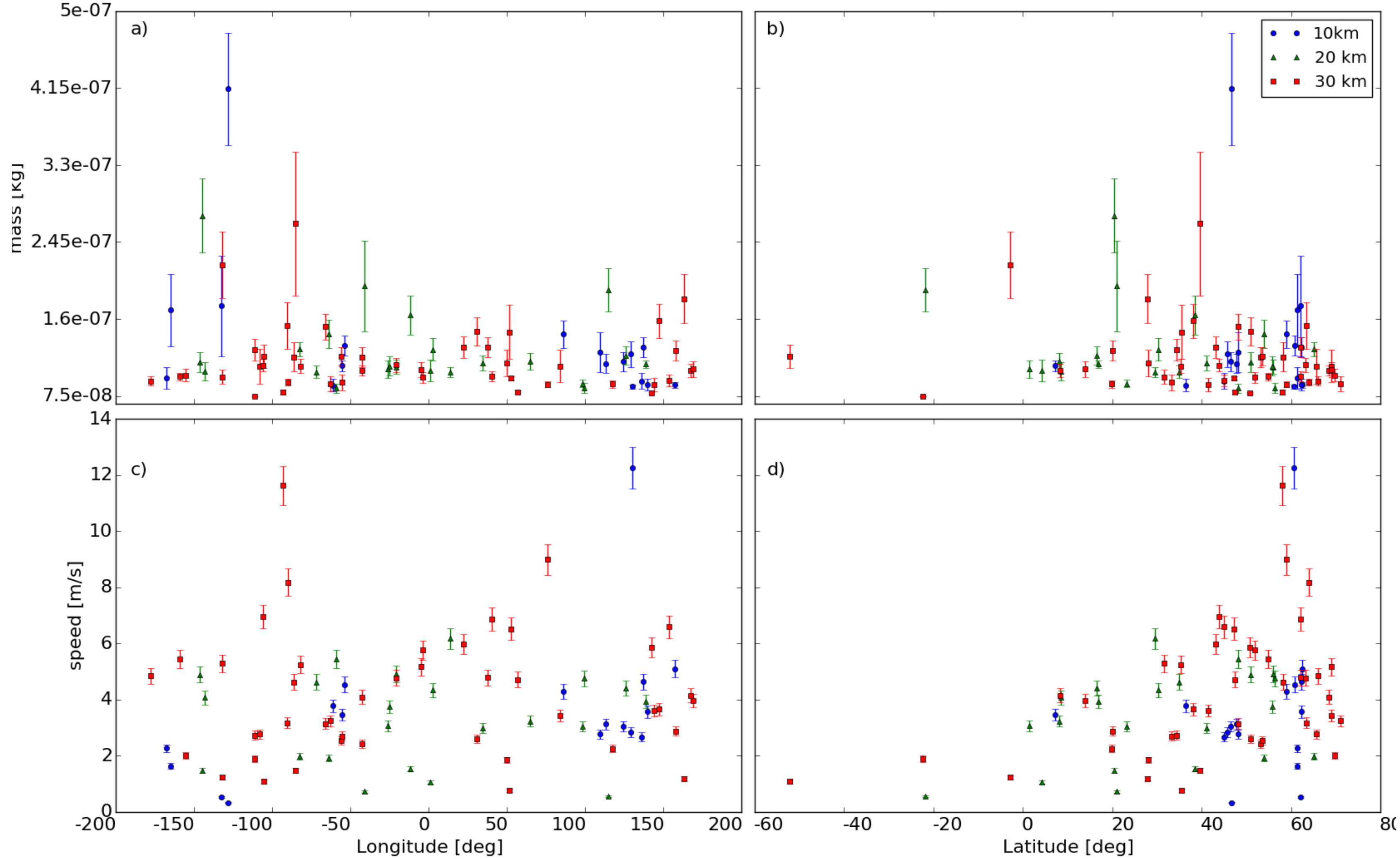
GIADA detections: Lat Long distribution



detection time	Lat [deg]	Long[deg]	detection type
22/10/14 15:08:53	45	135	GDS-IS
15:20:30	46	129	GDS-IS
15:29:26	46	124	GDS-IS
15:48:53	48	113	GDS-IS
16:19:39	50	109	IS-only
22:21:06	62	-132	GDS-IS
23:09:31	61	-164	GDS-IS
23:13:49	61	-167	GDS-IS
28/10/14 08:17:18	62.5	157	GDS-IS
08:24:25	62.5	152	IS-only
08:43:18	62.3	140	GDS-IS
08:47:06	62.3	137	GDS-IS
09:13:05	62.3	138	IS-only

- Fluffy particles are spread over all the lat. long. values for any nucleus distance.
- Compact and Small-Compact, lat. long. distribution varies with respect to the orbit radius.
- Enhancements in dust detection rate along the 10 km radius orbits: detections close in time identifying higher dust density coma region and suggesting active areas on the nucleus .

