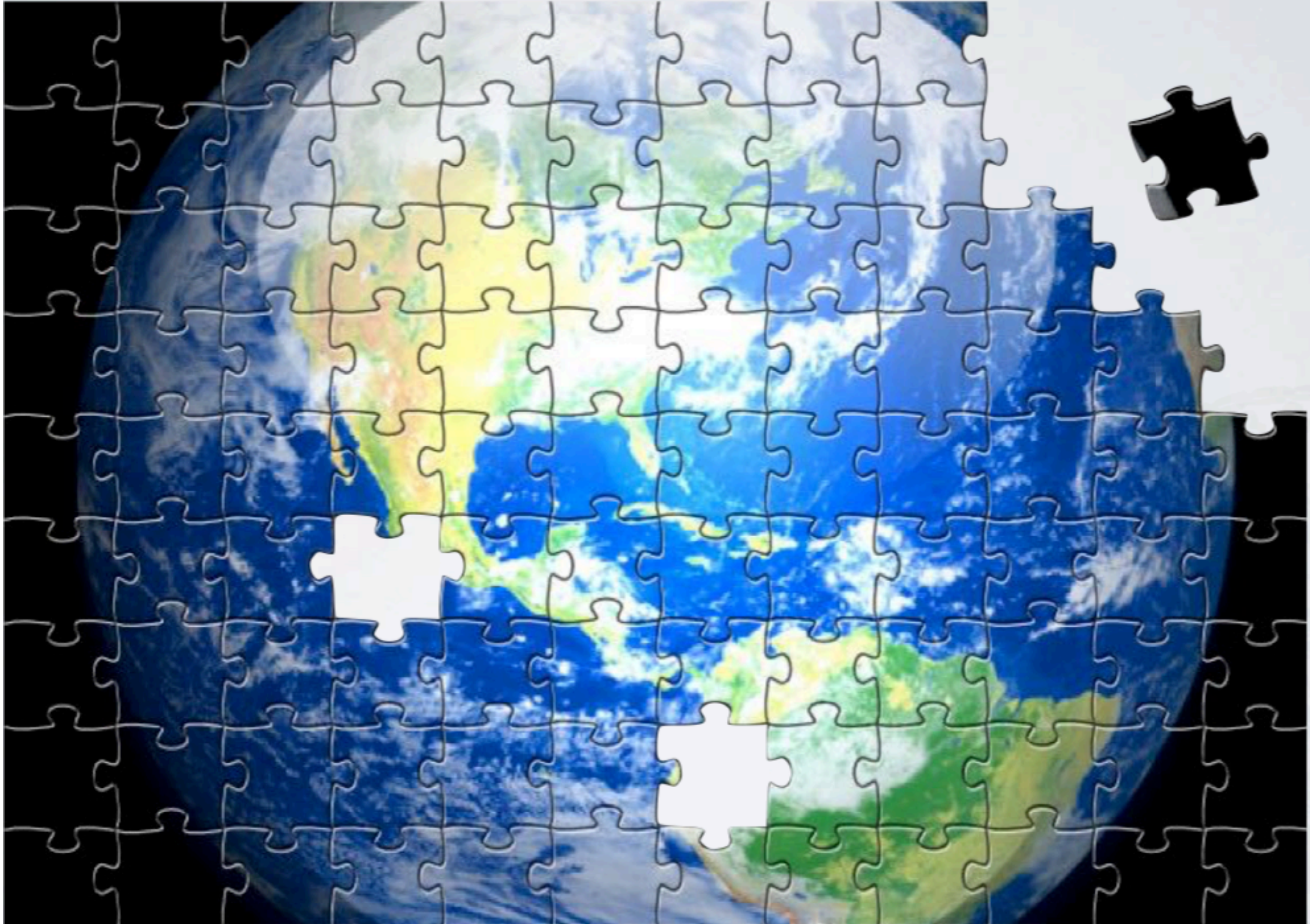
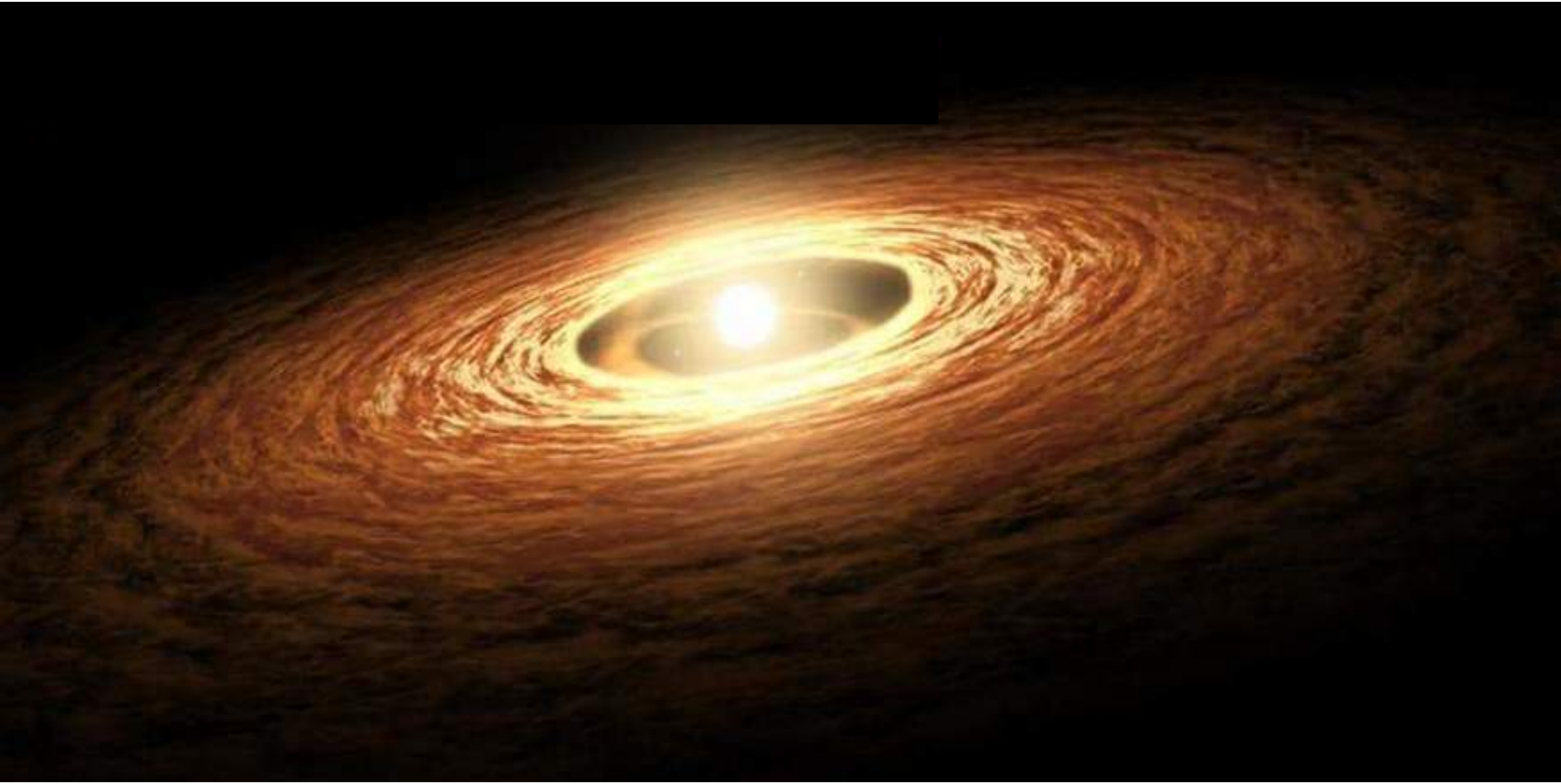
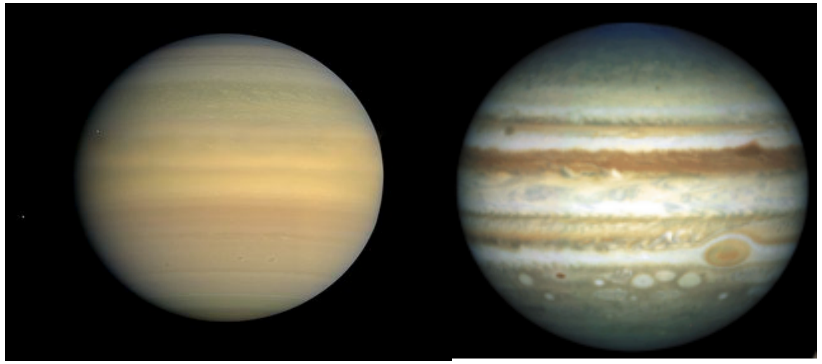
Class 16 – Mar 31st, 2020

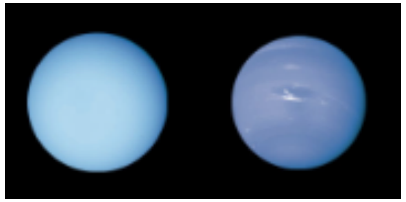


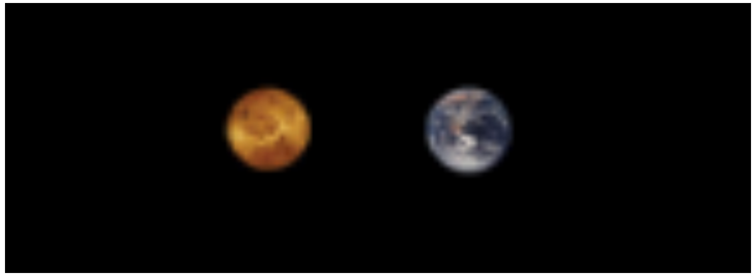
Growing planets

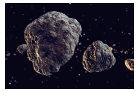
- Growth of small dust (forming planetesimals)
- Planetesimal Formation (building blocks of planets)
- Terrestrial planet formation (core accretion)
- Formation of gas giants (how to get the gas)











Dust growth

Dust bunny

From Wikipedia, the free encyclopedia

For the album by Bettie Serveert, see Dust Bunnies (album).

