Observatório Nacional
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A STUDY OF THE EFFECTS OF FAINT DUST COMA ON THE SPECTRA OF ASTEROIDS

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OBJECTIVES

GENERAL OBJECTIVES

Study and model the influence of the presence of a faint dust coma over the spectra of asteroids, for possible Active Asteroids (AA) or objects which has been reported some type of cometary activity, even when it is very weak. In this way, we pretend find a different method to the known radial profile for identify AA from photometric surveys.

Detection of Active Asteroids (AA)

(Gilbert&Wiegert, 2010)

Analysis of FWHM and comparison of star and asteroids radial profile.

CFHTLS

Canada-France-Hawaii Telescope Legacy Survey

(Waszczak. et al, 2013)

Use of statistical methods to determine the orbital similarity and the extended radial profile of AA with the cometary nucleus.

The Palomar Transient Factory

(Hsieh, 2015)

Comparison the objects radial profiles with the stars radial profiles.

Pan-STARRS

(Cikota, 2014)

Comparison of object magnitude with the expected magnitude.

The International Astronomical Union Minor Planet Center

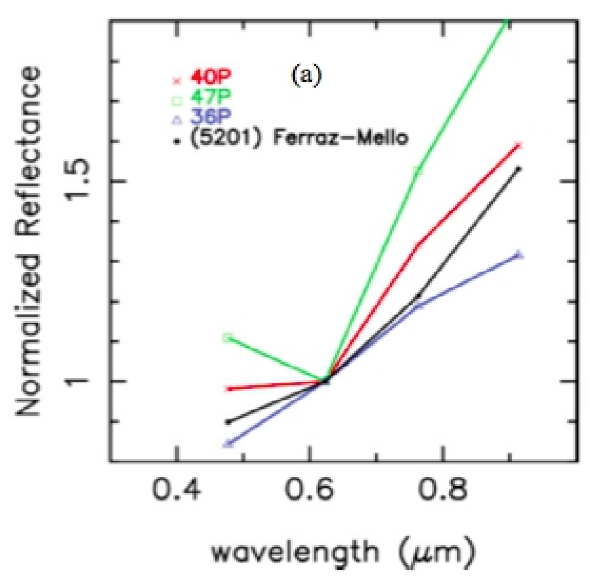
(Hsieh, 2009)

Comparison of radial profiles

Hawaii Trail Project

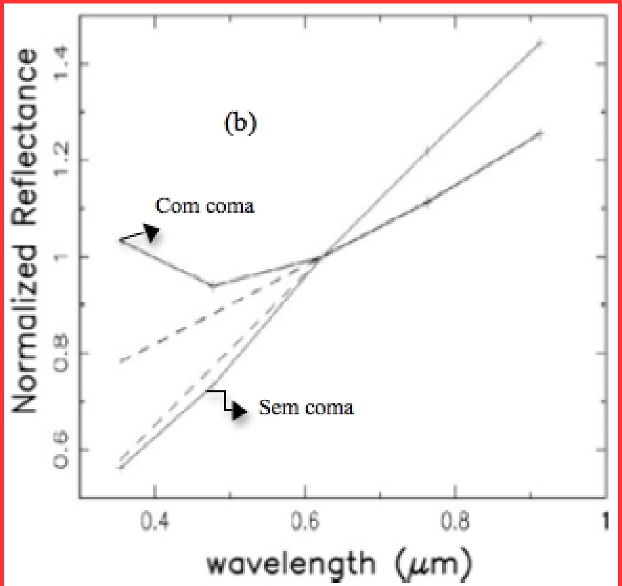
176P/Linear

(Carvano et al, 2008)



- Homogeneous spherical cloud.
- Spherical particle of the same size.
- Volumetric density of the cloud falling as the inverse of the square distance.

(Carvano & Lorenz, 2010)



THE MODEL

The equation that governs the movement of particles is given by:

$$\frac{d^2\vec{r}_S}{dt^2} = -GM_a\frac{\vec{r}_a}{r_a^3} - \mu GM_S\frac{\vec{r}_S}{r_S^3} \quad (1)$$

$$\mu = 1 - \beta \quad (2)$$

$$\beta = \frac{F_{rad}}{F_{grav}} \Rightarrow \beta = \frac{C_{pr}Q_{pr}}{2\rho_d r_d}; C_{pr} = \frac{3Q_{pr}E_S}{8\pi c G M_\Theta} \quad (3)$$

$$F_{grav} = \frac{GM_\Theta}{r^2}\left(\frac{\rho_d \pi d^3}{6}\right)$$

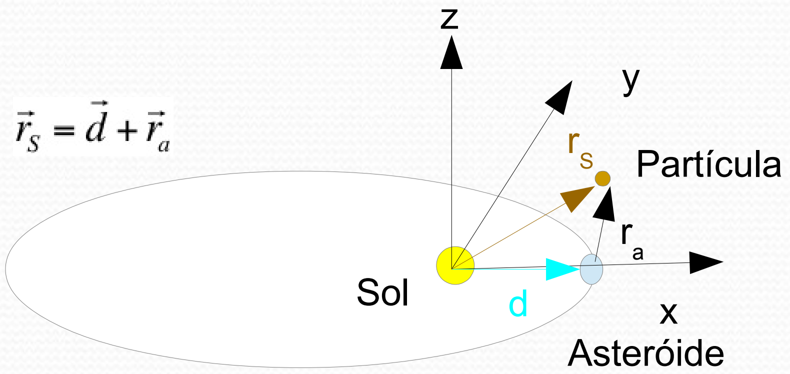
$$F_{rad} = \frac{Q_{pr}}{c}\left(\frac{E_S}{4\pi r^2}\right)\frac{\pi d^2}{4}$$

Where G is the gravitational constant, M_a is the mass of the asteroid, M_s is the mass of the Sun, r_s is the particle position with respect to the Sun and r_a is the particle position with respect to the asteroid, t is the time at which the particles ejections occurs, β is the relation between the solar gravitational force and the radiation pressure force, E_s is the average solar radiation $3.93\text{x}10^{26}$W, c is the light velocity, Q_{pr} is the average radiation pressure efficiency, also know as the radiation pressure coefficient ~ 1, ρ_d=1000 Kg/m^3 y r_d>0.25μm.

The differential equation is resolve using the 4th order Runge-Kutta method and the position of the asteroid is calculated by Keplerian dynamic, since we know the orbital elements.

$$\frac{d^2\vec{r}_S}{dt^2} = -GM_a\frac{\vec{r}_a}{r_a^3} - \mu GM_S\frac{\vec{r}_S}{r_S^3} = f(\vec{r},\vec{v},t)$$

$$\vec{r}_S = \vec{d} + \vec{r}_a$$



$$\frac{d^2\vec{r}_S}{dt^2} = -GM_a\frac{\vec{r}_S}{r_a^3} + GM_a\frac{\vec{d}}{r_a^3} - \mu GM_S\frac{\vec{r}_S}{r_S^3} = f(\vec{r},\vec{v},t)$$

$$r_o = r(t_o) \qquad v_o = v(t_o)$$

$$l_1 = hf(r_i, v_i, t_i) \qquad k_1 = hv_i$$

$$l_2 = hf(r_i + \frac{k_1}{2}, v_i + \frac{l_1}{2}, t_i + \frac{h}{2}) \qquad k_2 = h(v_i + \frac{l_2}{2})$$

$$l_3 = hf(r_i + \frac{k_2}{2}, v_i + \frac{l_2}{2}, t_i + \frac{h}{2}) \qquad k_3 = h(v_i + \frac{l_2}{2})$$

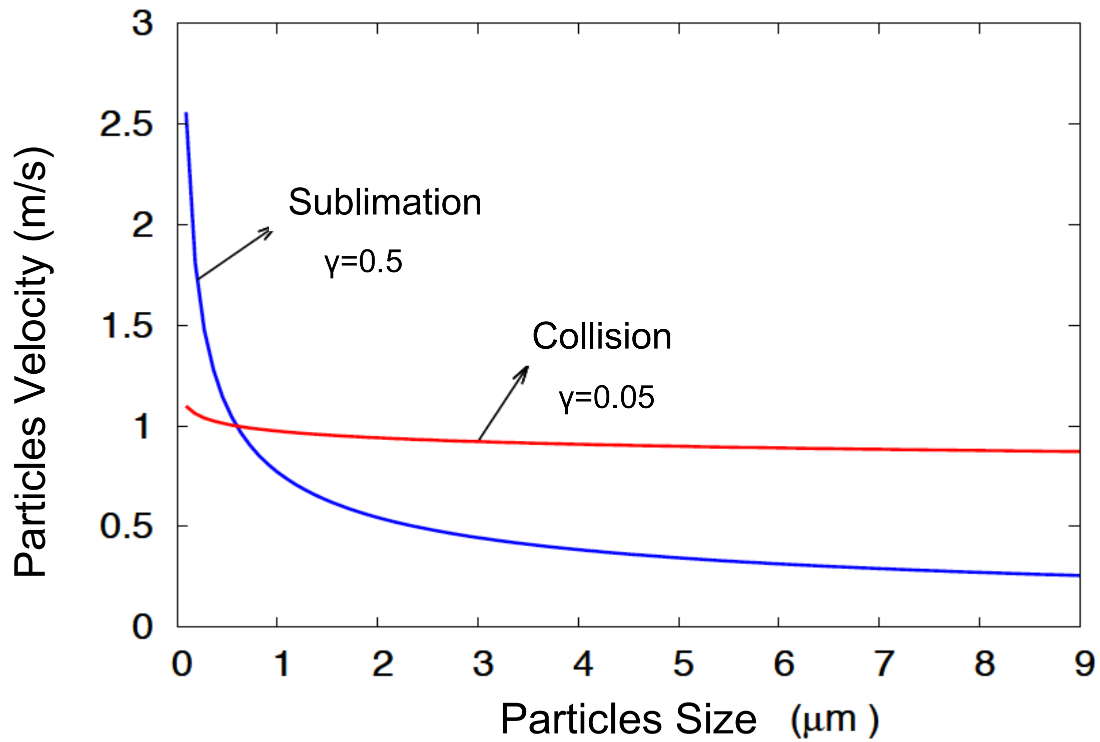
$$l_4 = hf(r_i + k_3, v_i + k_3, t_i + h) \qquad k_4 = h(v_i + l_3)$$

$$v_{i+1} = v_i + \frac{1}{6}(l_1 + 2l_2 + 2l_3 + l_4) \qquad r_{i+1} = r_i + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)$$