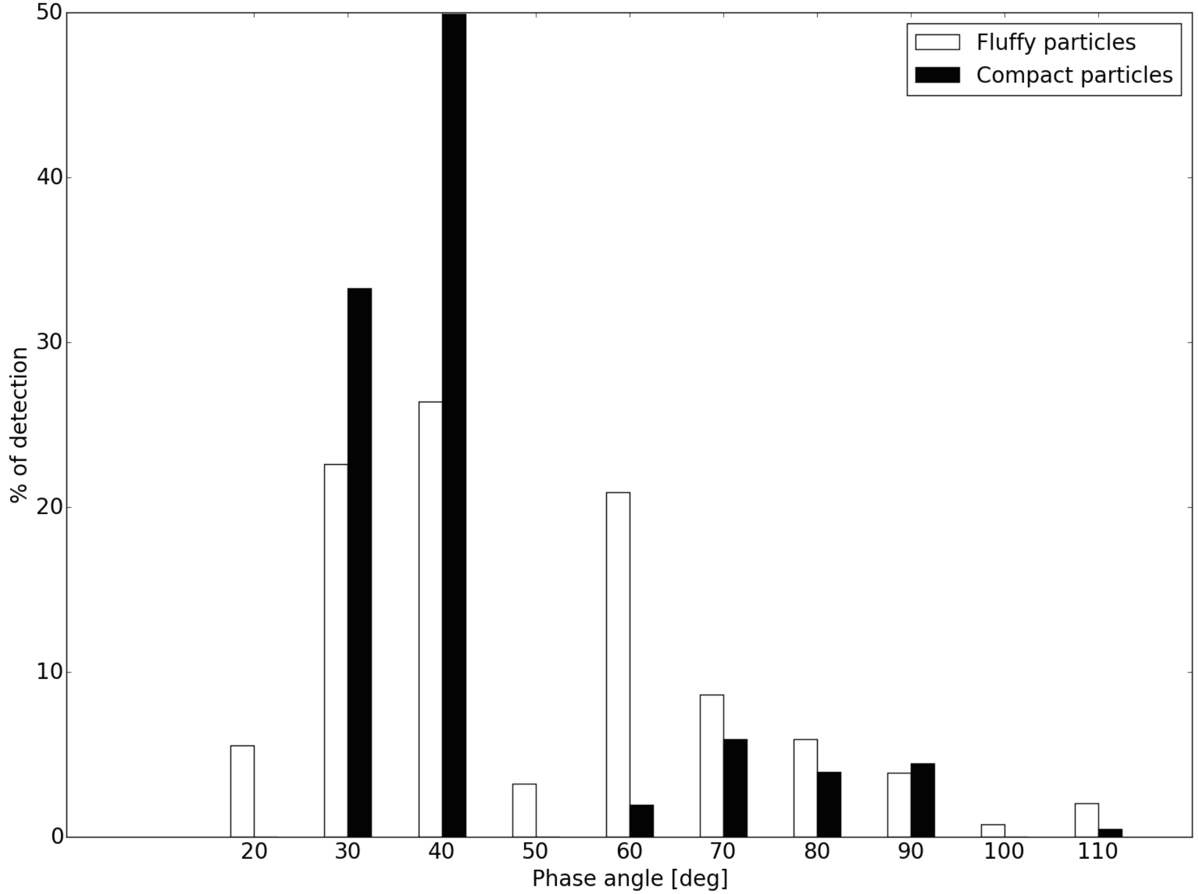
Masses and speeds, at different distances from the comet nucleus vs. latitude-longitude



- The highest masses and speeds are concentrated between 40 and 60 degree of latitude (@10km); Particles spread @20 30 km.
- Particles detected below the equator, are characterized by low speeds and low masses.