Dust bunnies (or **dustbunnies**), in American English, are small clumps of dust that form under furniture and in corners that are not cleaned regularly. They are made of hair, lint, dead skin, spider webs, dust and sometimes light rubbish and debris and are held together by static electricity and felt-like entanglement.[1] They can house dust mites or other parasites and can lower the efficiency of dust filters by clogging.[2] The movement of a single large particle can start the formation of a dust bunny.[3]

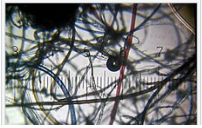
Dust bunnies

Dust bunnies are harmful to electronics, as they can obstruct air flow through heat sinks, raising temperatures significantly, and therefore shortening the life of electronic components.[4]

An American trademark for "Dustbunny" was registered in 2006 for the "Dustbunny Cleaner", a robotic ball with an electrostatic sleeve that rolls around under furniture to collect dust bunnies and other material.[5][6]

Dust bunnies have been used as an analogy for the accretion of cosmic matter in planetoids.[7][8]

Contents [hide]



Astrophysics

Formation of Cosmic Dust Bunnies

Lorin S. Matthews, Ryan L. Hayes, Michael S. Freed, Truell W. Hyde

(Submitted on 12 Jan 2007)

Planetary formation is an efficient process now thought to take place on a relatively short astronomical time scale. Recent observations have shown that the dust surrounding a protostar emits more efficiently at longer wavelengths as the protoplanetary disk evolves, suggesting that the dust particles are coagulating into fluffy aggregates, "much as dust bunnies form under a bed." One poorly understood problem in this coagulation process is the manner in which micron-sized, charged grains form the fractal aggregate structures now thought to be the precursors of protoplanetary disk evolution. This study examines the characteristics of such fractal aggregates formed by the collision of spherical monomers and aggregates where the charge is distributed over the aggregate structure. The aggregates are free to rotate due to collisions and dipole-dipole electrostatic interactions. Comparisons are made for different precursor size distributions and like-charged, oppositelycharged, and neutral grains.

Subjects: **Astrophysics (astro-ph)**
DOI: 10.1109/TPS.2007.892718
Report number: CASPER-07-02
Cite as: arXiv:astro-ph/0701385
(or arXiv:astro-ph/0701385v1 for this version)

Bibliographic data

[Enable Bibex (What is Bibex?)]