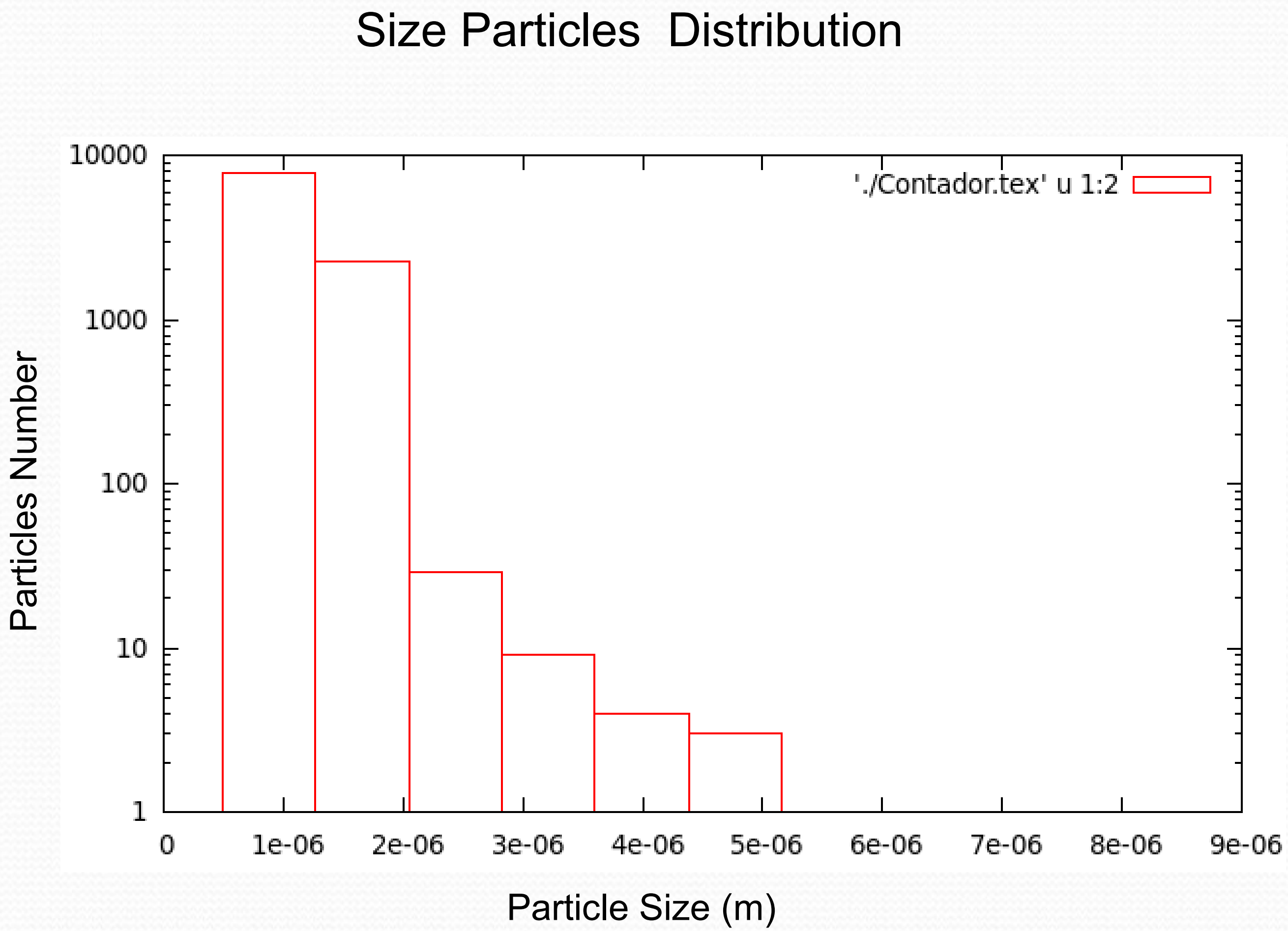
$$v_o = k\beta^\gamma = k\left(\frac{F_{rad}}{F_{grav}}\right)^\gamma \Rightarrow v_o = k\left(\frac{C_{pr}\,Q_{pr}}{2\,\rho_d\,r_d}\right)^\gamma \Rightarrow v_o = \left(\frac{k_1}{r_d}\right)^\gamma$$

(Moreno, 2011)

Where k must be determined and subject to the condition $v \geq v_{esc}$



Dust Distribution over an Asteroid



Polynomial particles size distribution (r^{-3}) ejected from the asteroid with a total of 1000 particles between 0.1μm until 10μm, with seed=123.

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PARAMETERS USED IN THE MODEL (596 Scheila)

Symbols	Parameters	Value
P_{Orb}	*Orbital Period*	$1828.75(d)^*$
e	*Orbital Eccentricity*	0.16485^*
a	*Semi Major Axis*	$2.92665(AU)^*$
R	*Radius*	$56.67(Km)^\dagger$
P_{Rot}	*Rotational Period*	$15.877(d)^\dagger$
ρ	*Density*	$1500(Kg/m^3)^\dagger$
v	*Ejection Velocity Parameter*	$90(m/s)^\dagger$
ψ	*Cosine Asymmetry Factor*	$0.1^\ddagger$
η	*Volumetric Fraction of Tholin*	$0.05^\ddagger$
d_c	*Particles Diameter on Asteroid*	$0.2\mu m^\ddagger$
d_a	*Particle Diameter in Coma*	$0.2\mu m^\ddagger$

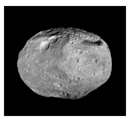
* *http://ssd.jpl.nasa.gov/*

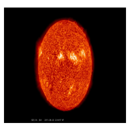
† Moreno et al. (2011b)

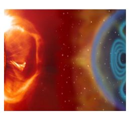
‡ Carvano & Lorenz-Martins (2009)

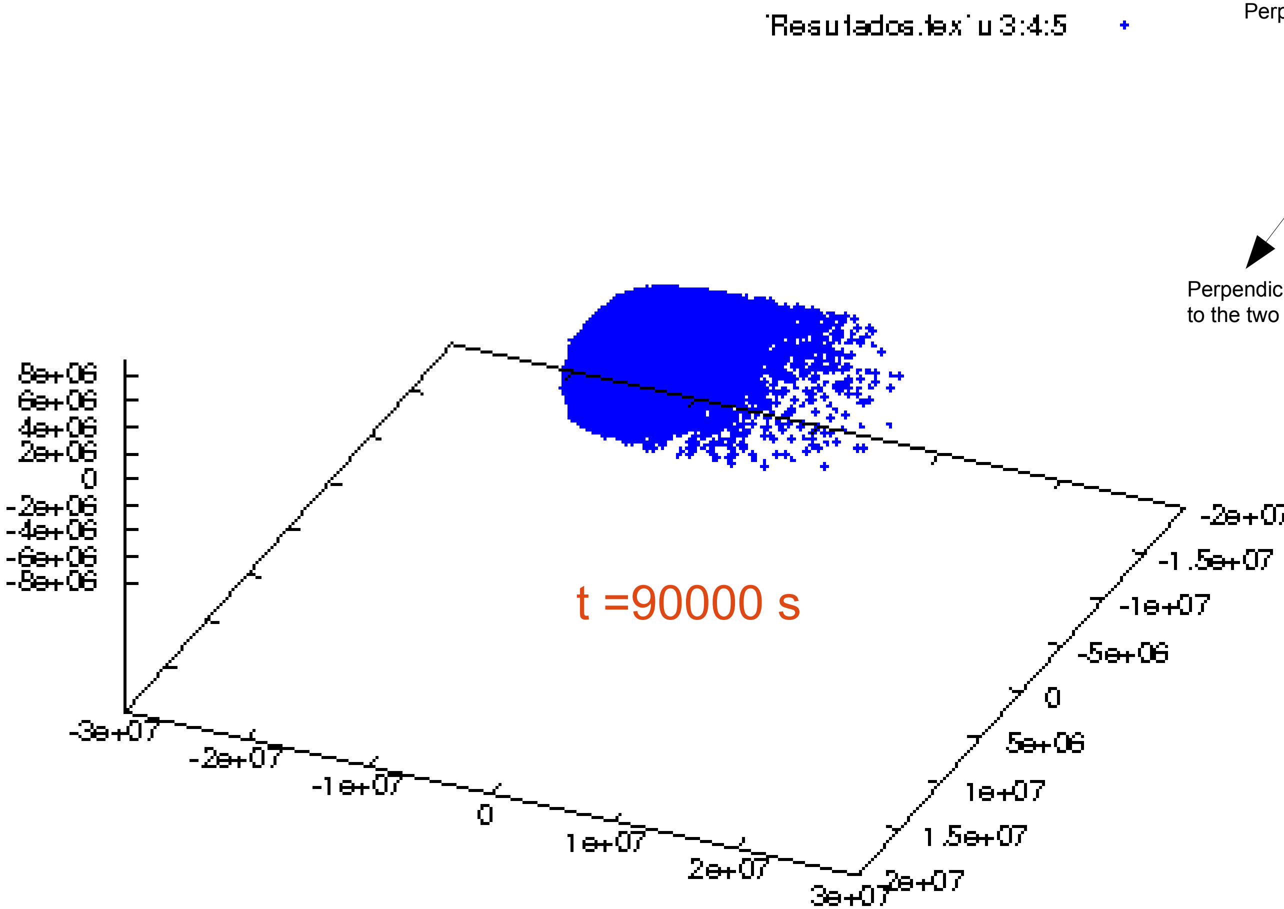
t =90000 s

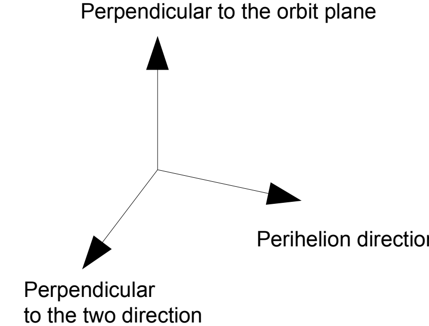
$\gamma = 0.05$







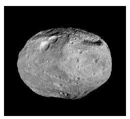


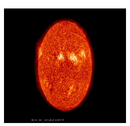


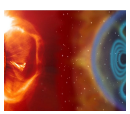
Position of 10000 particles subject to the asteroid and sun gravitational field as well as the sun radiation pressure. Considering θ=0, φ =0, h=10 m, step = 0.8 s , ρ = 1000 Kg/m3 y t = 90000 s.
View (139, 336), xrange (-30000000, 30000000), yrange (-20000000,20000000), zrange (-9000000, 9000000).

