ISSI Team
“3D+t 67P Gas & Dust Coma Models”

Summary of the first Meeting
(28 Sep – 1 Oct 2015)

M. Fulle – INAF Trieste

Participants

Vladimir Zakharov (LATMOS Team)

Mike Combi (ICES Team)

Nicolas Thomas (Bern Univ., Bern+Taiwan Team)

Joerg Knollenberg (DLR Berlin)

Francesco Marzari (Padova Univ., OSIRIS + LATMOS Team)

Fernando Moreno Danvila (IAA Granada)

Alessandra Rotundi (Napoli Univ.)

Vincenzo Della Corte (IAPS Roma)

Stavro Ivanovski (IAPS Roma)

Martin Rubin (Bern Univ., ICES)

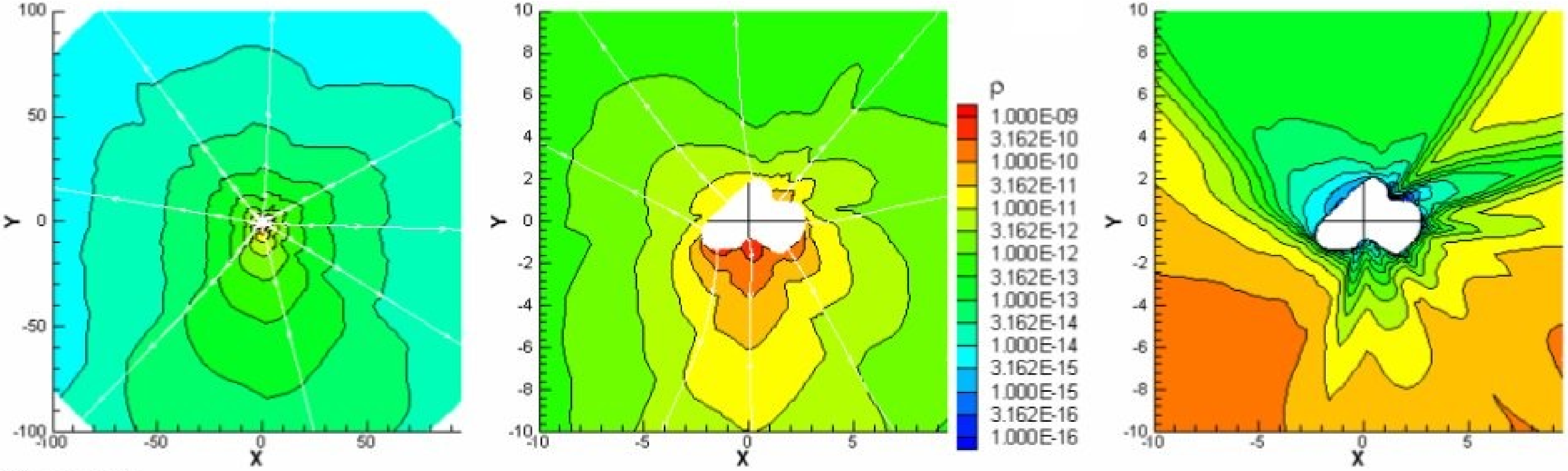
Marco Fulle (convener)

Invited Talks: 1. V. Zakharov (LATMOS)