SCIENTIFIC AMERICAN NOVEMBER 2005

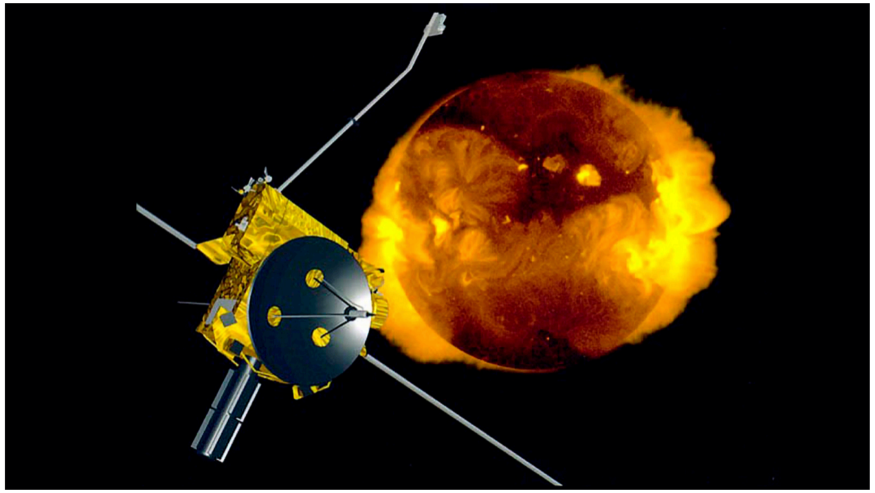
Comet Dust Bunny

Tempel 1 proves to be a ball of fluff

By George Musser

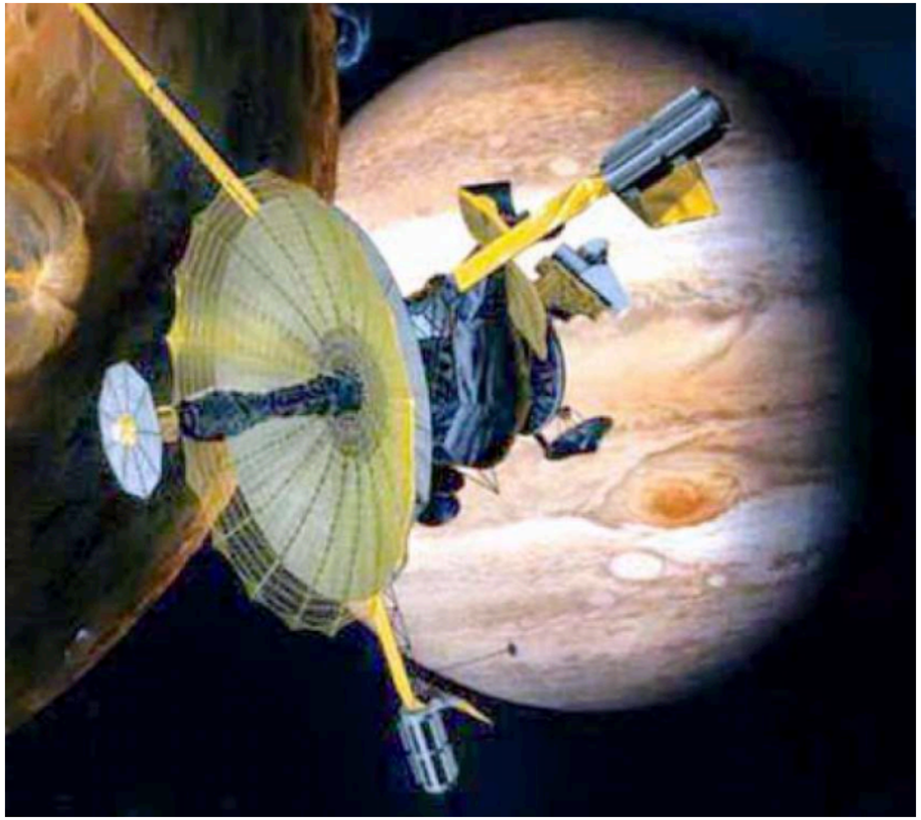
Measuring Interstellar Dust

Ulysses



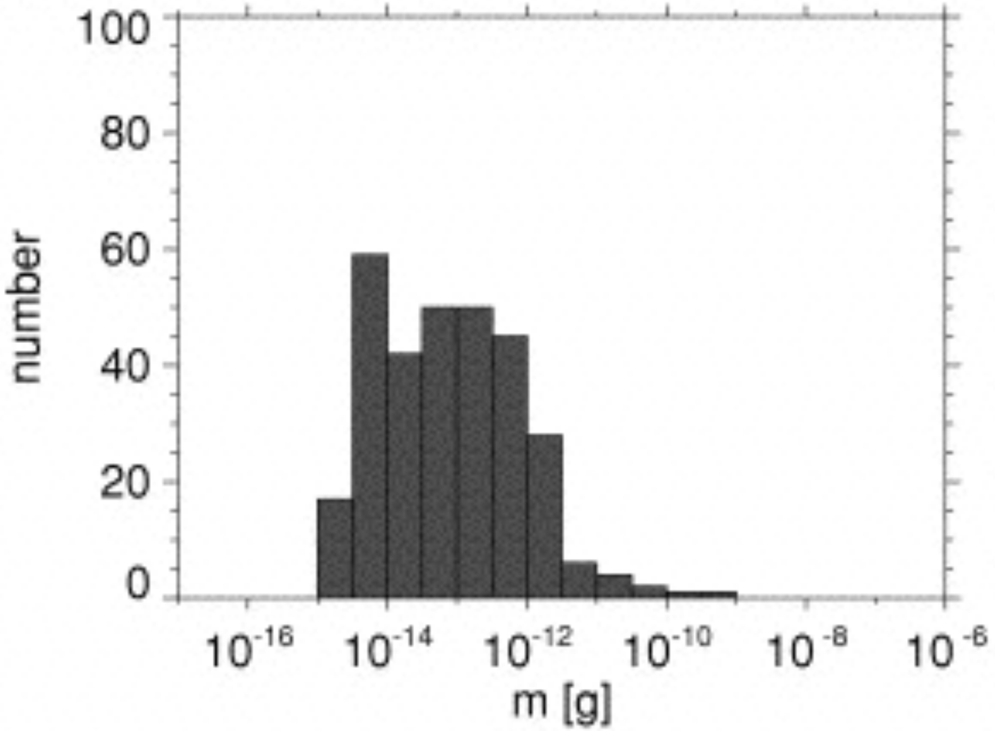
An artist's concept of the joint ESA-NASA Ulysses spacecraft.

Galileo

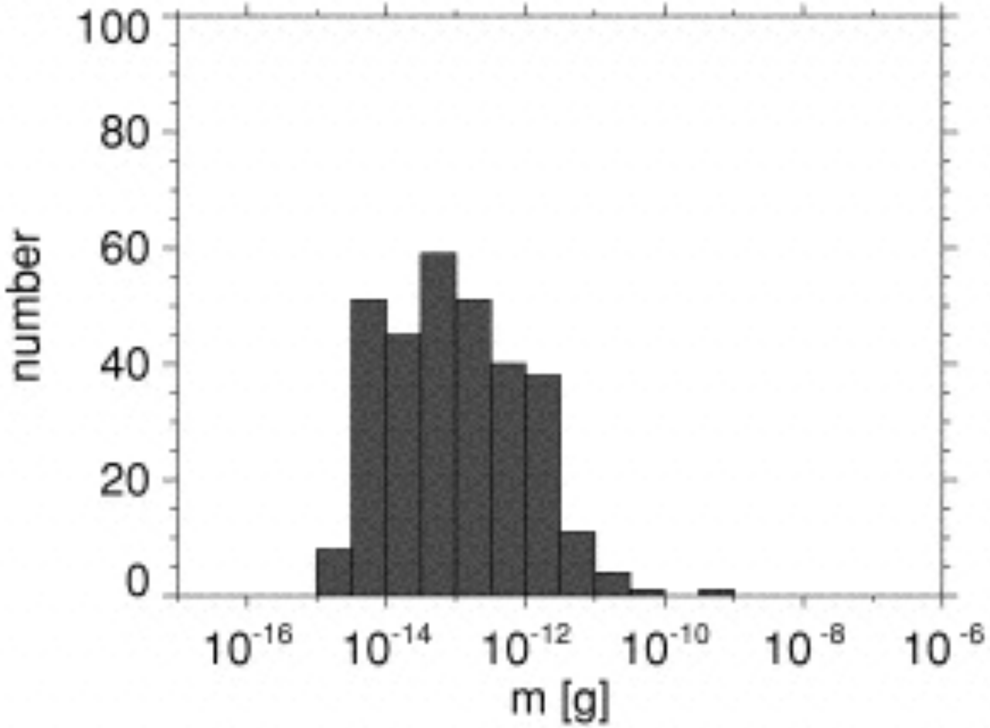


Measuring Interstellar Dust

Ulysses



Galileo



THE ASTROPHYSICAL JOURNAL, 548:296–309, 2001 February 10

DUST GRAIN–SIZE DISTRIBUTIONS AND EXTINCTION IN THE MILKY WAY, LARGE MAGELLANIC CLOUD, AND SMALL MAGELLANIC CLOUD

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Received 1999 July 19; accepted 2000 October 4

ABSTRACT

We construct size distributions for carbonaceous and silicate grain populations in different regions of the Milky Way, LMC, and SMC. The size distributions include sufficient very small carbonaceous grains (including polycyclic aromatic hydrocarbon molecules) to account for the observed infrared and microwave emission from the diffuse interstellar medium. Our distributions reproduce the observed extinction of starlight, which varies depending on the interstellar environment through which the light travels. As shown by Cardelli, Clayton, and Mathis in 1989, these variations can be roughly parameterized by the ratio of visual extinction to reddening, R_V. We adopt a fairly simple functional form for the size distribution, characterized by several parameters. We tabulate these parameters for various combinations of values for R_V and b_C, the C abundance in very small grains. We also find size distributions for the line of sight to HD 210121 and for sight lines in the LMC and SMC. For several size distributions, we evaluate the albedo and scattering asymmetry parameter and present model extinction curves extending beyond the Lyman limit.

Subject headings: dust, extinction — ISM: clouds

Measuring Interstellar Dust

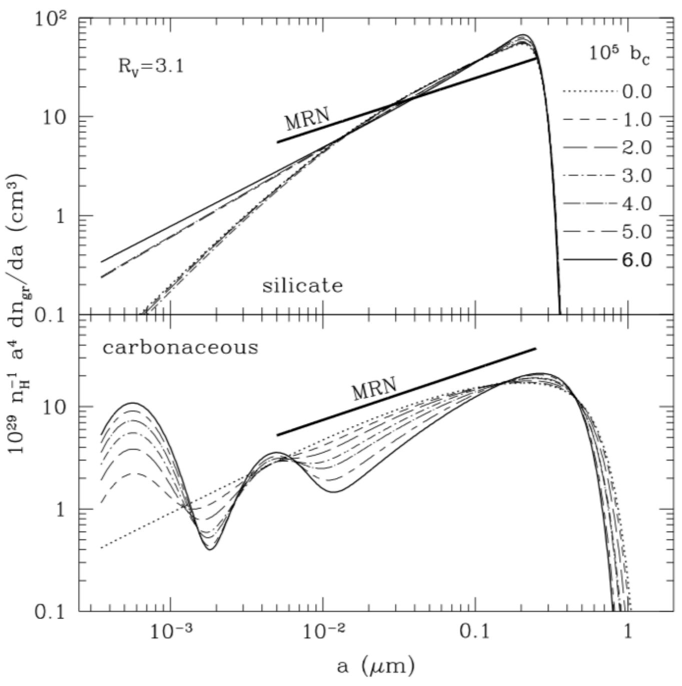


FIG. 2.—Case A grain-size distributions for $R_V = 3.1$. The values of b_C are indicated. The heavy, solid lines are the MRN distribution, for comparison. Our favored distribution has $b_C = 6 \times 10^{-5}$ (see text).