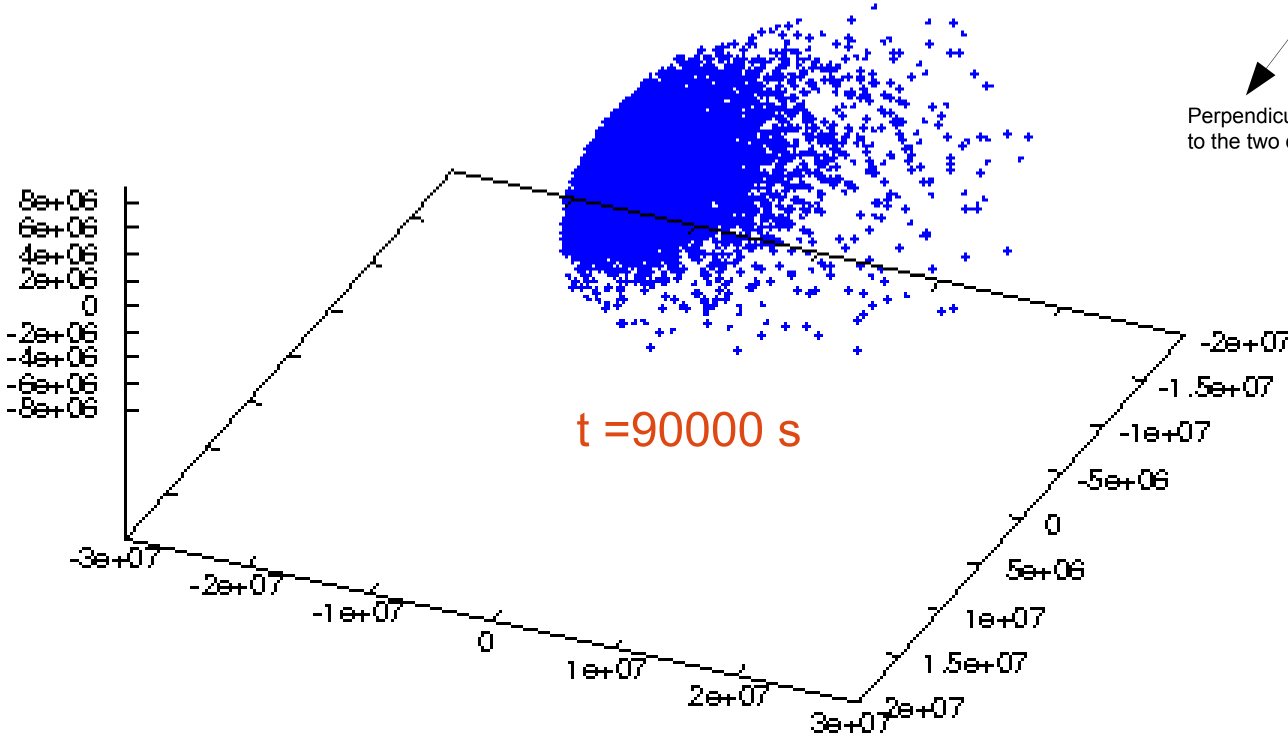
t =90000 s

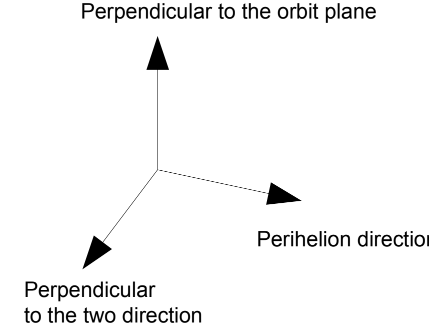
$\gamma = 0.5$











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View (139, 336), xrange (-30000000, 30000000), yrange (-20000000,20000000), zrange (-9000000, 9000000).

Influence of the Dust Distribution in the Spectra

For calculate the influence of the coma in the asteroids spectra we assume that the observed spectrum is the sum of two components: The first component is related with the light, reflected by the asteroid surface and the second component related with the light reflected by the coma.

$$S_T = S_{ast} + S_{cloud}$$

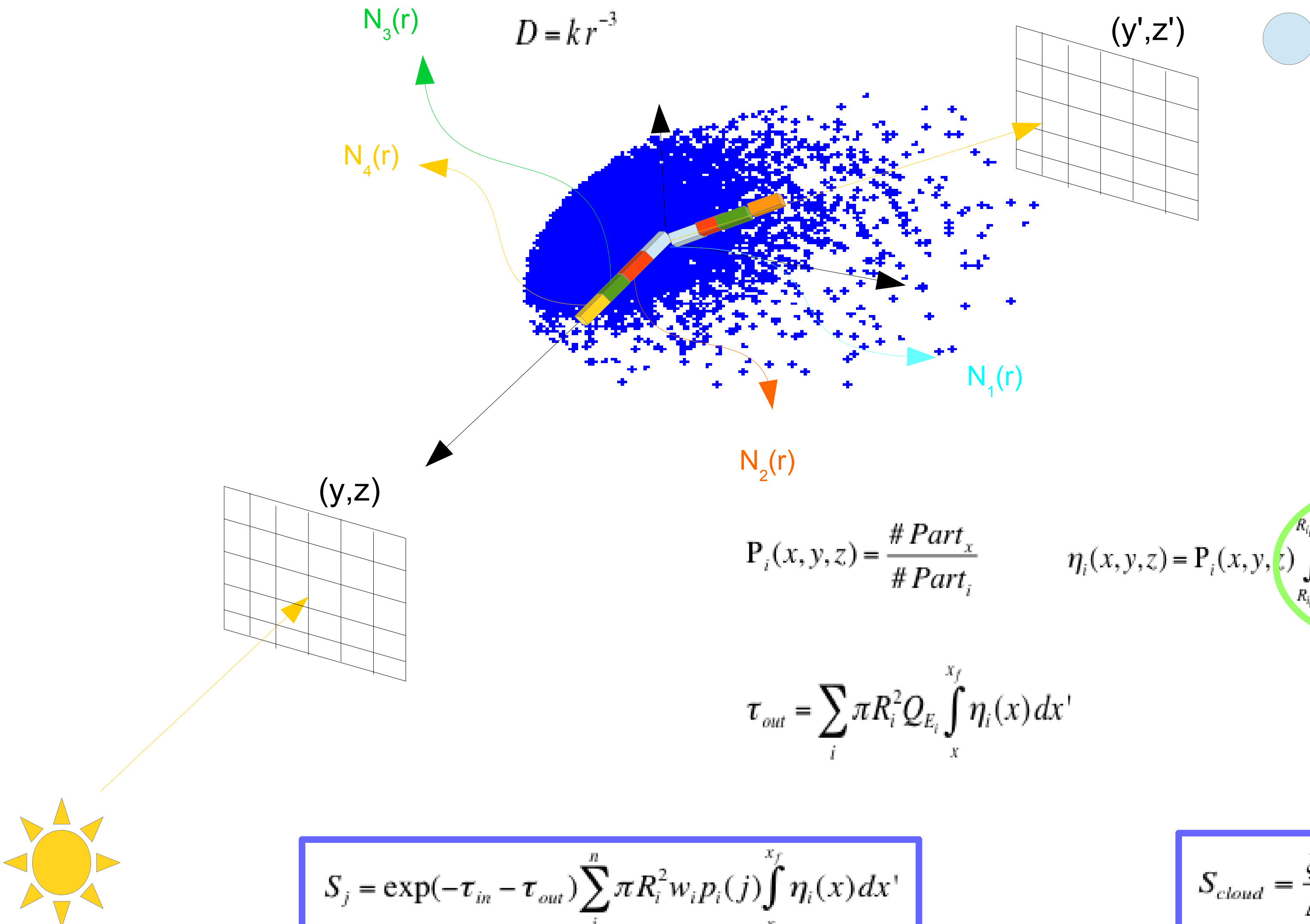
The first component is calculated by Hapke model, without take account the opposition effects and the superficial macroscopic roughness.

$$R_{sph_\lambda} = \frac{w_\lambda}{4\pi}\left(\frac{\mu_o}{\mu_o + \mu_e}\right)[p(\theta) + H(\mu_o)H(\mu_e) - 1]d\Omega$$

$$S_{ast} = \frac{R_b^2}{\Delta^2}\exp(-\tau_{in} - \tau_{out})\sum_f R_{sphf}$$

Where: w_λ is the single scattering albedo, $p(\theta)$ is the volumetric phase function, μ_o is the cosine of the incident angle, μ_e is the cosine of the emergence angle and H is the Chandrasekar function.

The scattering by coma is calulated using a Monte-Carlo code. Where the light beam leave from the Sun to coma, with a direction parallel to the X-axis, through a net that cover the whole coma.



$$P_i(x,y,z) = \frac{\#Part_x}{\#Part_i}$$

$$\eta_i(x,y,z) = P_i(x,y,z) \int_{R_{i_{min}}}^{R_{i_{max}}} N_p(R_p)\, dR_p$$

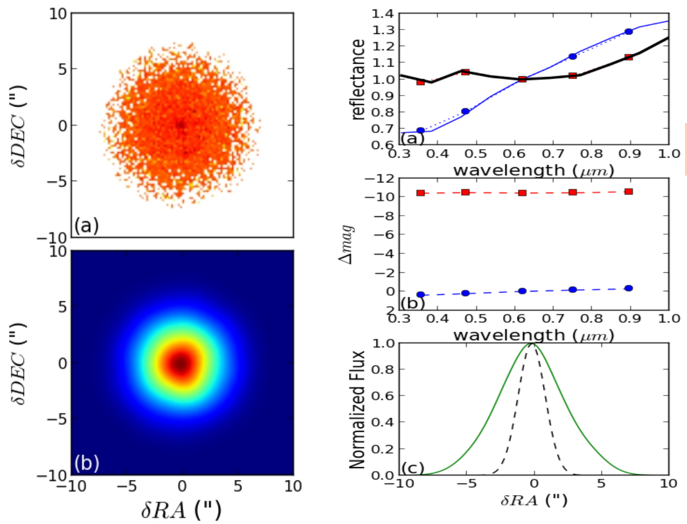
$$\tau_{out} = \sum_i \pi R_i^2 Q_{E_i} \int_x^{x_f} \eta_i(x)\, dx'$$

$$S_j = \exp(-\tau_{in} - \tau_{out}) \sum_i^n \pi R_i^2 w_i p_i(j) \int_{x_j}^{x_f} \eta_i(x)\, dx'$$