Dust emission with respect to nucleus illumination conditions

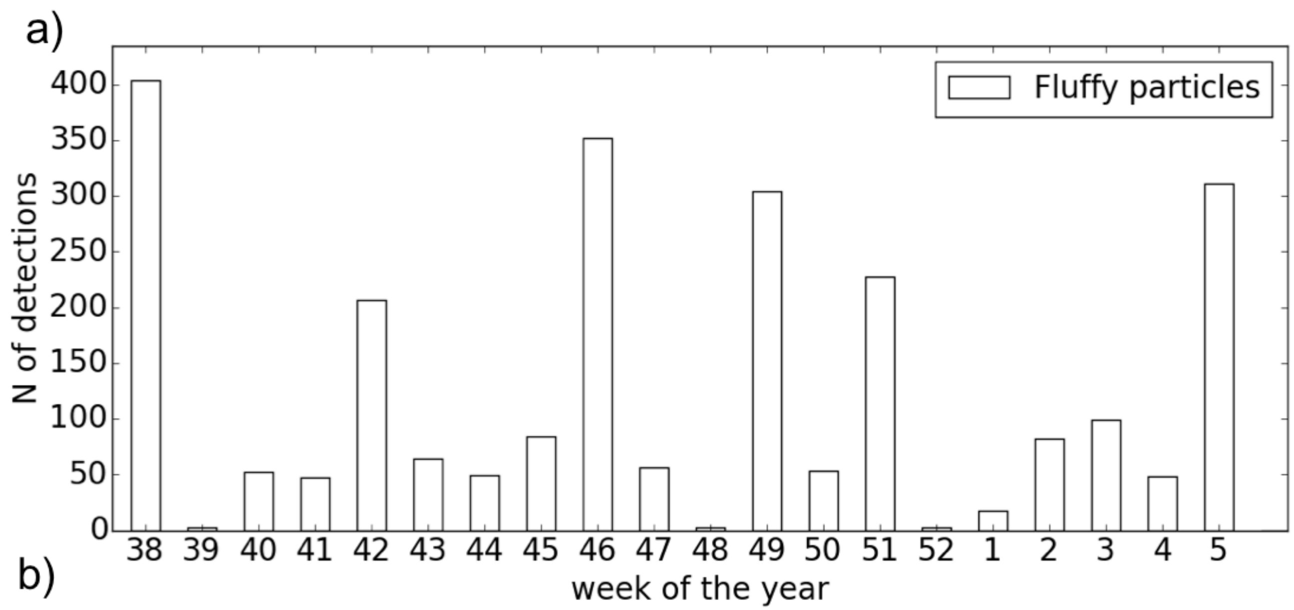
Also to evidence different spatial distributions with respect to the particle types



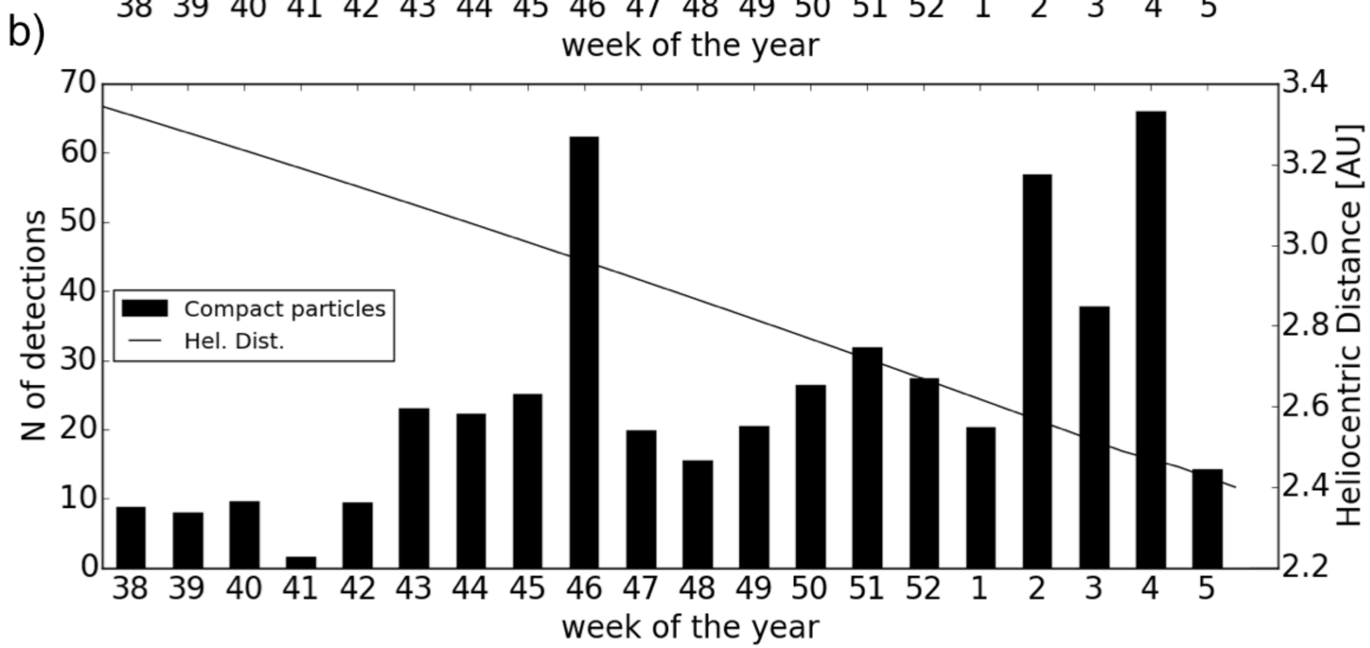
- Fluffy particles detection percentages occurred at every phase angles: they seem unconnected to a specific high dust production area.
- Compact particles detections have pronounced maxima at phase angles of 40° - 50°. In this case, as already shown with the latitude-longitude distribution of detections, the dust seems to be more correlated to a specific area in addition to specific phase angles.