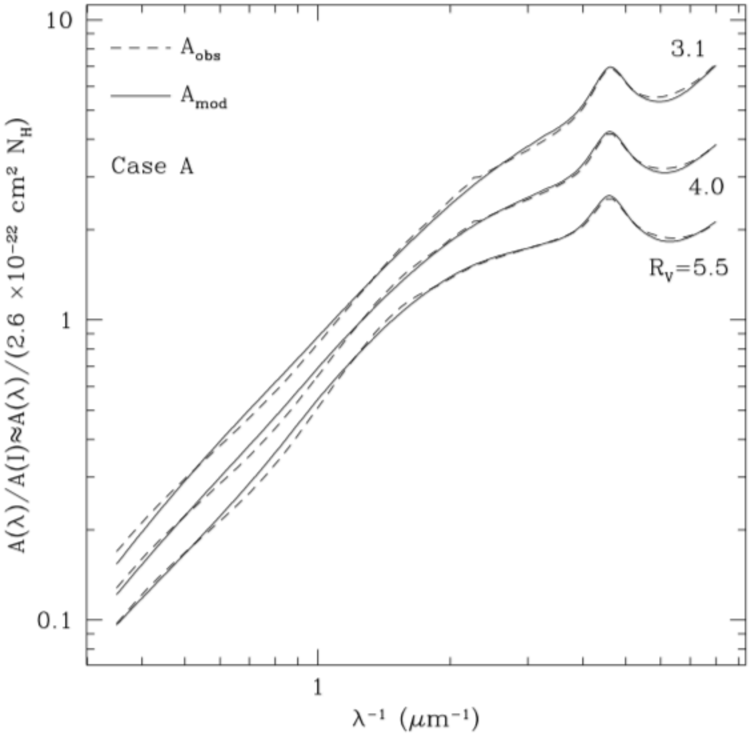
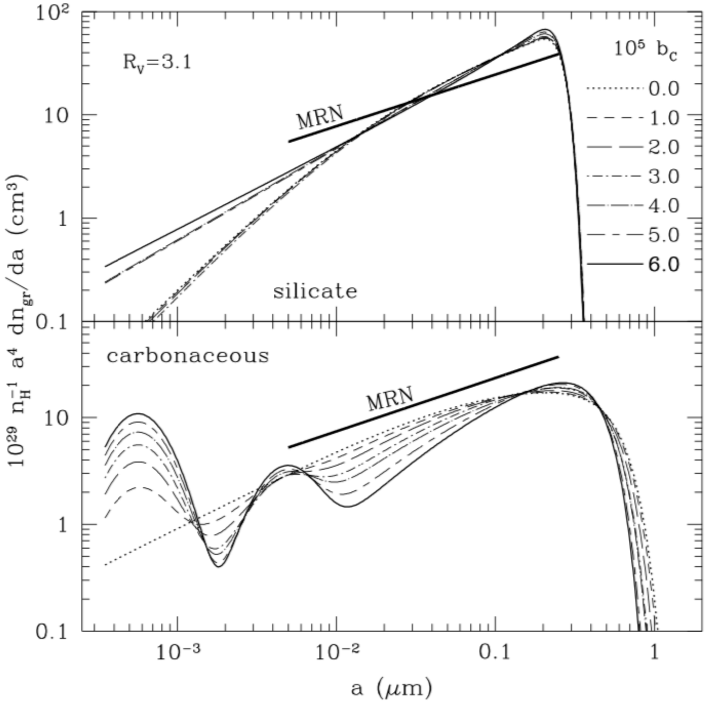
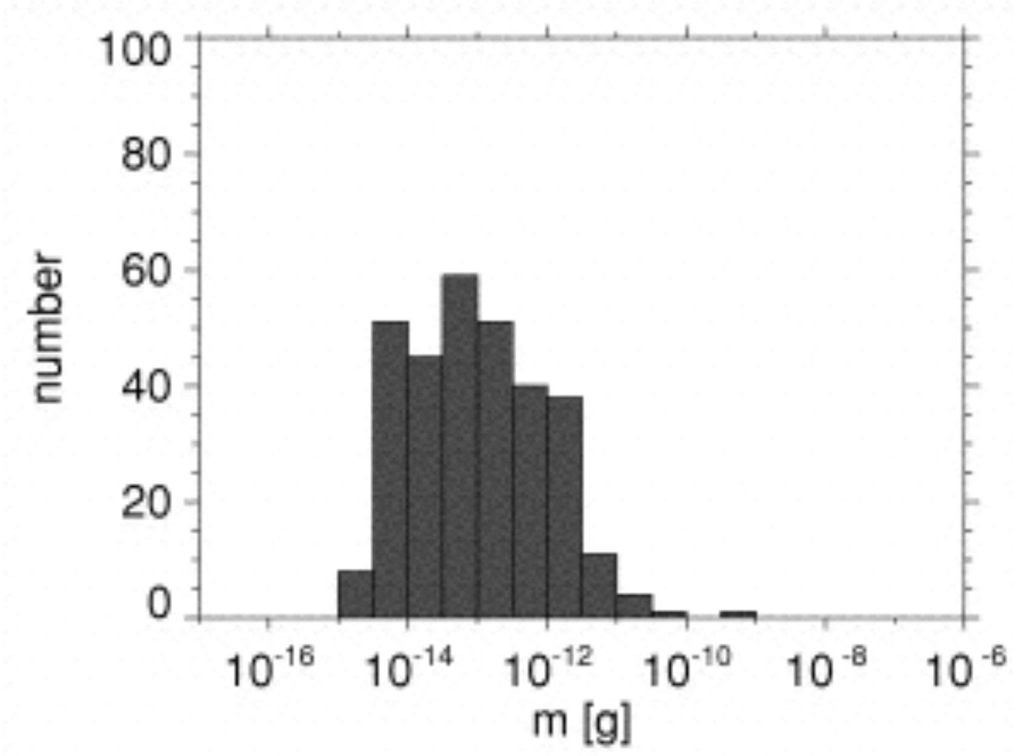


FIG. 7.—Average "observed" extinction A_{obs} and the extinction resulting from our case A models for $(R_V, 10^5 b_C) = (3.1, 6.0), (4.0, 4.0)$, and $(5.5, 3.0)$. The curves for $R_V = 4.0$ (5.5) are scaled down by a factor $10^{0.1}$ ($10^{0.2}$), for clarity.