$$S_{cloud} = \frac{\xi^2}{\Delta^2} \frac{1}{M} \sum_i^M S_j$$

Modeling the image profile and spectrum

Results for different mass values



$\gamma = 0.5$

$v = 80\, m/s$

$g = 0^o$

$D = 1\, dia$

$M = 10^9\, Kg$

D - Chiron

$\gamma = 0.5$

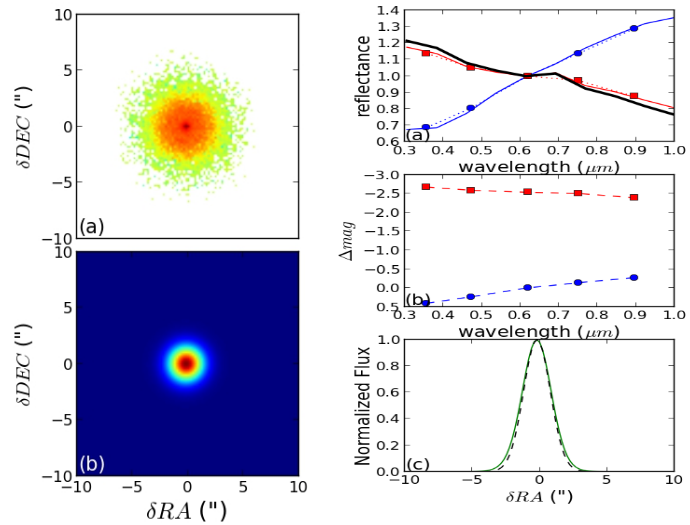
$v = 80\, m/s$

$g = 0^o$

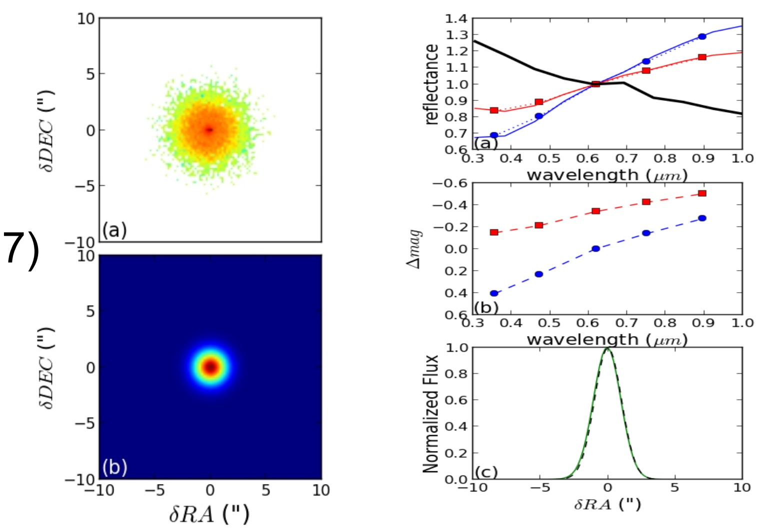
$D = 1\, dia$

$M = 10^6\, Kg$

D - B



(Rondon-Briceño et al. 2017)



$\gamma = 0.5$

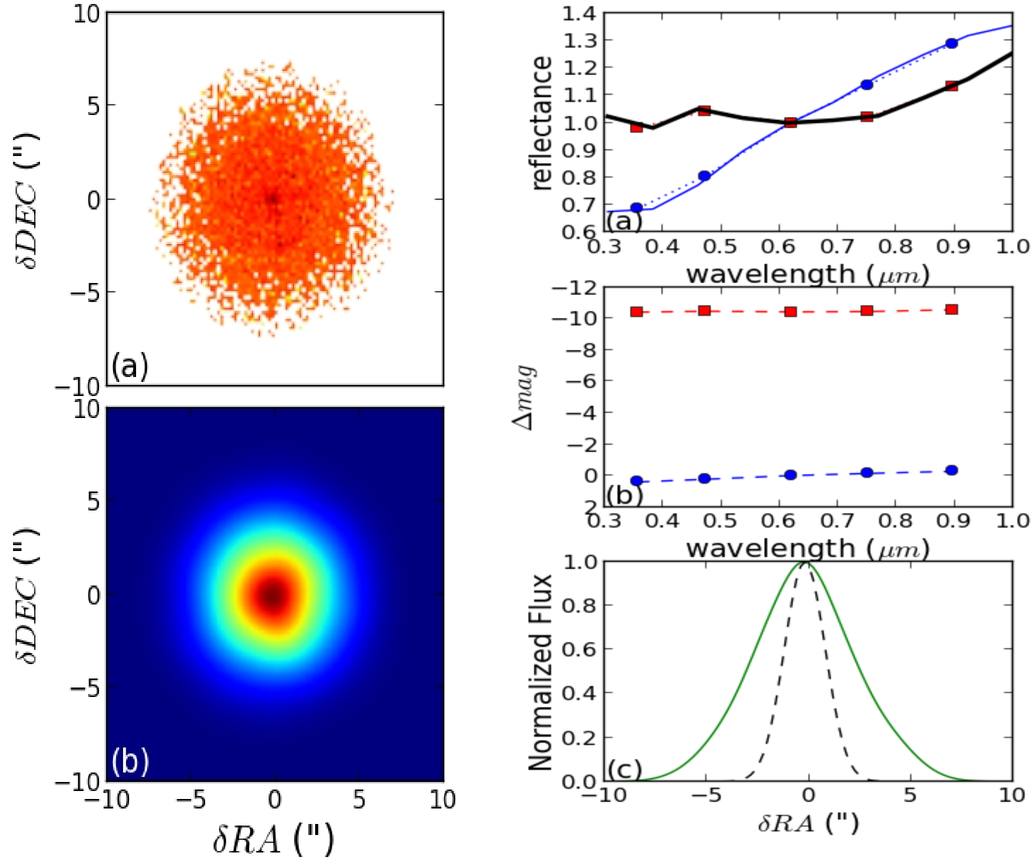
$v = 80\, m/s$

$g = 0^o$

$D = 1\, dia$

$M = 1.63x10^5\, Kg$

[Rondon-Briceño et al. 2017, MNRAS, 468]



$\gamma = 0.5$

$v = 80\, m/s$

$g = 0^o$

$D = 1\, dia$

$M = 10^9\, Kg$

D - Chiron

[Rondon-Briceño et al. 2017, MNRAS, 468]

$\gamma = 0.5$

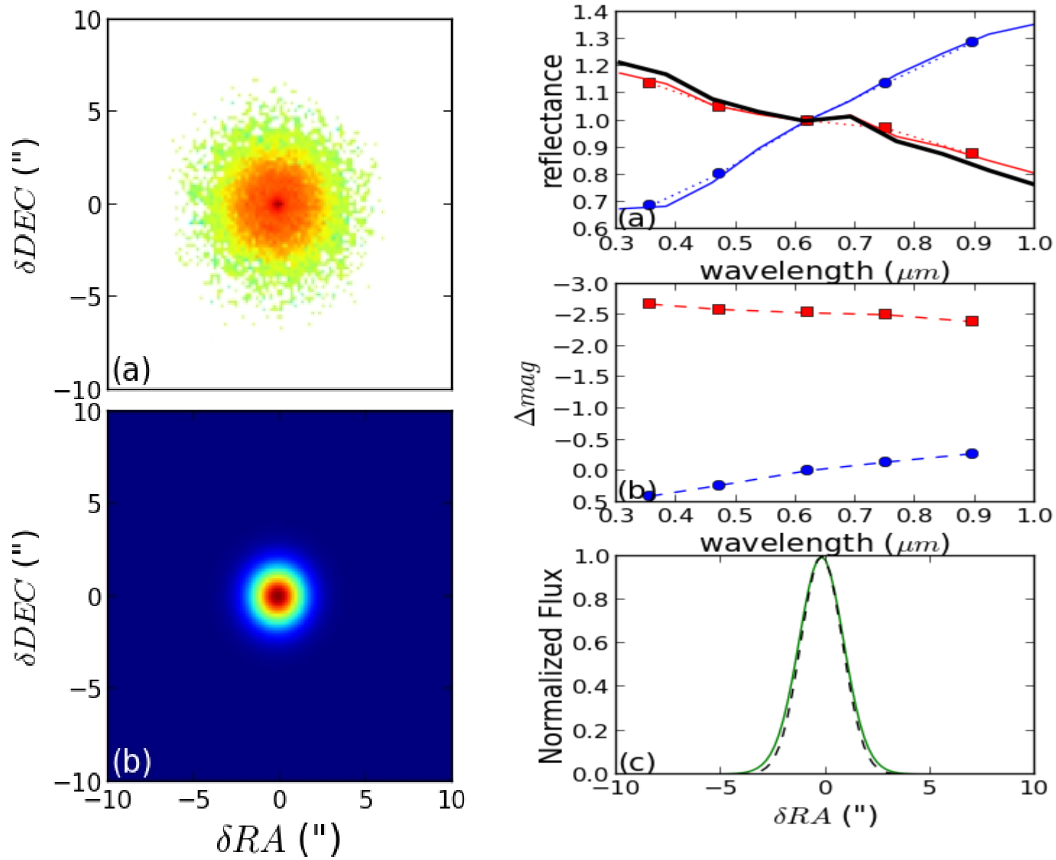
$v = 80\,m/s$

$g = 0^{o}$

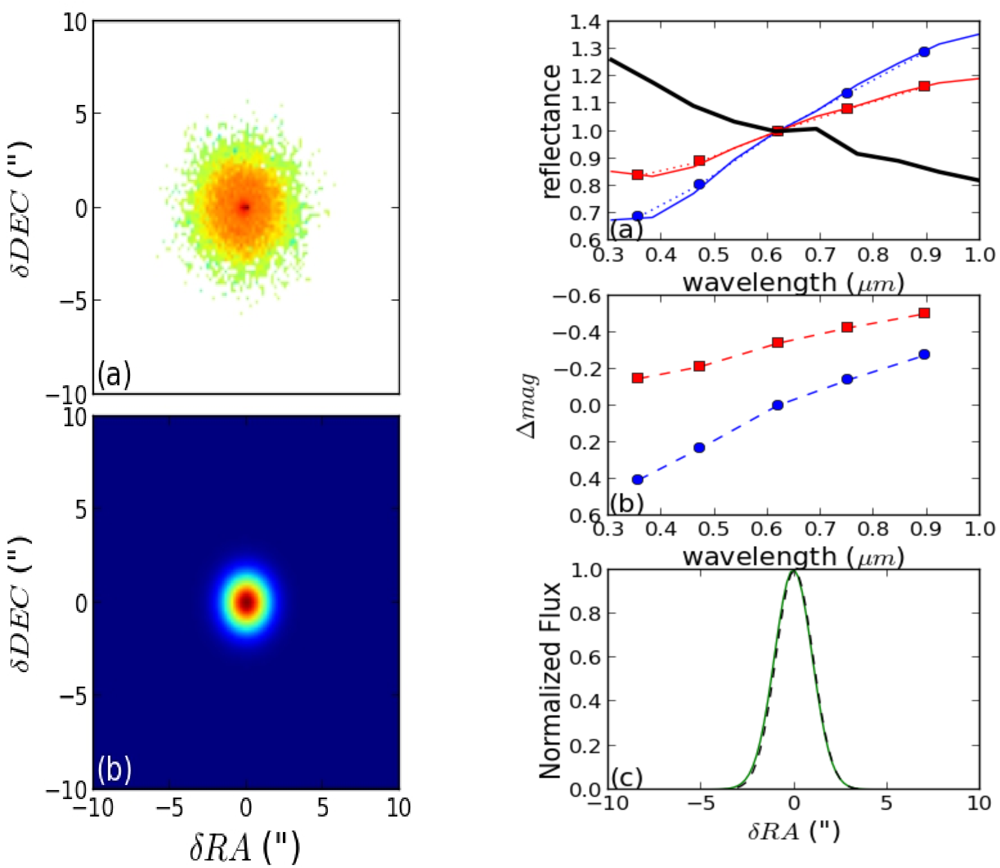
$D = 1\,dia$

$M = 10^{6}\,Kg$

D - B



[Rondon-Briceño et al. 2017, MNRAS, 468]