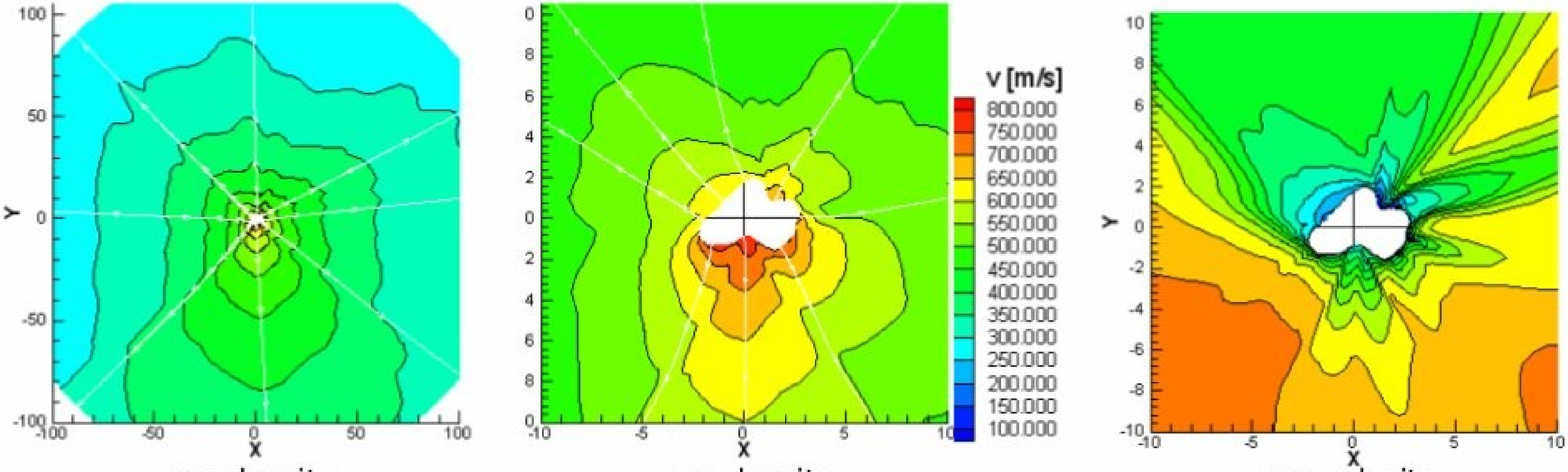
1. Nucleus Model: Shape 3 from RMOC, degraded to 2.5 x 2.5 deg (15k mesh, size 50m)
   illumination problem: solar zenithal angle (SZA) computed on the degraded mesh
   this can be very far from the real average SZA in case of small-scale nucleus roughness
2. Back gas flux on nucleus taken into account (LATMOS only, not ICES, partially Bern)
3. Gas coma models: both Fluid and DSMC (tests on convergence of both approaches)
4. Gas parameters by COPS data fit: water flux min/max = 0.8% – 1.8% (not yet fixed)
5. Starting condition: homogeneous water loss rate = 6E+25 mol/s (SZA dependent only)
6. COPS (and possibly DFMS) data fit improved by other gas models (e.g. thermal lag)
7. Water loss depends on heliocentric distance r_h and on diurnal solar illumination (SZA)
8. CO and CO2 loss rates depend on diurnal solar illumination only (not on r_h)
9. 3D+t gas and dust comae ready for 20-21 Aug 2014 and 8-11 Oct 2014 (all prelanding)
10. Maximum lifted radius = 3.3 mm (August) and 4.7 mm (October) at bulk density =1 g/cc

Comparison of gas density and velocity (effect of the shape model)