Measuring Interstellar Dust

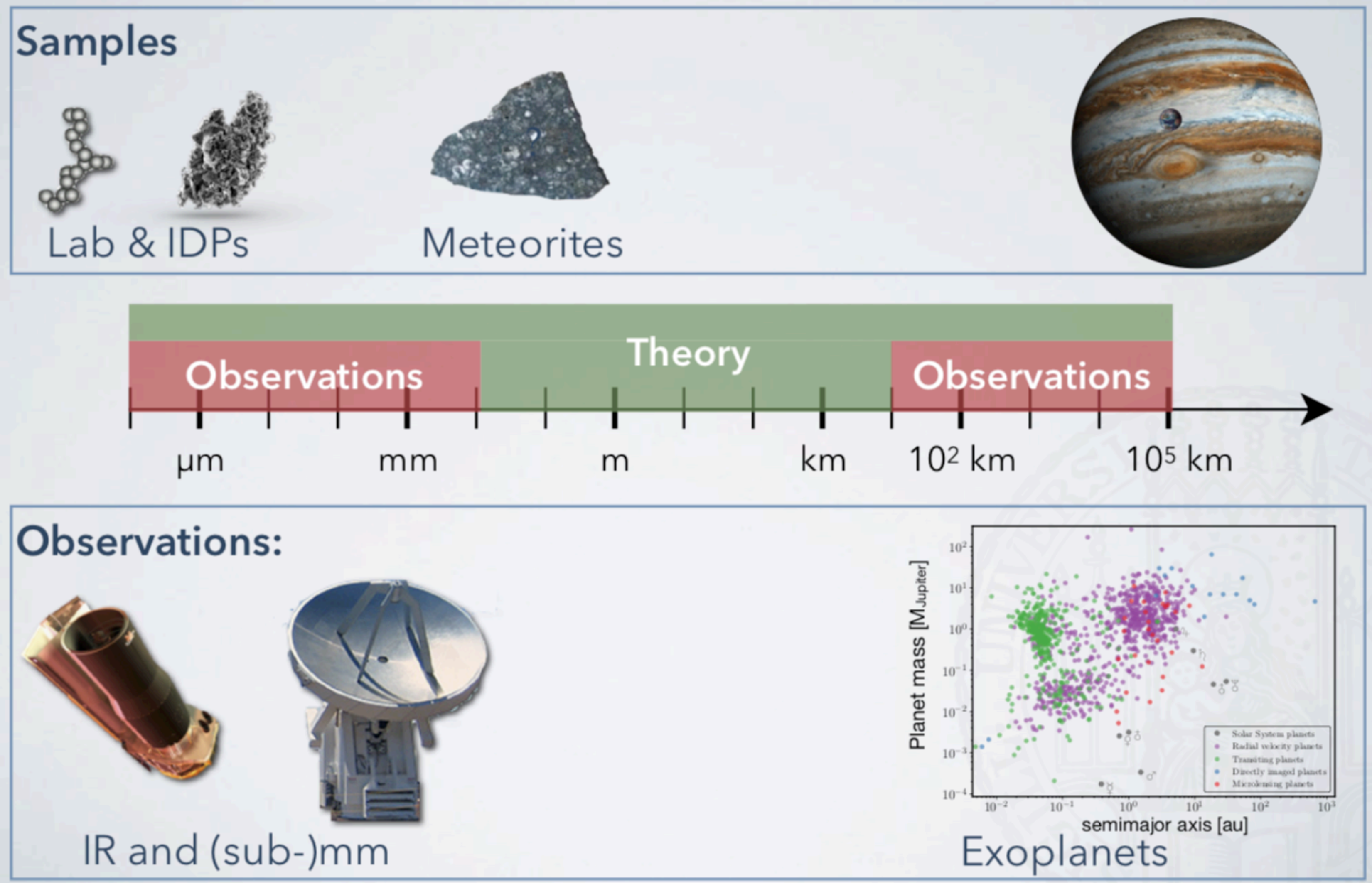




maximum size ~ 0.3-1 μm

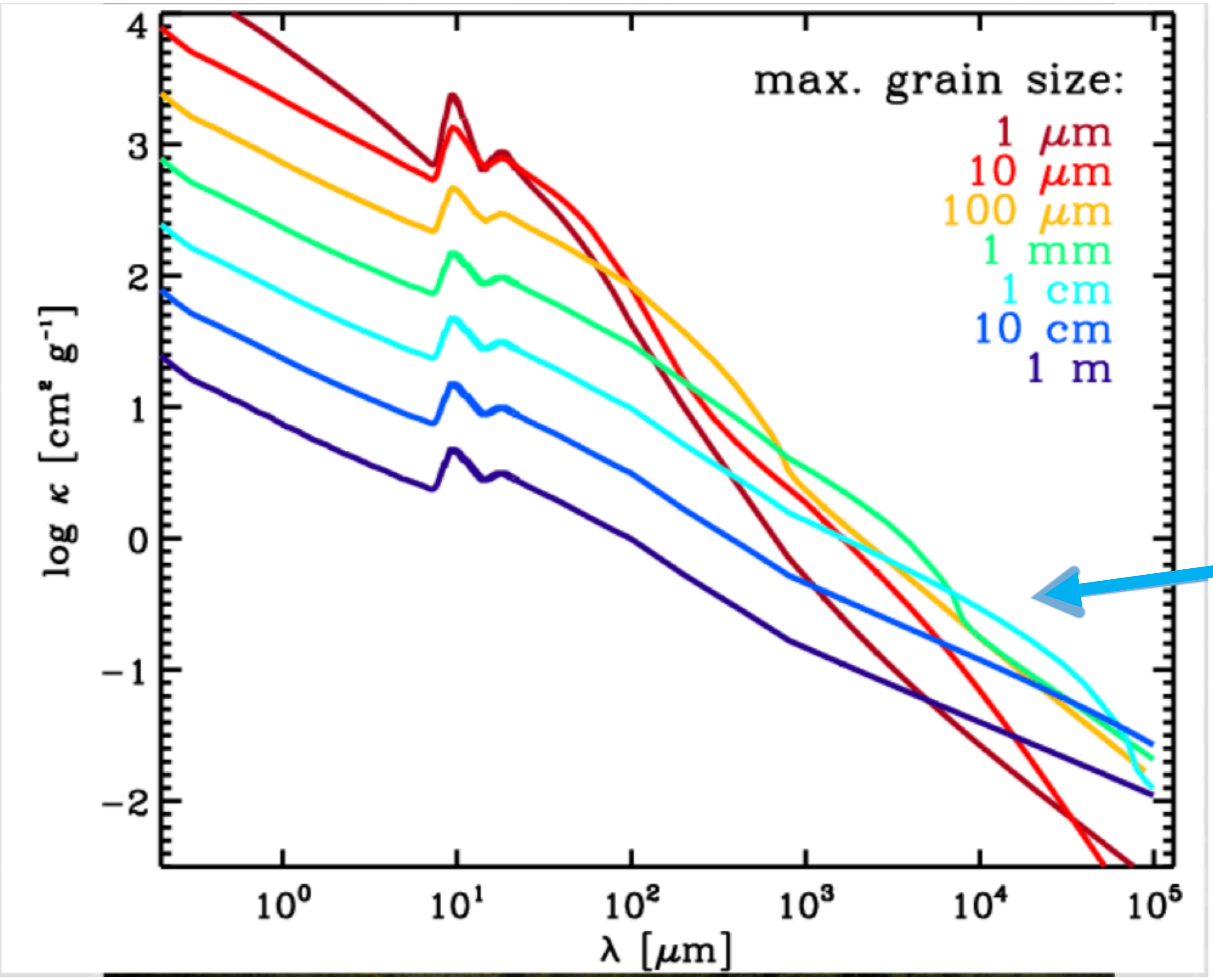
Chondrules

(mm-sized molten spherules)



Samples
Lab & IDPs
Meteorites
Theory
Observations
Observations
μm
mm
m
km
10² km
10⁵ km
Observations:
Planet mass [MJupiter]
semimajor axis [au]
Solar System planets
Radial velocity planets
Transiting planets
Directly imaged planets
Microlensing planets
IR and (sub-)mm
Exoplanets