$\gamma = 0.5$

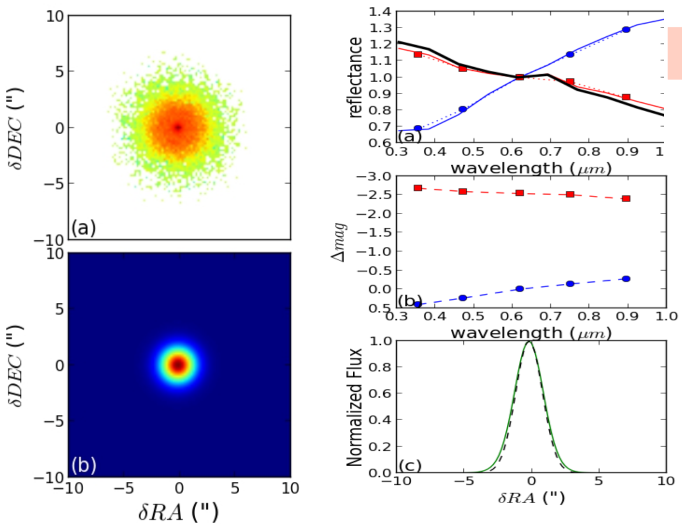
$v = 80\,m/s$

$g = 0^o$

$D = 1\,dia$

$M = 1.63x10^5\ Kg$

Results for different phase angle values



$\gamma = 0.5$

$v = 80\, m/s$

$g = 0^{o}$

$D = 1\, dia$

$M = 10^{6}\, Kg$

D - B

$\gamma = 0.5$

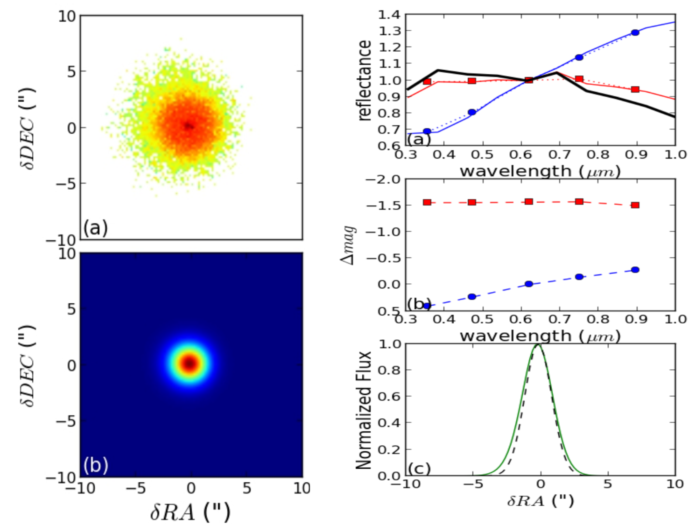
$v = 80\, m/s$

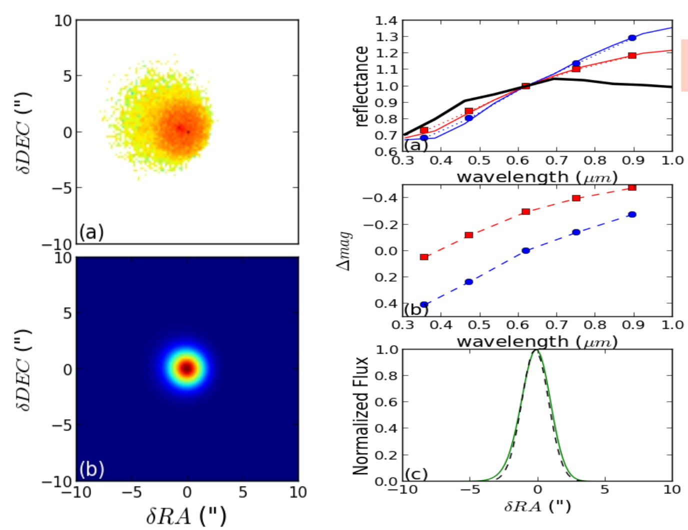
$g = 6^{o}$

$D = 1\, dia$

$M = 10^{6}\, Kg$

D - B





$\gamma = 0.5$

$v = 80\, m/s$

$g = 17^{o}$

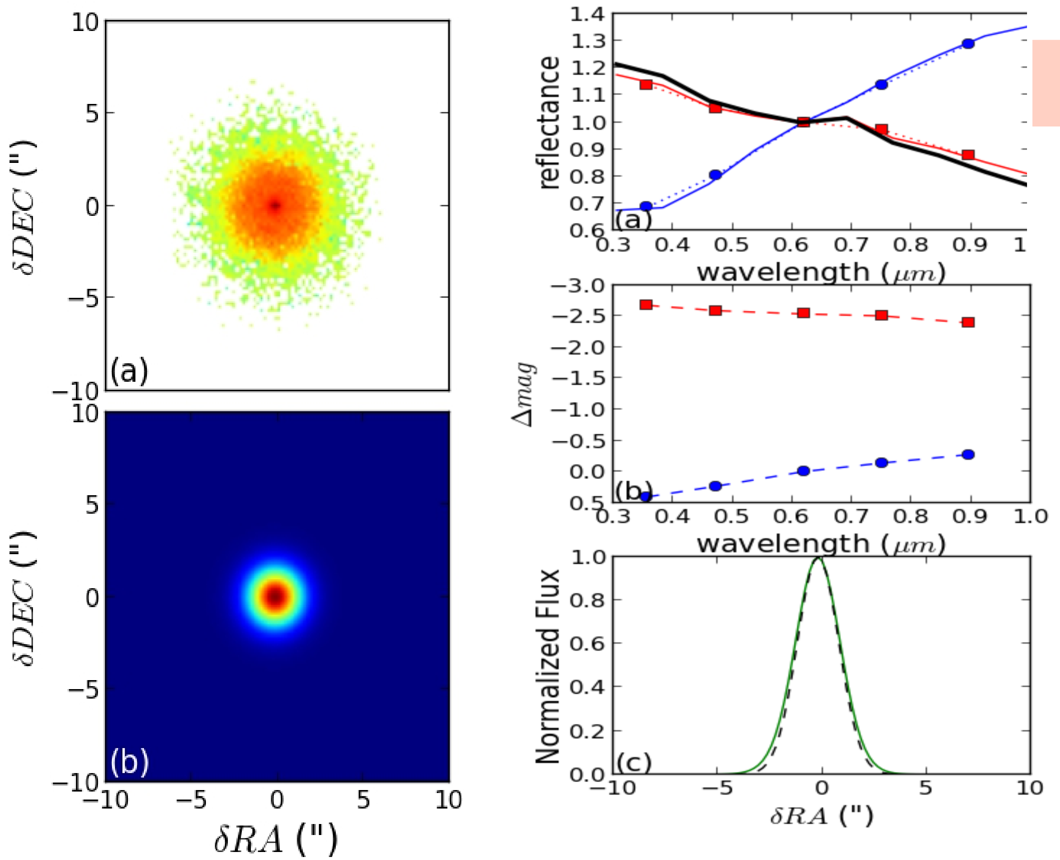
$D = 1\, dia$

$M = 10^{6}\, Kg$

D - S

(Rondon-Briceño et al. 2017)

[Rondon-Briceño et al. 2017, MNRAS, 468]



$\gamma = 0.5$

$v = 80\, m/s$

$g = 0^{o}$

$D = 1\, dia$

$M = 10^{6}\, Kg$

D - B

[Rondon-Briceño et al. 2017, MNRAS, 468]