Monitoring the terminator dust environment:

Dust emission vs. heliocentric distance



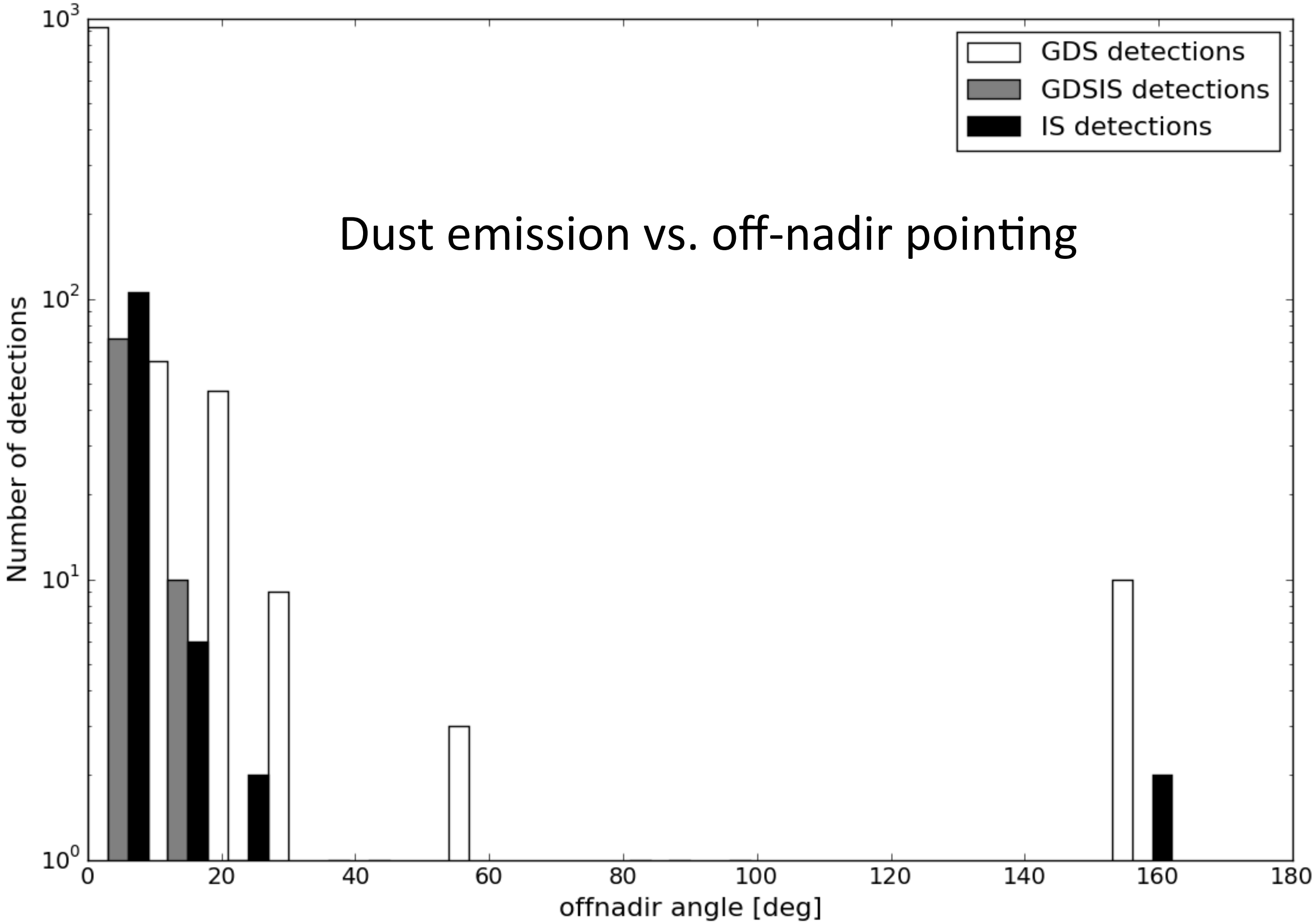
- Fluffy particles do not show a definite trend with respect to time.



- Compact particles show an overall trend with time indicating that the emission of these particles has a slight increase with decreasing heliocentric distance.