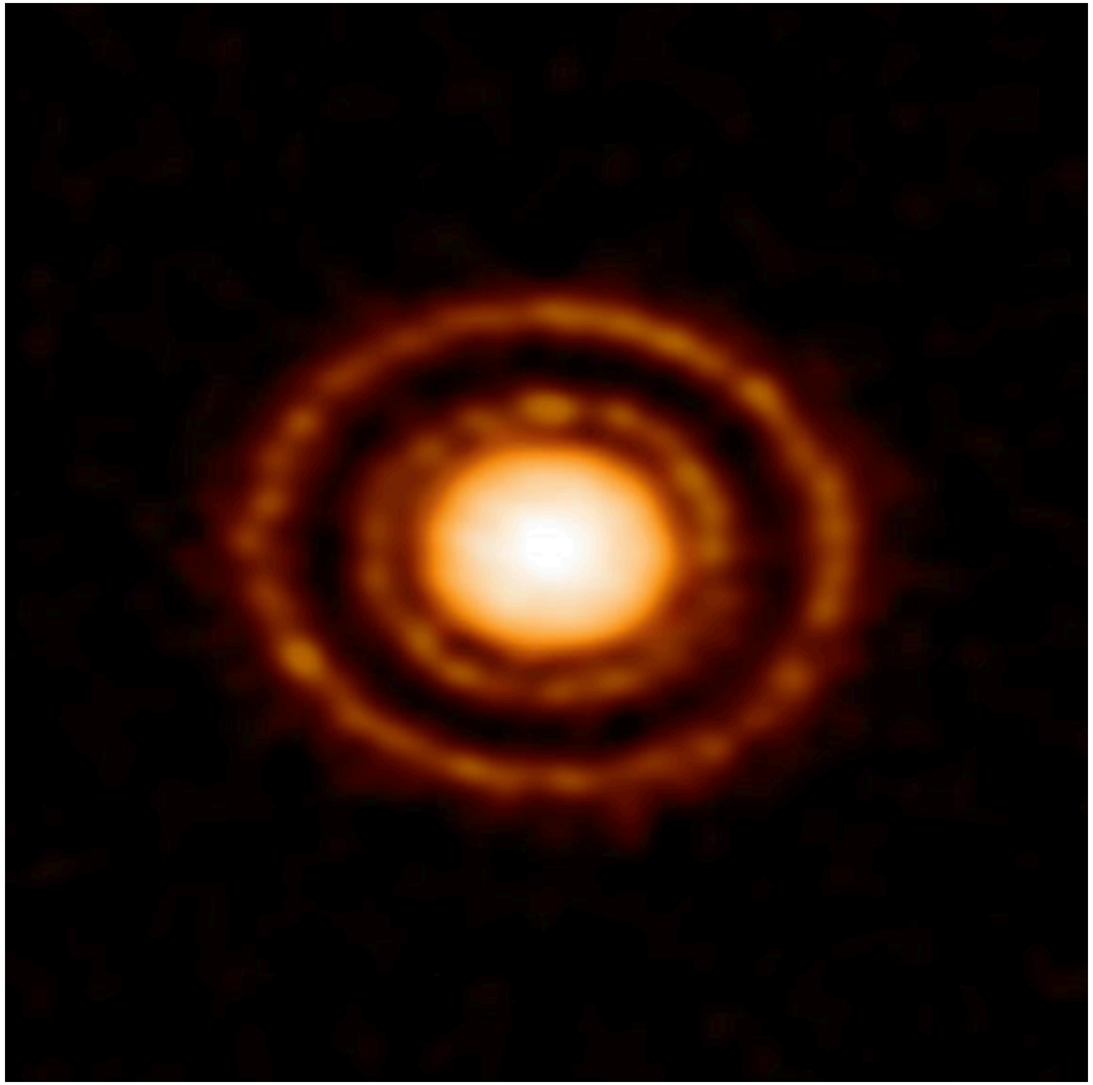
Opacity dependency on grain size



In mm

$\kappa(\nu)\ \alpha\ \nu^{\beta}$

AS 209



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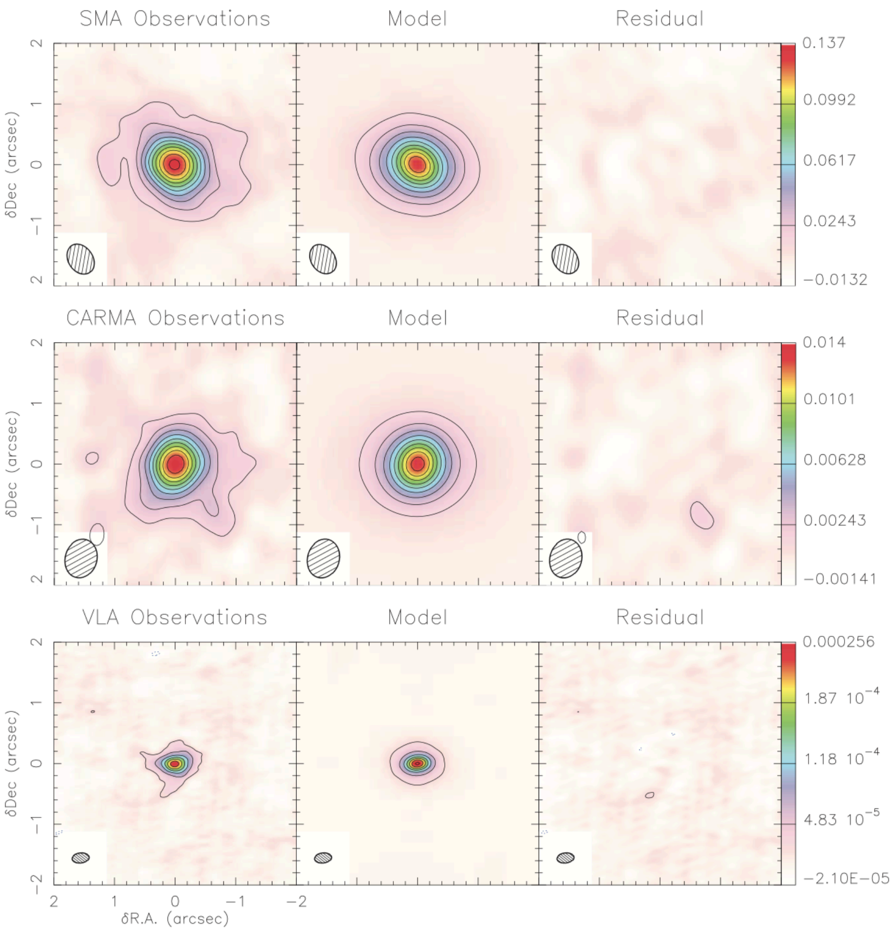
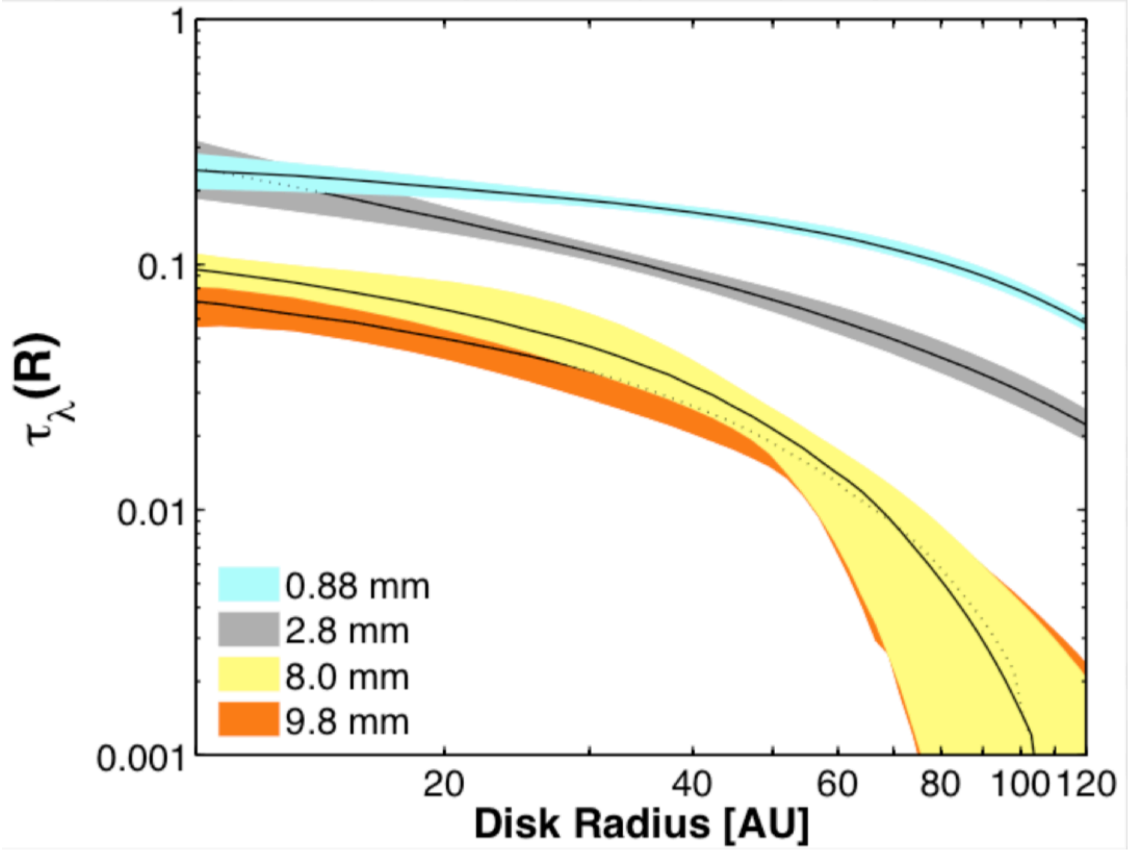
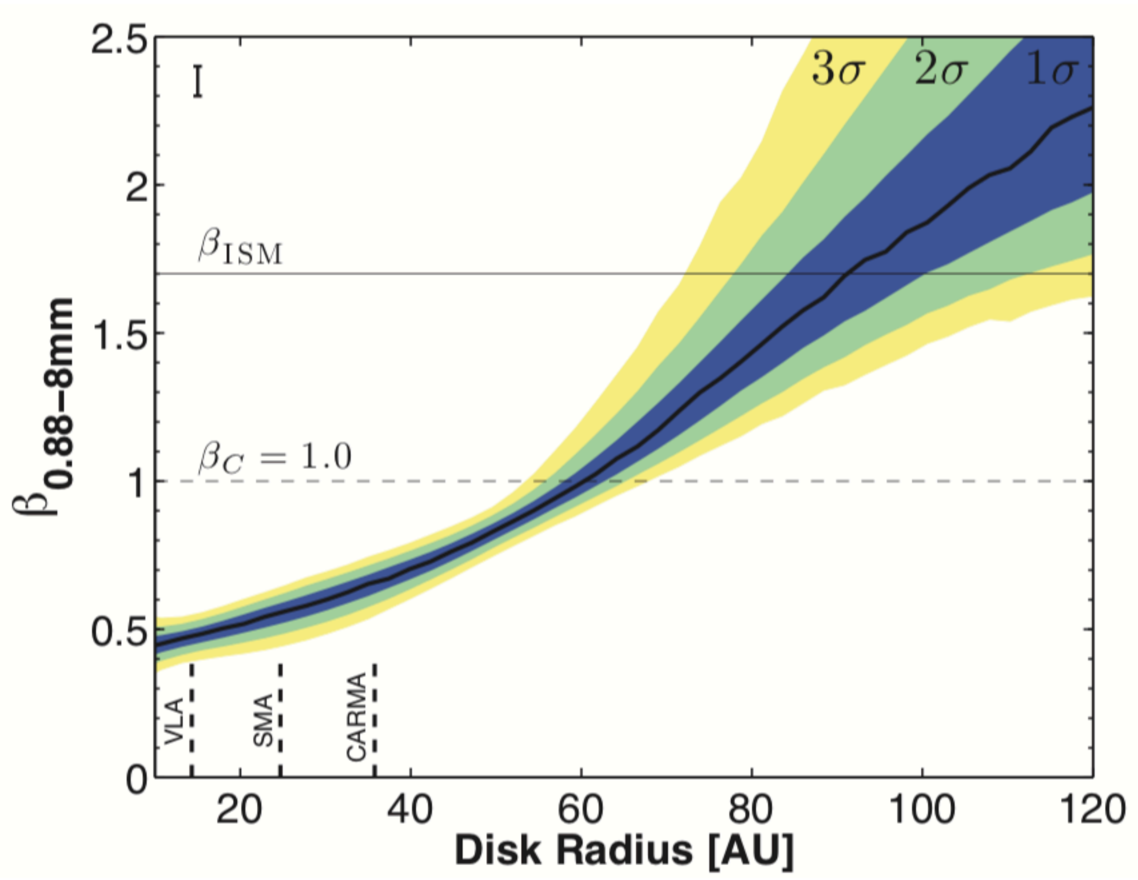
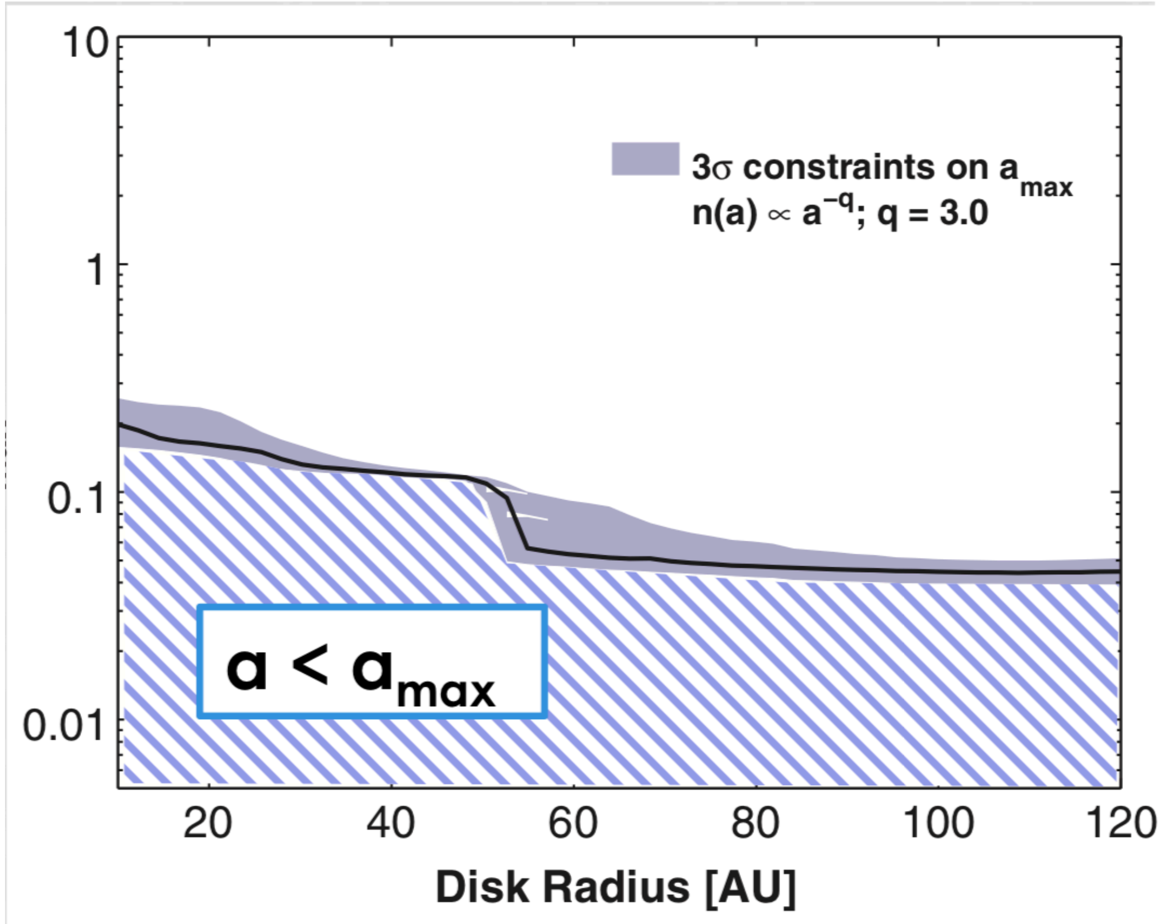