Shape 1v3



Shape 2



gas density

gas density

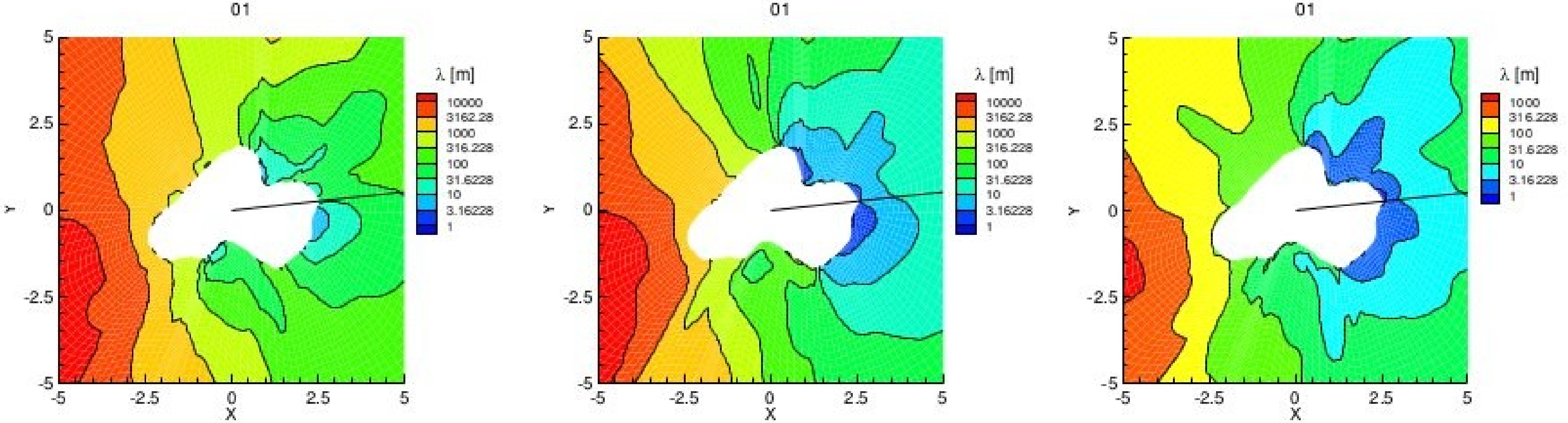
gas velocity

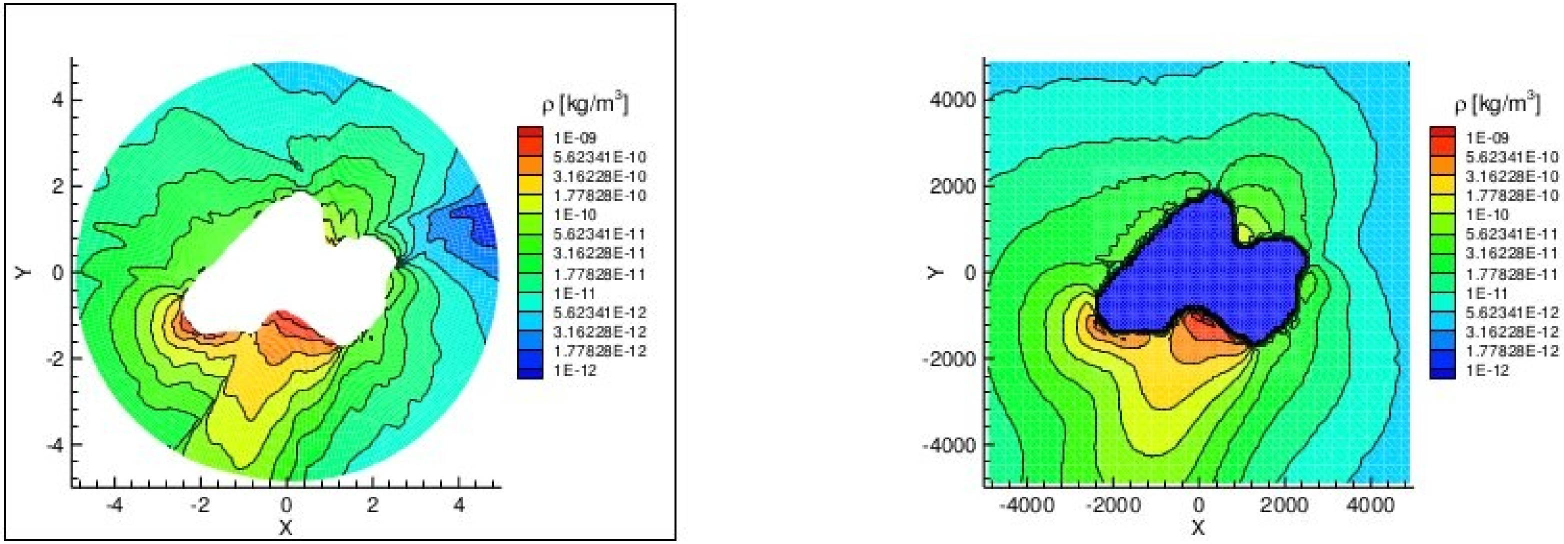
($r_h=3$ AU, $a_0=0.1$, $Q_{CO}=10^{25}$, $Q_{CO2}=3\cdot10^{24}$, $Q_{H2O}=5\cdot10^{25}$, $\theta_{Sun}=51°$, $\varphi_{Sun}=266°$)

Fluid and kinetic description

Mean free path

r_h= 3.2 AU r_h=2.0 AU r_h=1.24 AU





Gas density distribution by the BE-NSE (left) and DSMC (right) at r_h=3.3 AU.