Detection types are related to the GIADA pointing configuration

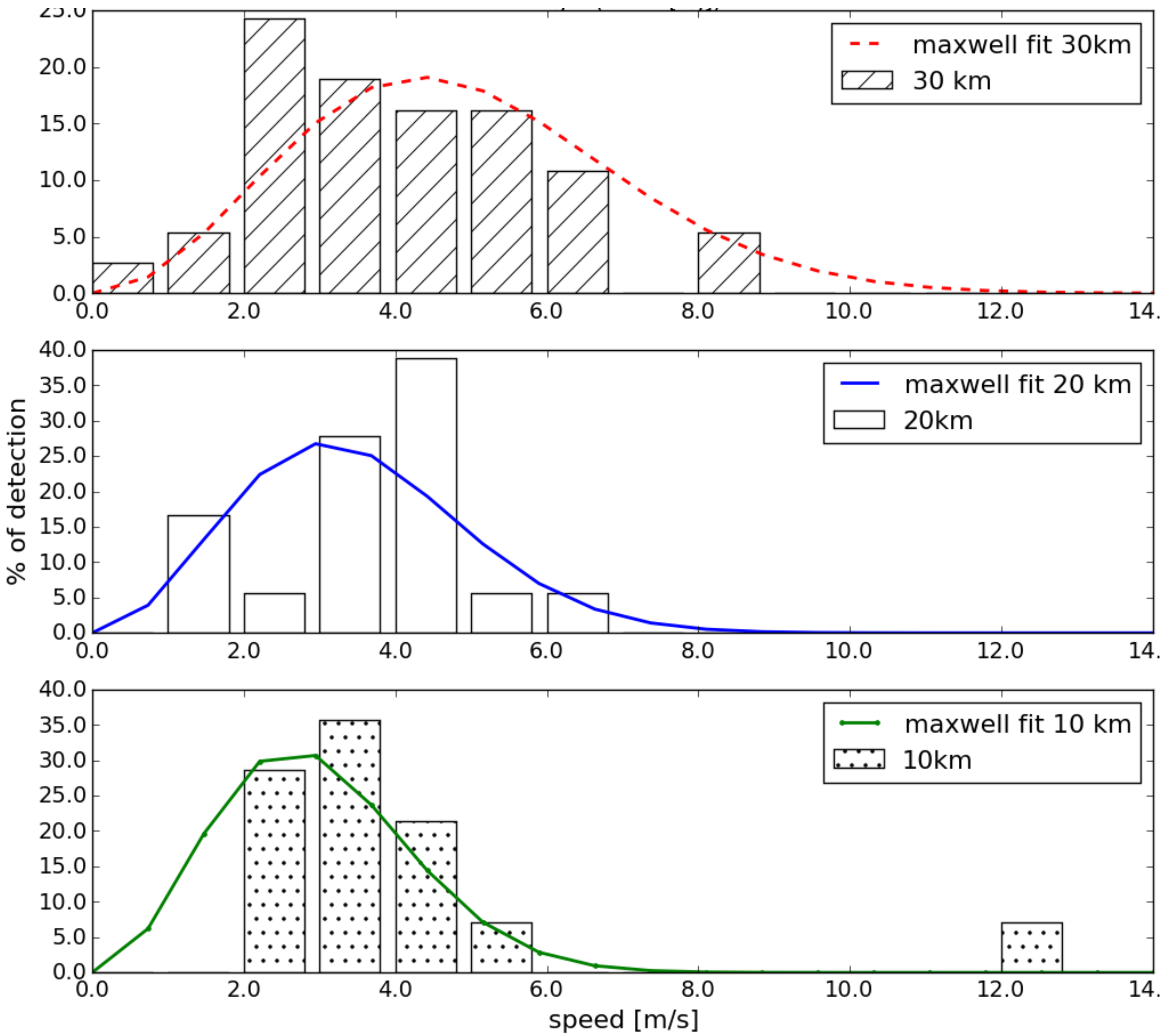
Falling back particles?



- Fluffy particles detections occur also at high off-nadir angles;
- Fluffy particles can move along directions ≠ from radial;
- Recall: fluffy particles dynamic is influenced by the spacecraft potential (Fulle et al., 2015)

- Two Compact particles detected with GIADA pointing about anti nadir direction;
- Reflected particles: particles falling back to the nucleus(?)
- Momenta of about 2 x 10^{-8} kg m s^{-1} and masses about 10^{-8} kg, i.e. in the range of the largest masses detected by GIADA.