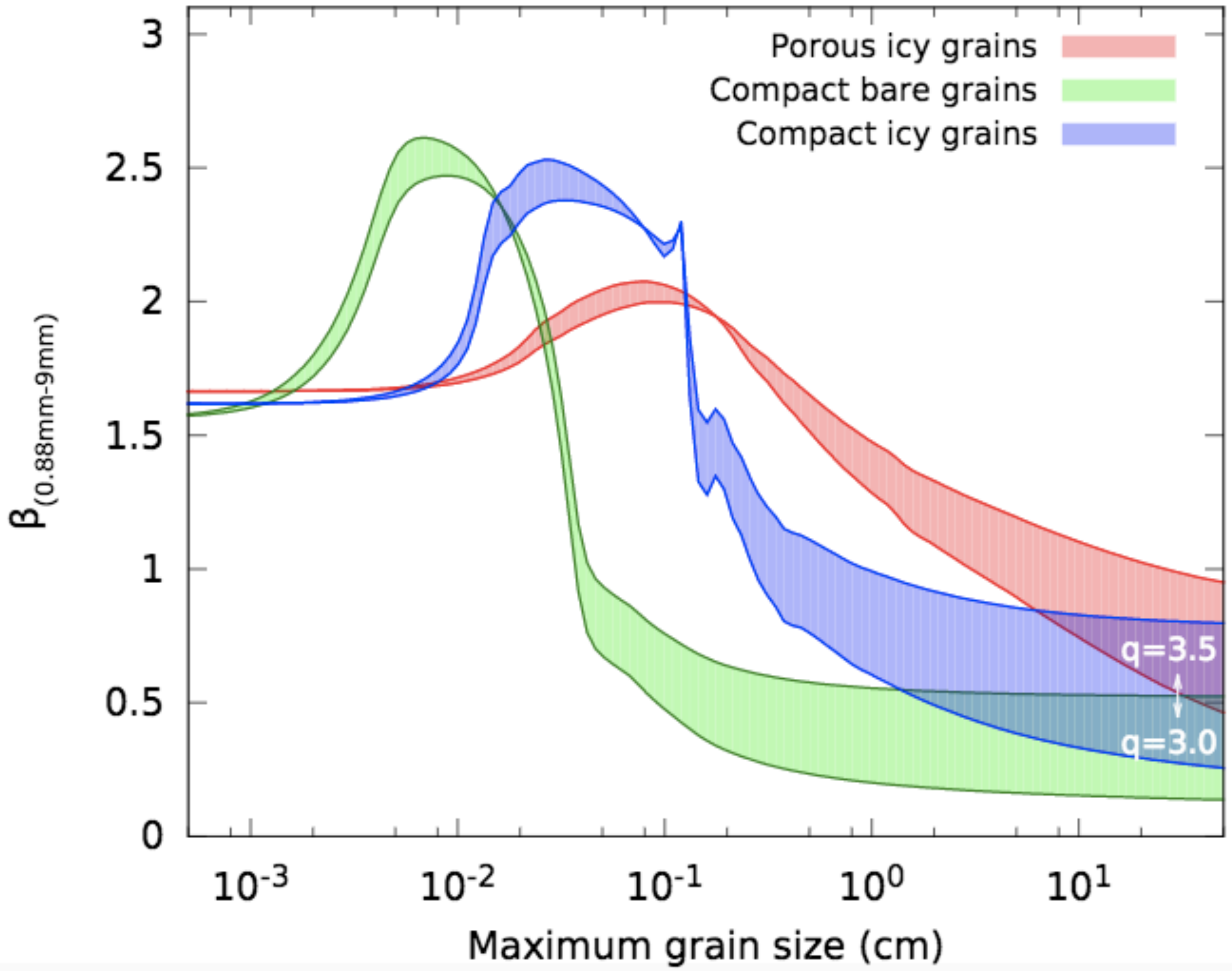
Fit a Chiang-Goldeich model, obtain opacity

AS 209





Convert opacity to β,
and β to a_{max}



Porous icy grains
Compact bare grains
Compact icy grains
q=3.5
q=3.0
$\beta_{(0.88mm-9mm)}$
Maximum grain size (cm)
0
0.5
1
1.5
2
2.5
3
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}