$\gamma = 0.5$

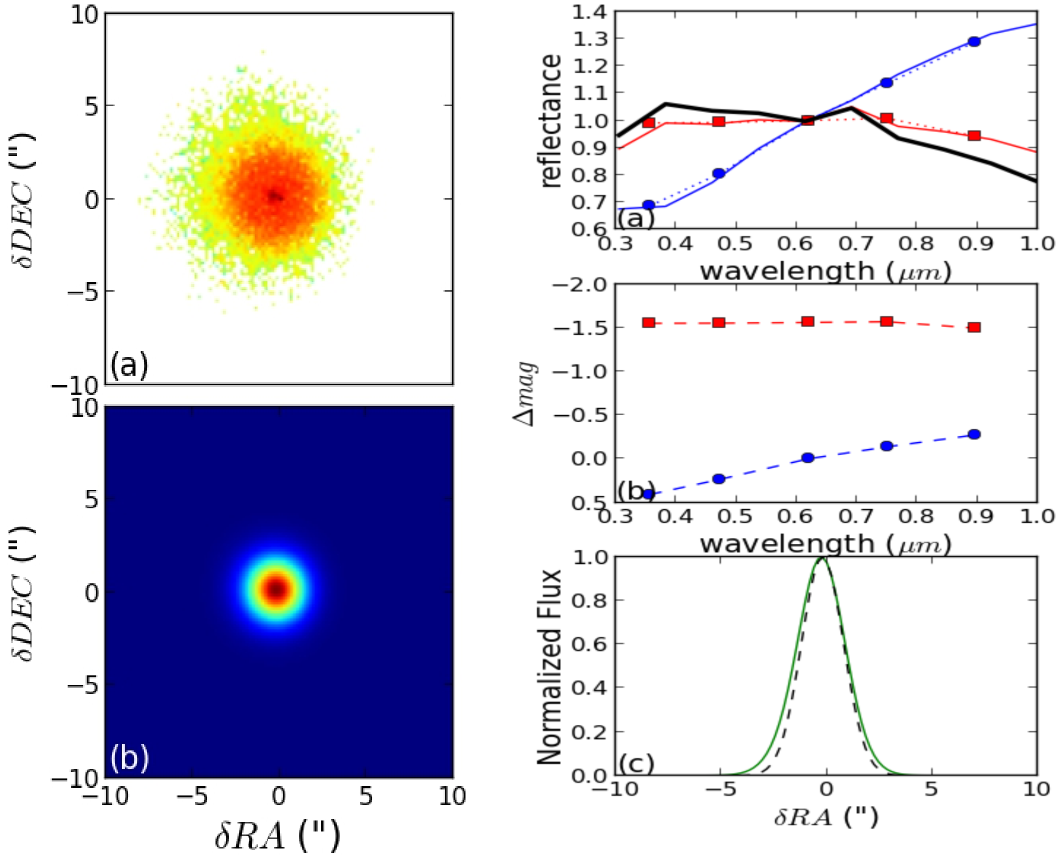
$v = 80\,m/s$

$g = 6^{o}$

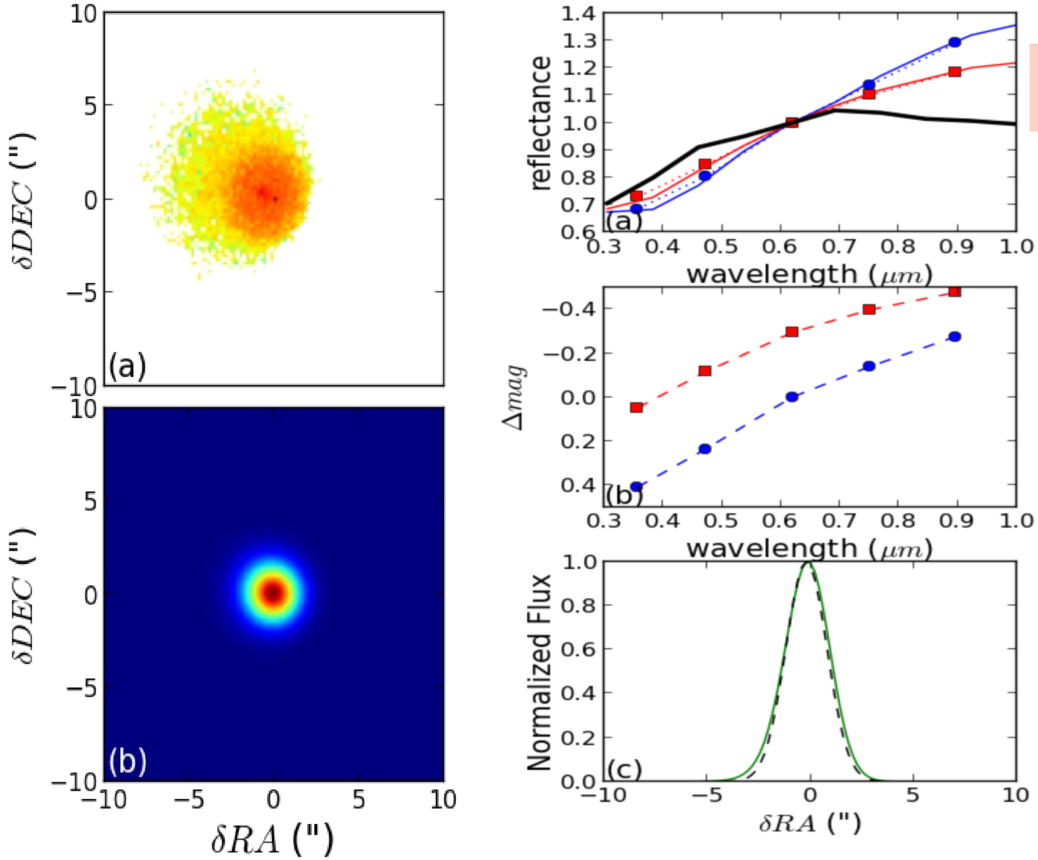
$D = 1\,dia$

$M = 10^{6}\,Kg$

D - B



[Rondon-Briceño et al. 2017, MNRAS, 468]



$\gamma = 0.5$

$v = 80\, m/s$

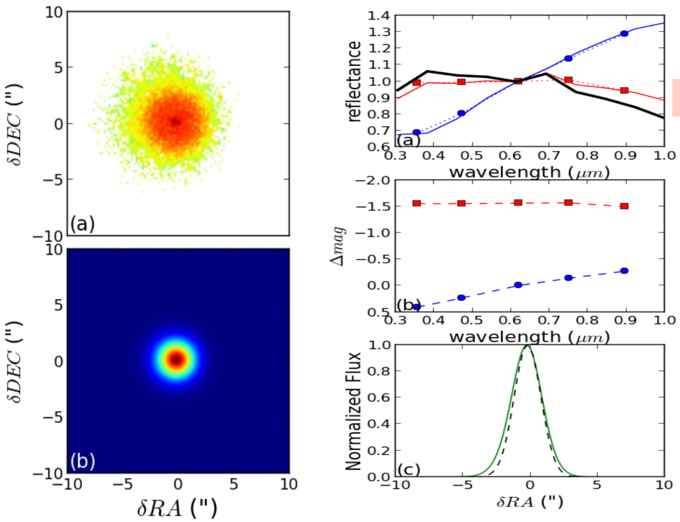
$g = 17^o$

$D = 1\, dia$

$M = 10^6\, Kg$

D - S

Results for the evolution in time

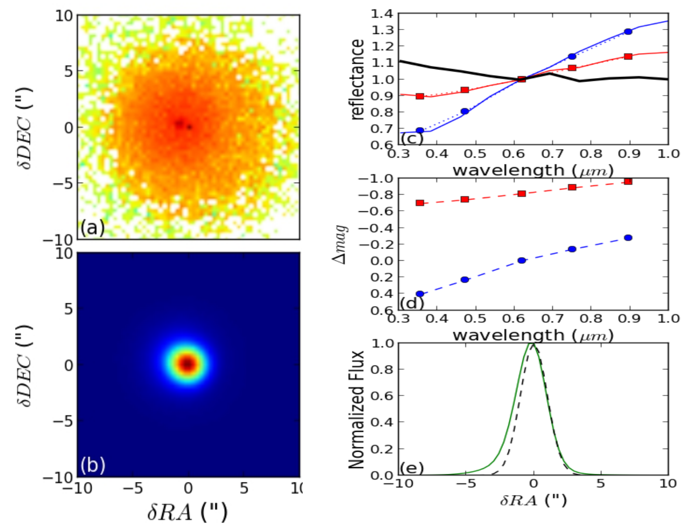


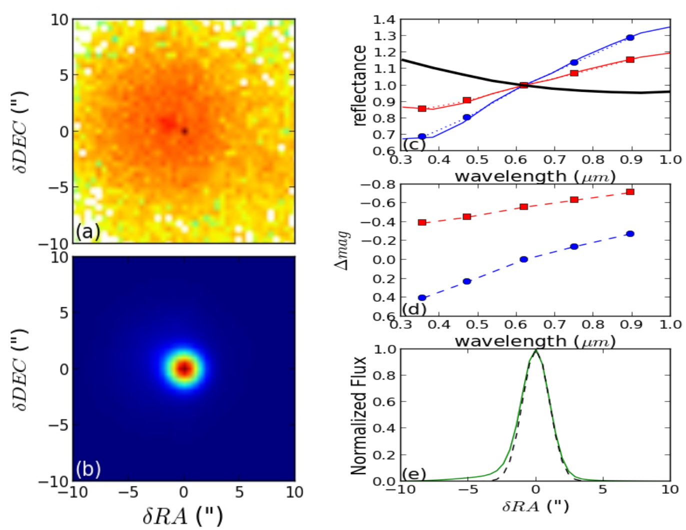
$\gamma = 0.5$
$v = 80\, m/s$
$g = 6^o$
$D = 1\, dia$
$M = 10^6\, Kg$

D - B

$\gamma = 0.5$
$v = 80\, m/s$
$g = 6^o$
$D = 3\, dia$
$M = 10^6\, K$

D - X=EM



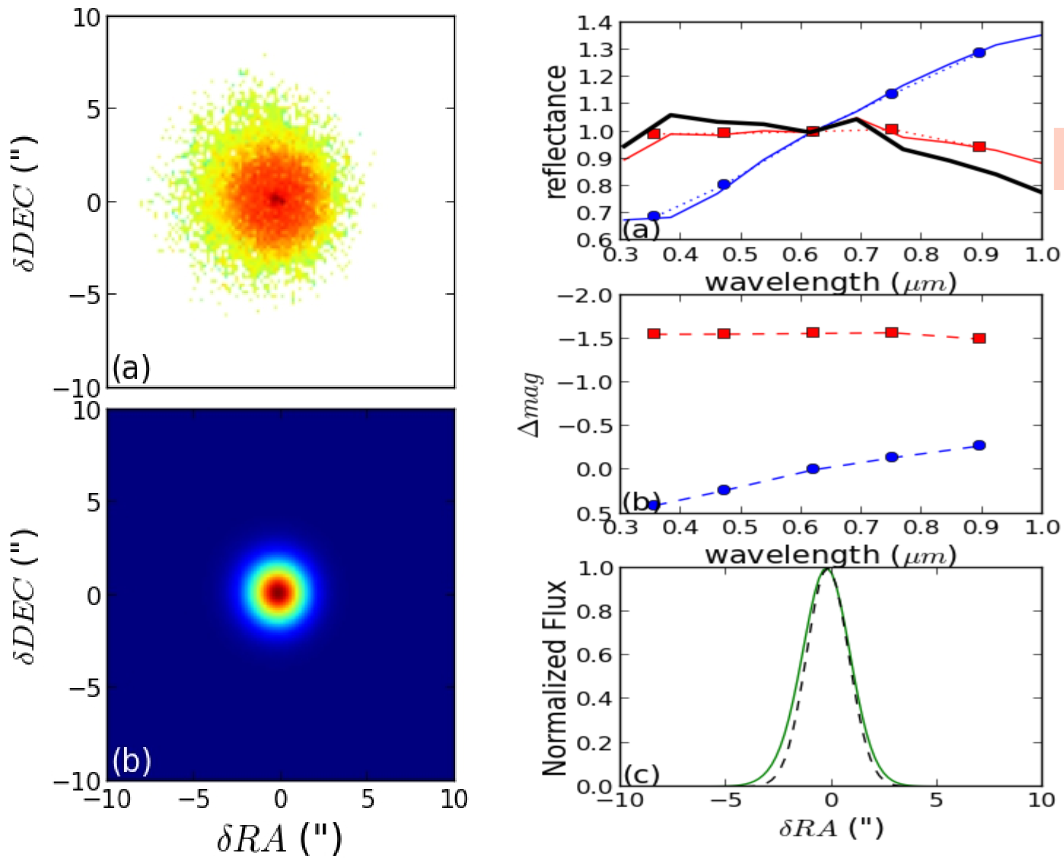


$\gamma = 0.5$
$v = 80\, m/s$
$g = 6^o$
$D = 7\, dia$
$M = 10^6\, Kg$

D - X=EMP

(Rondon-Briceño et al. 2017)