Dust acceleration



Dust-gas drag (spherical symmetry, Wallis 1982)

$v^2 – v_0^2 = [1 – R/r] [(size_{max}/size) -1] 2 GM_n / R$

$v << v_{gas}$, 2nd order Taylor approx. valid for GIADA

v_0 starting dust speed at r = R

R equivalent nucleus radius (radial motion for r > R)

$size_{max}$ = 17 mm (Rotundi et al., Science 2015)

GM_n = 667 $m^3 s^{-2}$ (Sierks et al., Science 2015)

v independent of dust equivalent bulk density

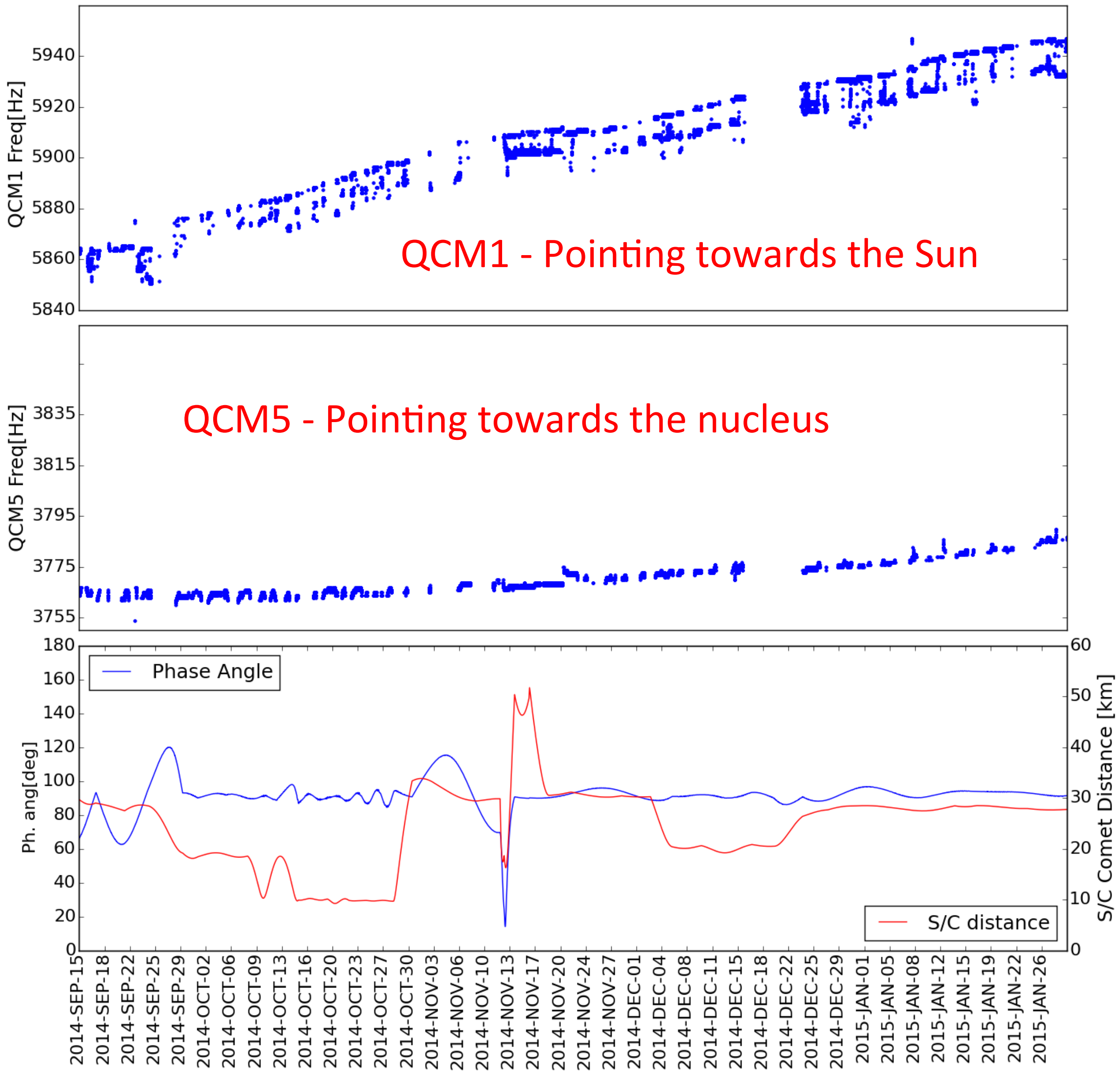
90% of GDS+IS detections in the 10^{-8}-10^{-7} kg bin

Average size = 400 micron and R = 4.7 km provide
- v = 2.5 m/s at r = 10 km
- v = 3.0 m/s at r = 20 km
- v = 3.2 m/s at r = 30 km

Acceleration region observed in 4 months spent in terminator orbits (steeper than predicted):
- v = 2.5 m/s at r = 10 km
- v = 3.0 m/s at r = 20 km
- v = 4.3 m/s at r = 30 km