Invited Talks: 2. M. Combi (ICES)

1. Nucleus Model: both Shape 3 from RMOC and Shape 4 from OSIRIS
   degraded to 1.5 x 1.5 deg (50k mesh, size 30m on the nucleus surface)
   illumination problem: solar zenithal angle (SZA) computed on the degraded mesh
2. Gas coma models: DSMC steady only (not foreseen soon 3D+t comae)
3. Gas parameters constrained by COPS data fit:
   water flux night/day = 2%, CO2 night/day = 10%
4. Starting condition: homogeneous water loss rate = 7.6E+25 mol/s (SZA dependent only)
5. COPS and DFMS data fit already improved by “active areas” (spherical harmonics):
   80% of water from the neck (20% other); 80% of CO2 from south (20% other)
6. 3D gas and dust comae soon ready for end of August 2014
7. Maximum lifted radius = 0.6 mm on 23 August 2014 at bulk density = 1 g/cc

Invited Talks: 3. N. Thomas (Bern+Taiwan)

1. Nucleus Model: Shape 4 from OSIRIS, degraded to 1.5 x 1.5 deg (50k mesh, size 32m) illumination problem: solar zenithal angle (SZA) computed on the degraded mesh
2. Gas coma models: purely kinetic DSMC, no time-dependent coma foreseen
3. No feedback in T from coma, T = 0 when non illuminated, water flux on night = 0
4. Not only half-maxwellian flux (LATMOS, ICES), but also cos^n to simulate sinkholes
5. Starting condition: homogeneous water loss, then non-homogeneous asap
6. COPS data fit by non-homogeneous water loss from 29 Aug to 22 Sep 2014
7. backflux of gas absorbed (areas at T = 0) vs reflected (sunlit areas) taken into account
8. CO and CO2 outflow not taken into account
9. Dust coma of spheres of radius up to 0.3 mm with constant drag coefficient C_D = 2, no back-reaction on gas, bulk dens.=1 g/cc, no dust-dust collision, nucleus point-like gravity
10. WAC fits on 5 Sep 2014, single sizes, dust/gas = 2 at r = 15 µm, 800 (??) at r = 150 µm

Invited Talks: 4. J. Knollenberg (DLR)

1. Models of Imhotep outburst (12 Mar 2015) and of collimated outburst (22 Aug 2015)

2. Imhotep outburst:

   Motion of dust due to gas drag and nucleus gravity

   Free molecular gas-dust interaction, spherical dust, drag C_D from Bailey & Hiatt 1971

   Steady (hr time scale) production fits data much better than explosive outburst

   Power-law size distribution in the range 10 μm – 10mm poorly fits data; good fit by:

   2.1 Truncated size distr. between 10 μm – 1mm with diff. Index = -2.6 (dust/gas = 0.66)

   2.2 “Knee” size distr. provided by GIADA with knee at radius = 0.5 mm (dust/gas = 1-2)