[Rondon-Briceño et al. 2017, MNRAS, 468]



$\gamma = 0.5$

$v = 80\,m/s$

$g = 6^{o}$

$D = 1\,dia$

$M = 10^{6}\,Kg$

D - B

[Rondon-Briceño et al. 2017, MNRAS, 468]

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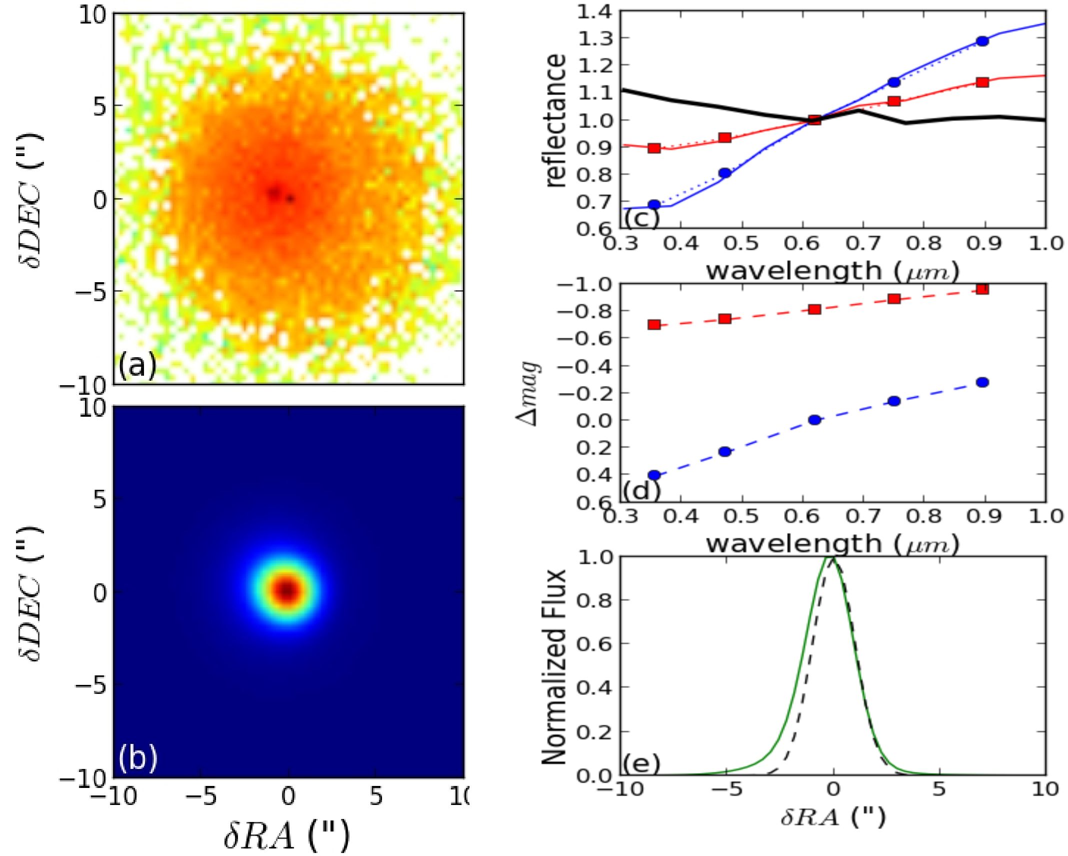
$v = 80\, m/s$

$g = 6^{o}$

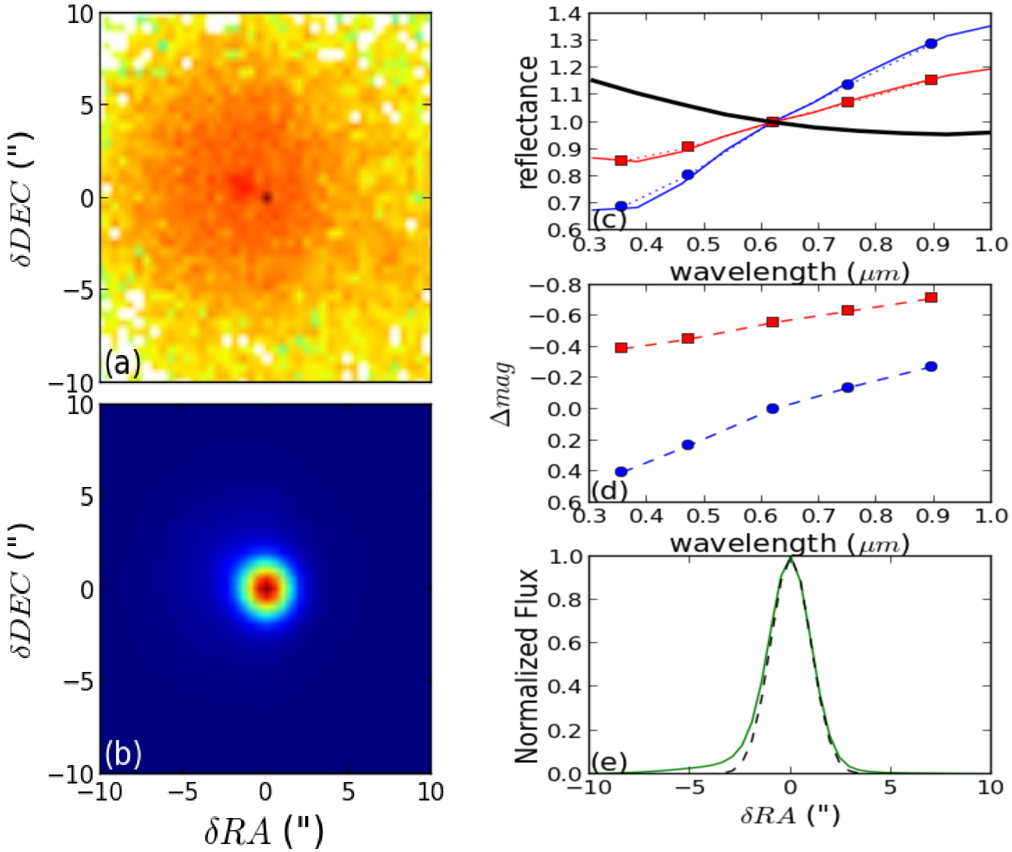
$D = 3\; dia$

$M = 10^{6}\; Kg$

D - X=EMP



[Rondon-Briceño et al. 2017, MNRAS, 468]