Mass dust flux of nanogram particles

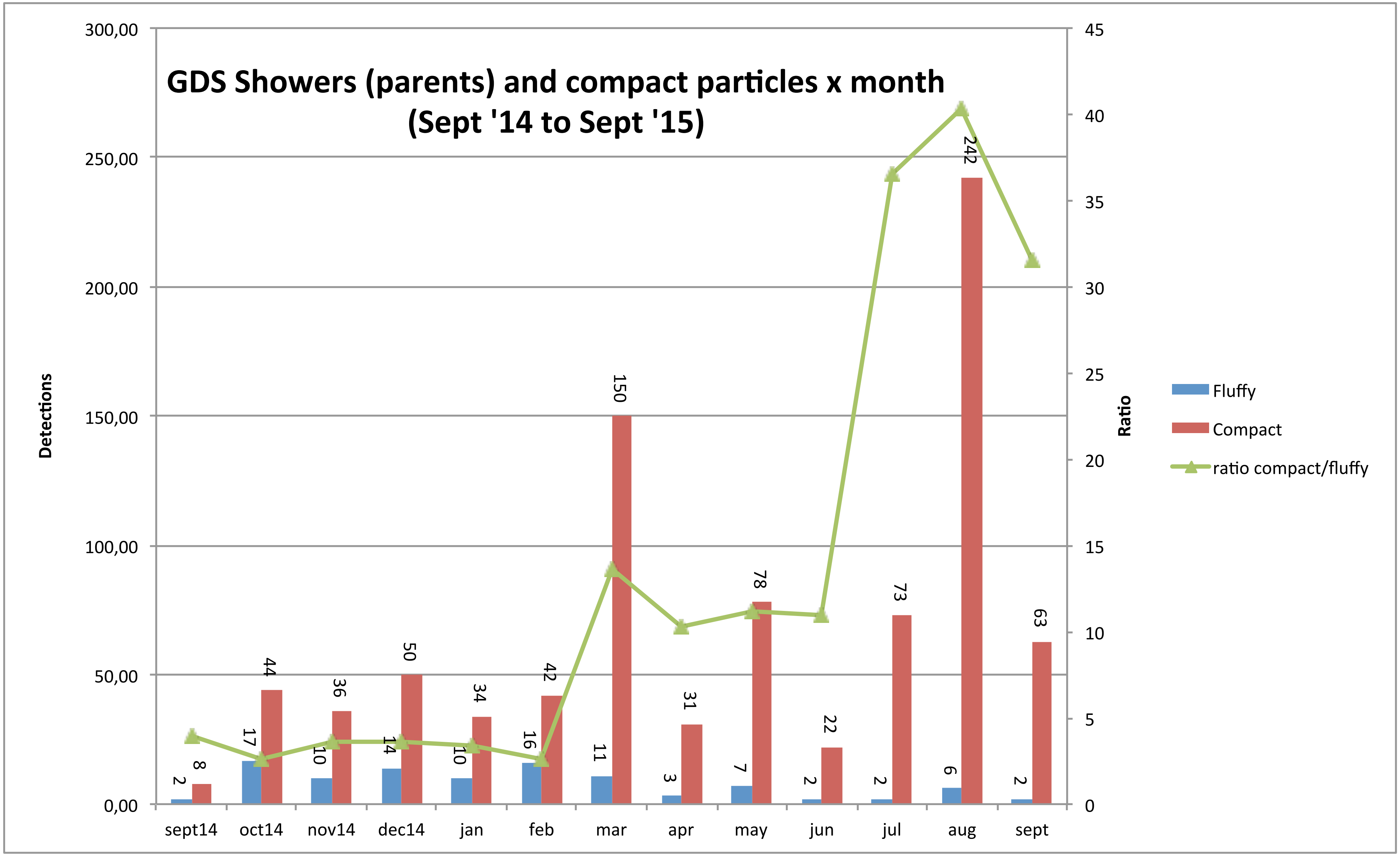
micron-sized particles reflected by the solar radiation pressure



- The integrated flux of nanogram particles coming from the Sun direction is about 3 times larger than the flux coming directly from the comet nucleus (QCM1 vs. QCM5).