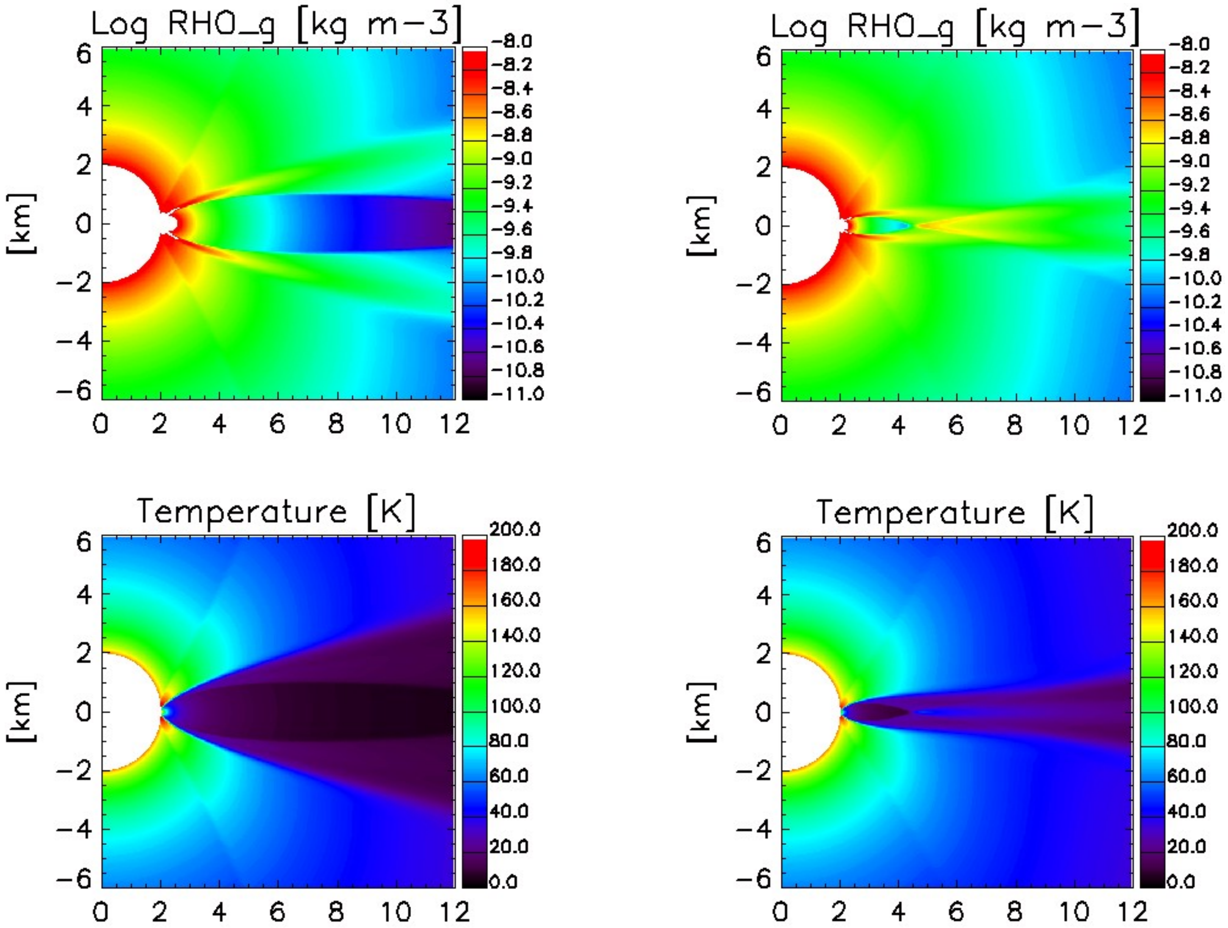
3. Collimated outburst (see next slide):

   Outflow from surface area into the background gas explains data (no need of sinkhole)

Outflow into background gas (fluid approximation)