$\gamma = 0.5$

$v = 80\,m/s$

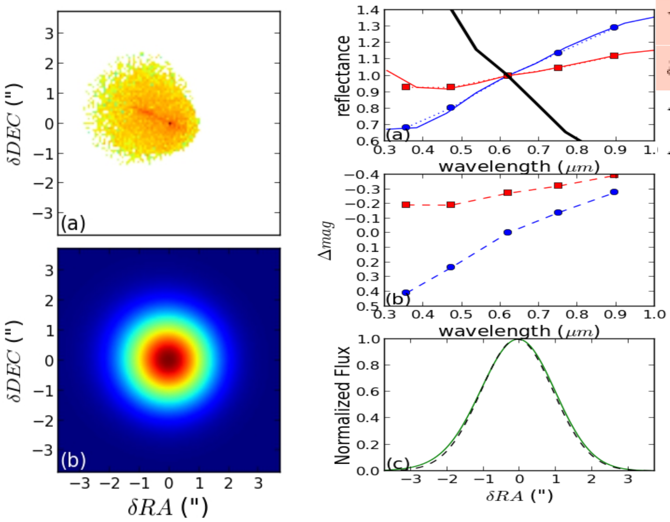
$g = 6^{o}$

$D = 7\ dia$

$M = 10^{6}\ Kg$

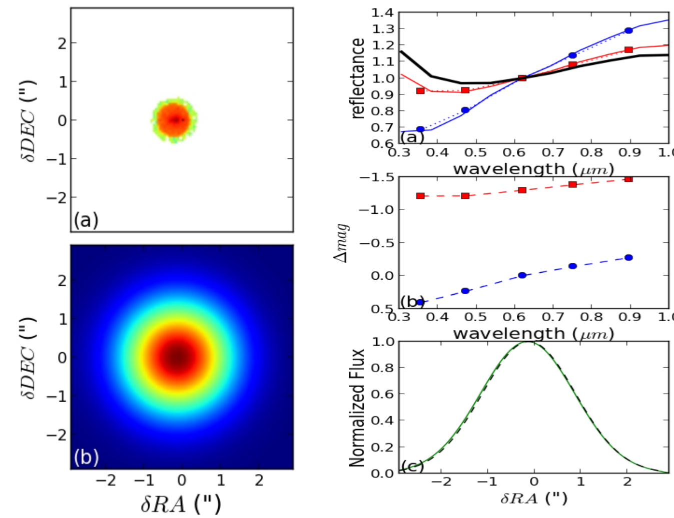
D - X=EMP

Resultados para diferentes velocidades de eyección



$\gamma = 0.5$
$v = 25 m/s$
$g = 17^o$
$D = 1\ dia$
$M = 0.5x10^5\ Kg$

$\gamma = 0.05$
$v = 22 m/s$
$g = 0^o$
$D = 1\ dia$
$M = 10^5\ Kg$



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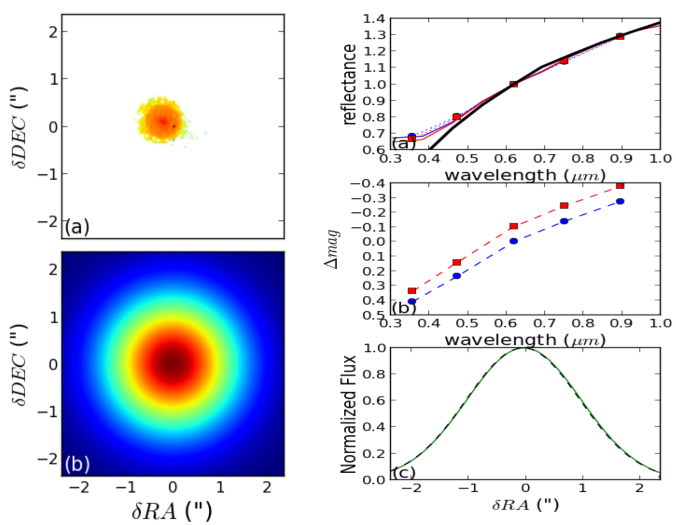
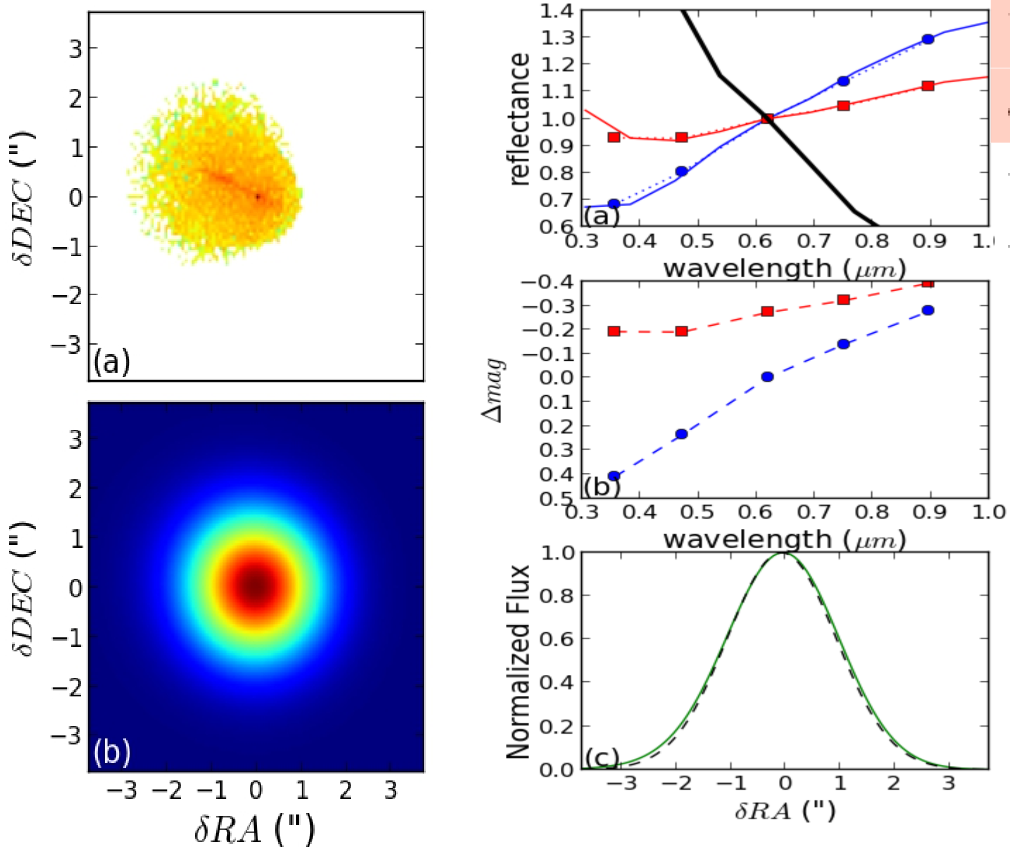
$v = 22 m/s$
$g = 17^o$
$D = 1\ dia$
$M = 10^5\ Kg$



(Rondon-Briceño et al. 2017)

[Rondon-Briceño et al. 2017, MNRAS, 468]



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[Rondon-Briceño et al. 2017, MNRAS, 468]

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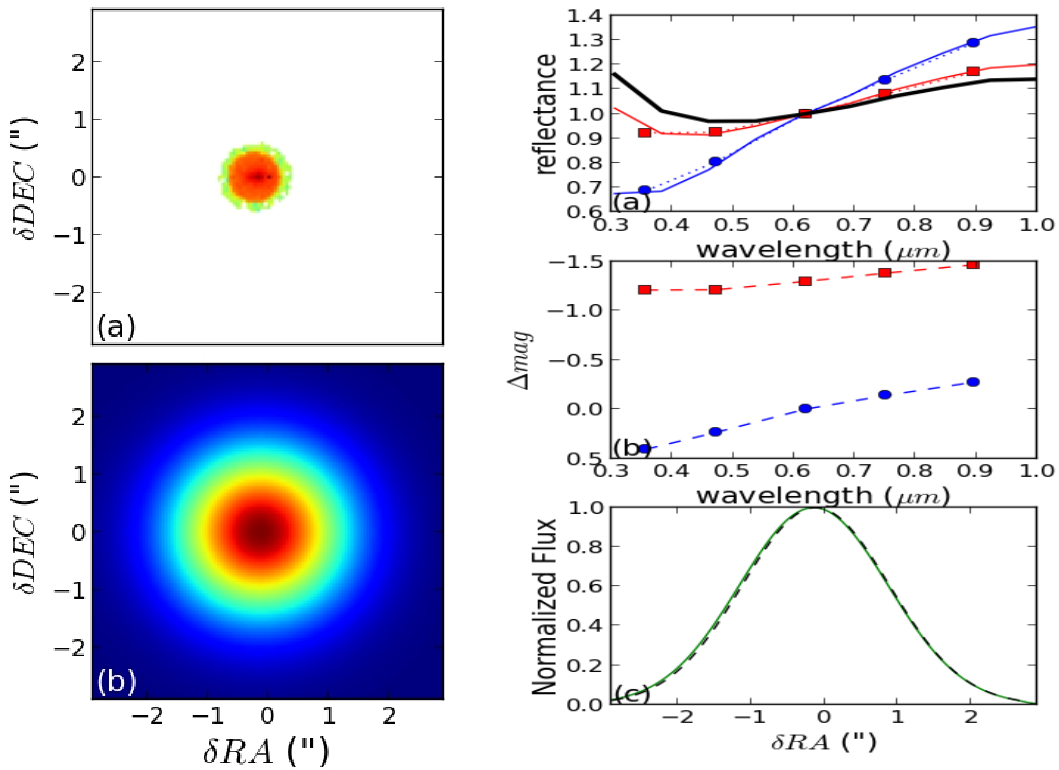
$D = 1\, dia$

$M = 10^{5}\ Kg$



[Rondon-Briceño et al. 2017, MNRAS, 468]

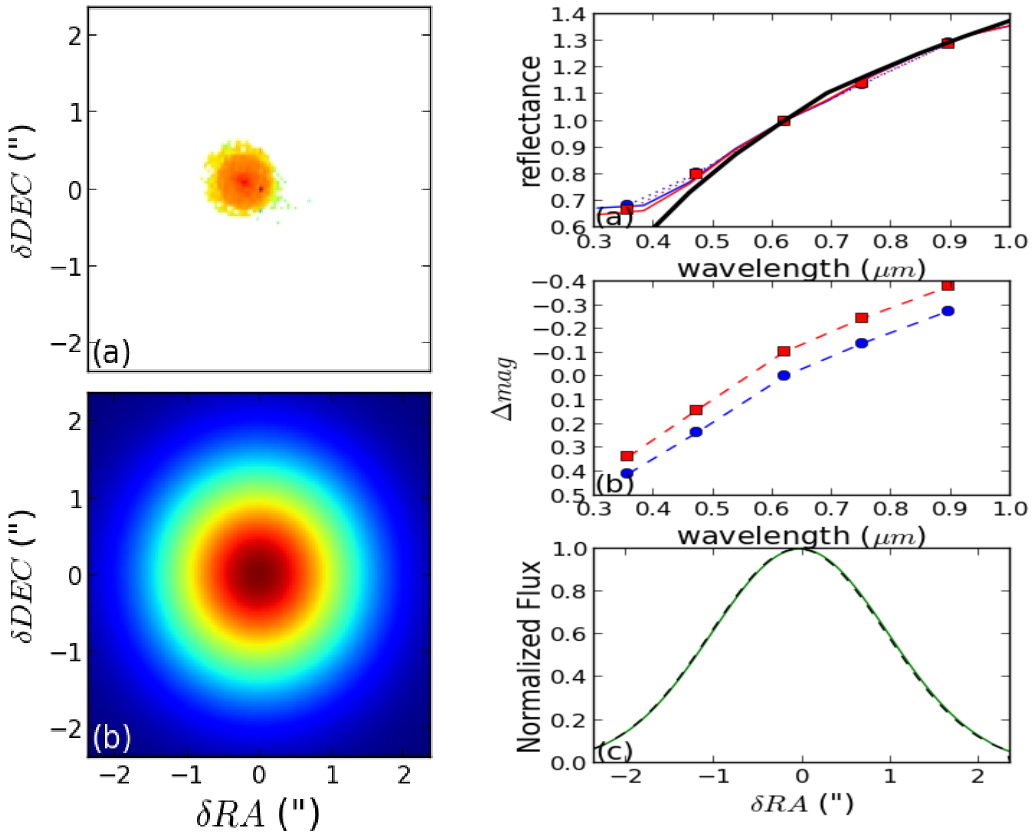
$\gamma = 0.05$

$v = 22 m/s$

$g = 17^o$

$D = 1\ dia$

$M = 10^5\ Kg$



Conclusions

- We can see that the presence of a faint dust coma over the asteroid modify the observed spectrum.

- The mass of the coma is a parameter that modify the shape of the asteroid spectrum, if the mass of the coma to reach to a specific limit will induce drastic change in the shape of the asteroid spectrum.

- The variations that we have observed in the spectra due to the presence of a faint dust coma can be associated to others effects as a asteroid surface with a non-homogeneous albedo distribution (Szabo, 2004), the effect of the nucleus shape (Carvano, 2015) and the phase angle (Jasmin, 2013).

- Only the spectral change can not be used as an evidence of presence of coma over an asteroid, however, a marked characteristic in the spectra is a reflectance increase in the bluer part of the spectrum, this characteristic could be used for specify the possible presence of a coma. A problem here is that although exist many SDDSS data with this characteristic the u filter tend to have the higher photometric uncertainties, and those increase in the reflectance is consistent with random errors.

THANKS YOU!