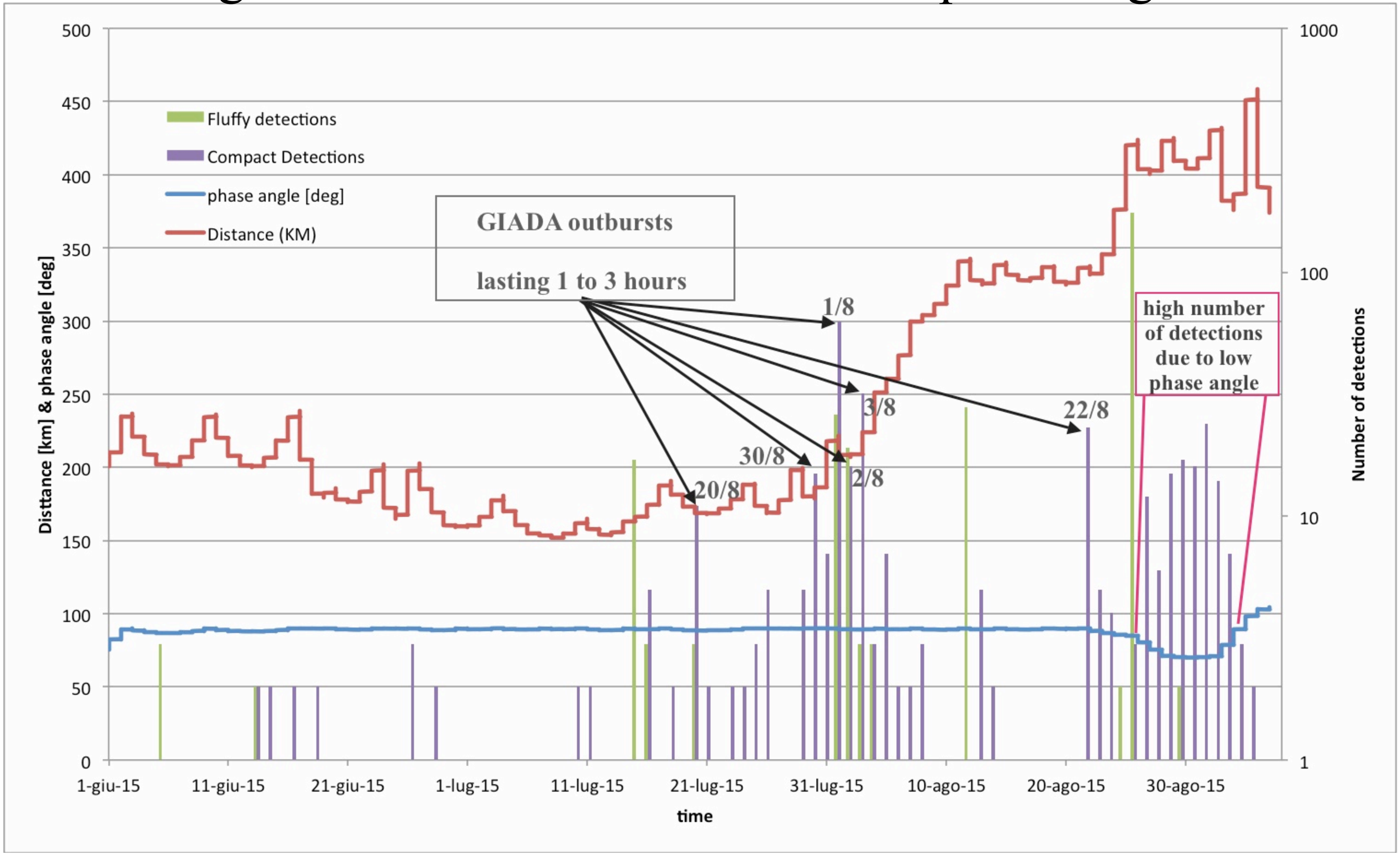
- Terminator areas eject a flux of nanogram dust a factor < 15% than the nucleus areas characterized by a sun-zenith angle < 50°.

GIADA @ Perihelion



N. of Detections vs. time:

- Outbursts
- High dust detection rate due to low phase angle



CONCLUSIONS: GIADA@ bound orbits

- GIADA detected two family of dust particles:
  - compact particles (Rotundi et al., Science, 2015) are associated to confined areas;
  - fluffy particles (Fulle et al., 2015) appear to have a more diffuse origin.

- Dust emission with respect to nucleus illumination conditions:
  - strong correlation for compact particles;
  - no strong correlation for fluffy particles.

- Monitoring the terminator dust environment:
  - increase of compact particles about 4 times higher @ 2.4 AU than @ 3.2 AU;
  - no evident increase for fluffy particles.

- Compact particle speeds and acceleration:
  - speeds at 10 km < than those at 20 km < than those at 30 km

    => dust at least till 30 km is accelerating.

- MBS measured the mass dust fluxes of nanogram particles:
  - Solar direction about 3 times higher than the one coming from the nucleus.

To summarize what GIADA "saw" close to perihelion….

- Particles morphology shows evolution with time, likely to reflect different source regions:
  - **recent collections** detections shown a lot of **small compact particles**
  - **compact particles** are more abundant in the **northern hemisphere during the first part of the mission, now in the southern hemisphere**

- **Very few micron-sized particles** during June measured by GIADA

- In August, higher flux thanks to "outbursts" and low phase angles

- **Faster dust (->35m/s) close to perihelion**

Aknowledgments:

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