D=140 m

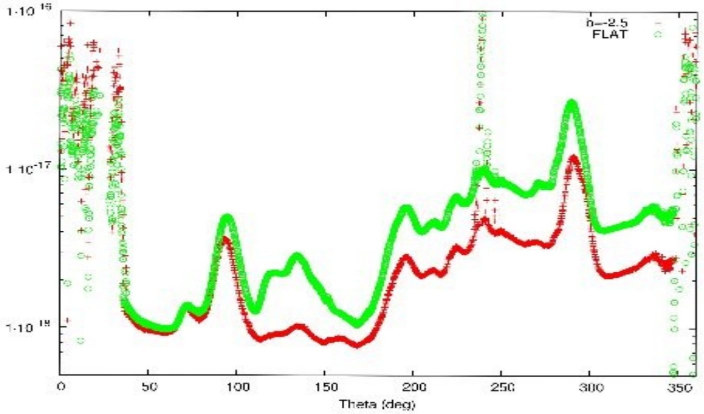
D=70 m

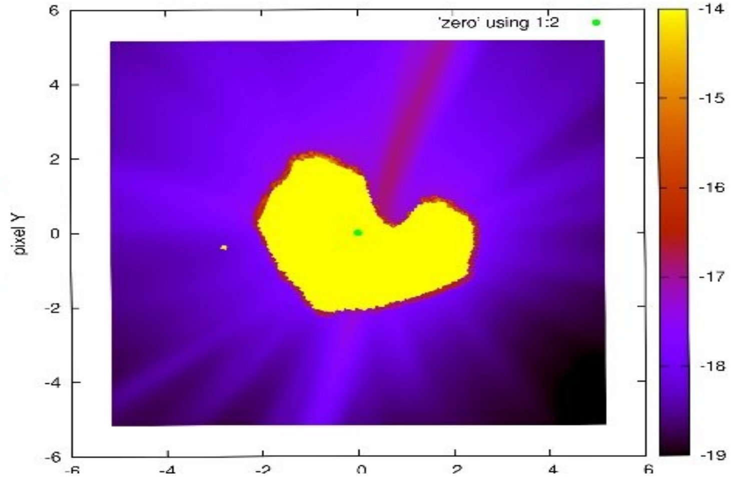


- Gas stream can be effectively collimated by interaction with background pressure (Zjet/Zback=100, Qback= 3 10^27 s-1)

Invited Talks: 5. F. Marzari (OSIRIS-LATMOS)

1. Input: LATMOS coma dust space density
2. Output: synthetic dust coma images
3. Parameters: OSIRIS-SC kernels
4. Assumptions: dust Mie scattering (slide 12!)
   4.1 Organic (interstellar, Jenniskens 1993)
   4.2 Silicates (amorphous and crystalline olivine and piroxene, Bertini et al. 2007)
5. Example of synthetic dust coma image →
6. Comparison with data performed by polar plots (both radial and angular →)
7. The neck jet is clearly dominant in the model (assumed dust radius from 6 to 15 μm, to be expanded to 0.1 mm – 3D+t - at least)

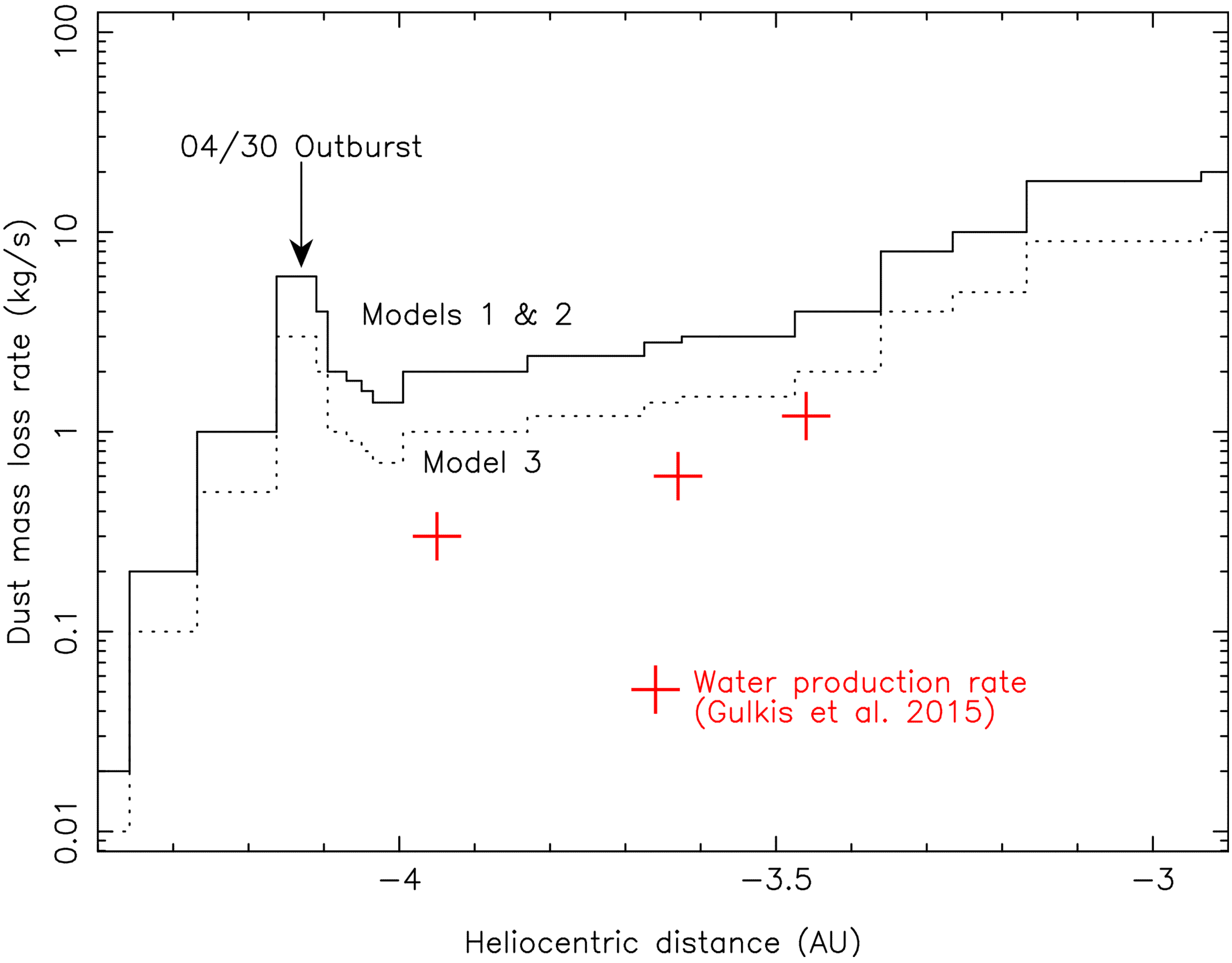




Invited Talks: 6. F. Moreno Danvila (IAA)

1. Fit of VLT and OSIRIS dust coma images taken from April to October 2014
2. Assumptions:
   2.1 Several dust velocity (time & size) functions (size dependent and independent)
   2.2 GIADA size distr. with diff. index = -2 (GIADA) or -3 (Fulle et al. 2010) below the knee
   2.3 Dust loss rate provided by coma photometry best fit (inverse technique, next slide)
3. Significantly better coma fit with index = -3 than -2 below the knee
4. Coma fit less dependent on the assumed ejection velocity
5. The extracted dust loss rate recovers the outburst observed on April 2014 (next slide)

DUST AND WATER LOSS RATES



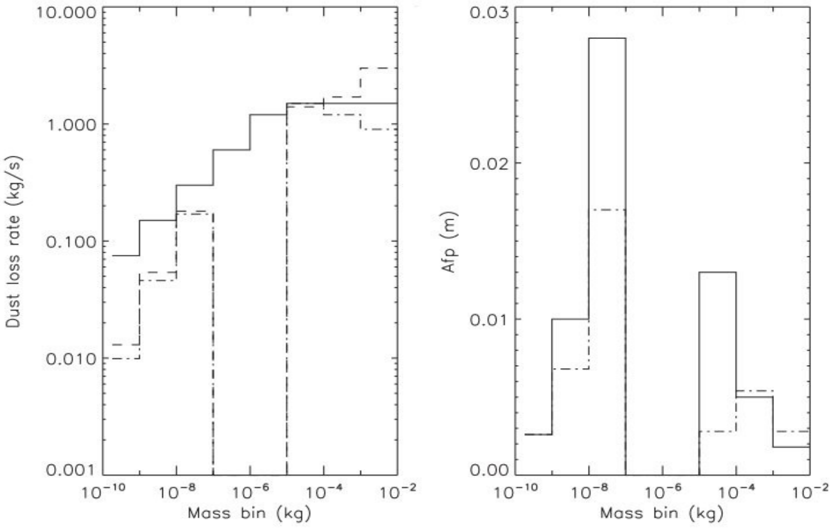
Invited Talks: 7. A. Rotundi (GIADA)

1. Description of the instrument
2. two big dust families so far detected:
   - 2.1 Compact dust (providing by far most mass and also cross section)
   - 2.2 Fluffy dust (high charge/mass, complex dynamics, fragmentation)
3. Strong evolution after perihelion TBC
4. Correlations with other instruments (COSIMA, new: ROSINA-COPS)

Constraints on dust cross section distribution

1. “Knee”-distribution best fitting most data
2. Regarding cross section, the observed knee distribution is well approximated by a DELTA FUNCTION of dust radius r:

During all 2014, 67P size distr. = $\delta(r - r\_knee)$



Coma brightness fit provides the dust/gas ratio

Since r_knee > 0.1mm, dust brightness must follow the geometric optical approximation

Let's fit the dust coma by two single-value size distributions, $\delta(r - r_1)$ and $\delta(r - r_2)$

The coma brightness is $I_1 = k N_1 \pi r_1^2 = I_2 = k N_2 \pi r_2^2$ so that $N_1 / N_2 = r_2^2 / r_1^2$

The dust mass in the coma is $M_1 = N_1 4/3 \pi r_1^3$ and $M_2 = N_2 4/3 \pi r_2^3$ and depends on Q/v

where Q is the dust loss rate and v is the dust velocity (v depends on $r^{-1/2}$)

We obtain $Q_1 / Q_2 = M_1 v_1 / M_2 v_2 = (N_1 r_1^3 / N_2 r_2^3) (r_1 / r_2)^{-1/2} = (r_1 / r_2)^{1/2}$

Changing the single radius r, the dust/gas ratio changes as the square root of r

Bern model gets dust/water ratio = 2 at r = 15 µm, i.e. dust/water ratio = 6 at r = 150 µm (in perfect agreement with GIADA results): but it gets a dust/water 100 times higher

Probable source of error (TBC): Fink's Mie code, not converging at sizes > 10 µm

Action Item 4. All used Mie codes must be verified to converge up to mm-sizes

Summary and Action Items 1

1. Nucleus Model: RMOC Shape 3 (LATMOS & ICES) vs. OSIRIS Shape 4 (ICES & Bern)
2. Thermal feedback on nucleus taken into account by LATMOS only
3. homogeneous vs. non-homogeneous surface, improved coma fit by:

   Alternative gas models, e.g. thermal lag (LATMOS) vs. active areas (ICES & Bern)
4. Water night activity: night/day = 2% (LATMOS & ICES) vs. none (Bern)

   Physical explanations: 4.1 2% is the water loss rate from extended sources (upper limit)

   4.2 2% mimics nucleus thermal lag (extended sources << 2%)
5. **Action Item 1: Plot COPS data fit at hr resolution for all second half August 2014**
6. Available gas coma models at << 1 hr resolution:
   - 6.1 20-21 August 2014 (LATMOS)
   - 6.2 23 August 2014 (ICES)
   - 6.3 5 September 2014 (Bern)

Summary and Action Items 2

7. Maximum ejected dust radius = 3.1 mm (LATMOS) vs. 0.6 mm (ICES): significant ?
   One possible explanation: C_D = 2 (ICES) vs. C_D up to 5 when Mach=1 (LATMOS)
8. Nucleus mesh size seems not a problem to eject largest dust:
   8.1 LATMOS adopts the largest mesh but ejects the largest dust
   8.2 r = 3.1 mm a factor 3 below the observed largest radius = 9 mm (Rotundi et al. 2015)
   8.3 Only neck "upper" gas coma can eject largest dust out of the nucleus gravity field
9. **Action Item 2: Plot "% nucleus surface ejecting to infinity" vs. "max. lifted radius"**
   to recover a significant dust/gas ratio taking into account dust fall-back
10. **Action Item 3: Assume single-value dust size distr.: r = 1 μm, 10 μm, 100 μm**
11. The extracted dust/gas ratio should grow as sqrt(r): **Action Item 4: Test of Mie code**
12. **Action Item 5: fit of the WAC data set of 30-31 August 2014** (by spheres of 1 g/cc)
    Comparison by polar radial and angular plots (avoid image data-model comparisons)