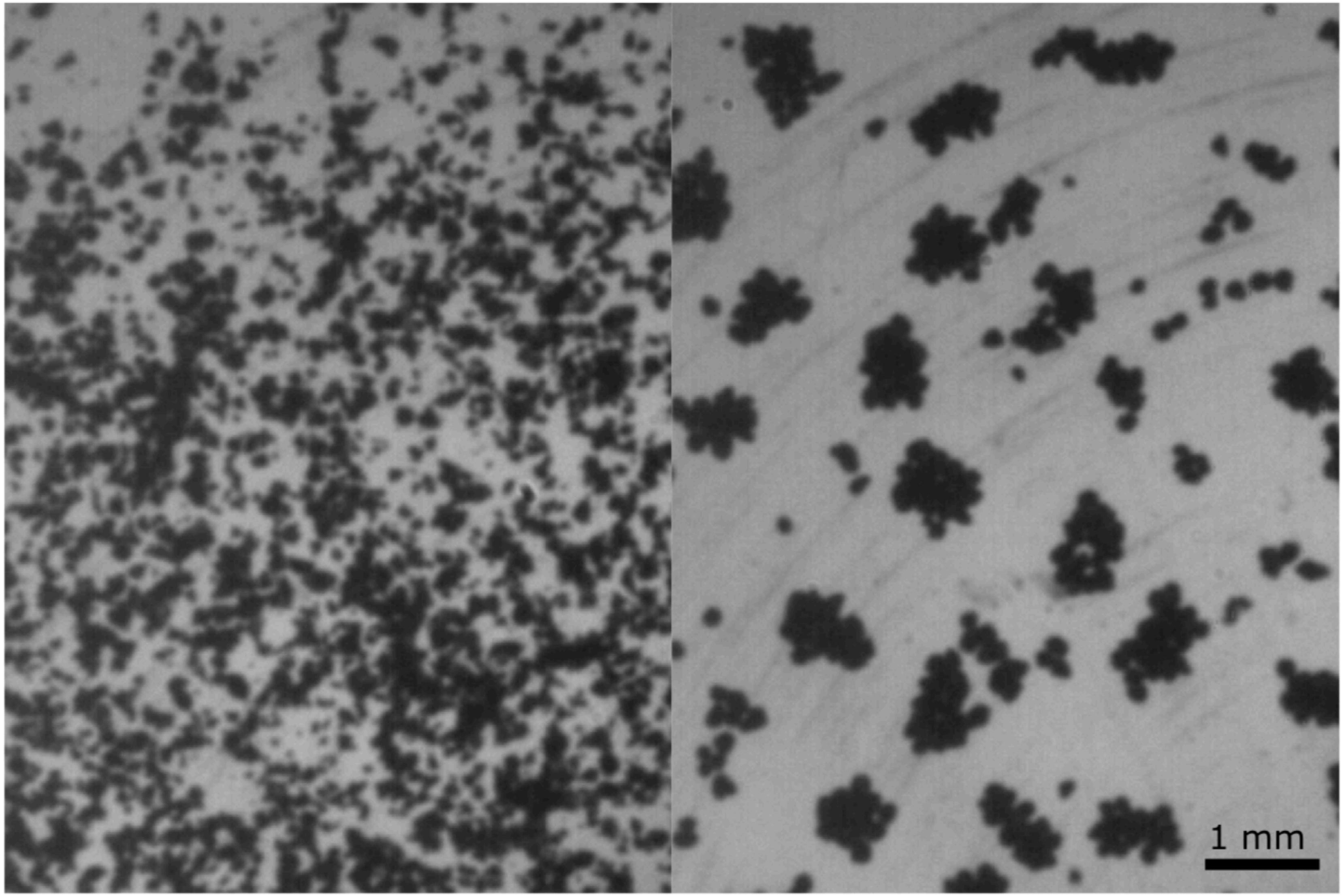


Figure 2. Initial and final ensemble in a laboratory experiment where dust aggregates are levitated at low ambient pressure on a hot surface by a self-generated Knudsen compressor. Starting with 100 micrometer dust aggregates, mm-aggregatges grow at speeds of mm/s to cm/s. (from Demirci et al. [27]).

The Growth Mechanisms of Macroscopic Bodies in Protoplanetary Disks

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[2]Institut für Planetologie, Westfälische-Wilhelms-Universität Münster, Germany; email: gwurm@uni-muenster.de

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0066-4146/08/0922-0021$20.00

Key Words

dust growth, laboratory astrophysics, origin of solar system, planet formation, planetesimals, protoplanetary dust

Abstract

The formation of planetesimals, the kilometer-sized planetary precursors, is still a puzzling process. Considerable progress has been made over the past years in the physical description of the first stages of planetesimal formation, owing to extensive laboratory work. This review examines the experimental

The outcome of protoplanetary dust growth: pebbles, boulders, or planetesimals? I. Mapping the zoo of laboratory collision experiments ⋆

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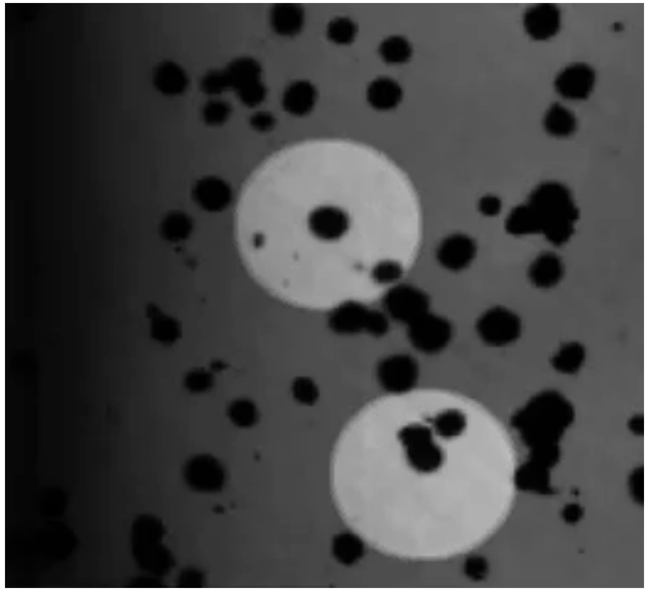
ABSTRACT

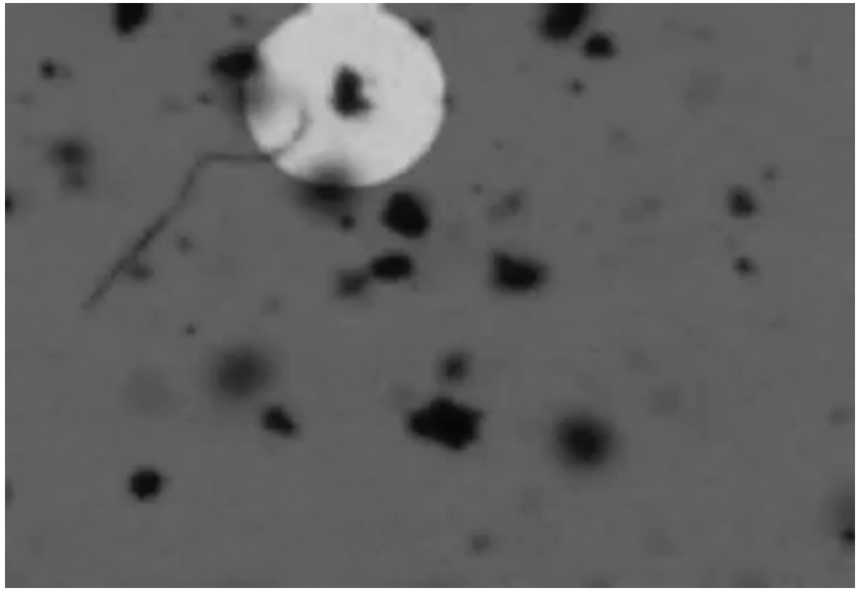
Context. The growth processes from protoplanetary dust to planetesimals are not fully understood. Laboratory experiments and theoretical models have shown that collisions among the dust aggregates can lead to sticking, bouncing, and fragmentation. However, no systematic study on the collisional outcome of protoplanetary dust has been performed so far so that a physical model of the dust evolution in protoplanetary disks is still missing.
Aims. We intend to map the parameter space for the collisional interaction of arbitrarily porous dust aggregates. This parameter space encompasses the dust-aggregate masses, their porosities and the collision velocity. With such a complete mapping of the collisional outcomes of protoplanetary dust aggregates, it will be possible to follow the collisional evolution of dust in a protoplanetary disk environment.
Methods. We use literature data, perform own laboratory experiments, and apply simple physical models to get a complete picture of the collisional interaction of protoplanetary dust aggregates.
Results. In our study, we found four different kinds of sticking, two kinds of bouncing, and three kinds of fragmentation as possible outcomes in collisions among protoplanetary dust aggregates. Our best collision model distinguishes between porous and compact dust. We also differentiate between collisions among similar-sized and different-sized bodies. All in all, eight combinations of porosity and mass ratio can be discerned. For each of these cases, we present a complete collision model for dust-aggregate masses between 10^{-12} and 10^{2} g and collision velocities in the range $10^{-4} \ldots 10^{4}$ cm s^{-1} for arbitrary porosities. This model comprises the collisional outcome, the mass(es) of the resulting aggregate(s) and their porosities.

Grain collision outcomes

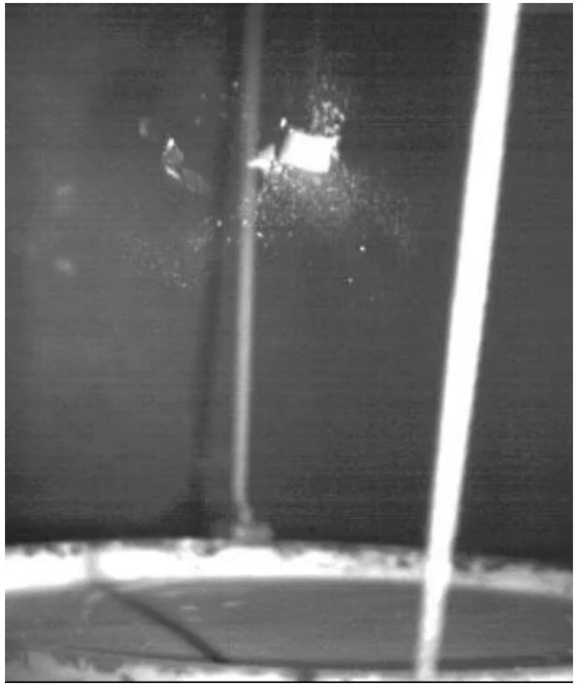
Bouncing



Sticking



Fragmentation



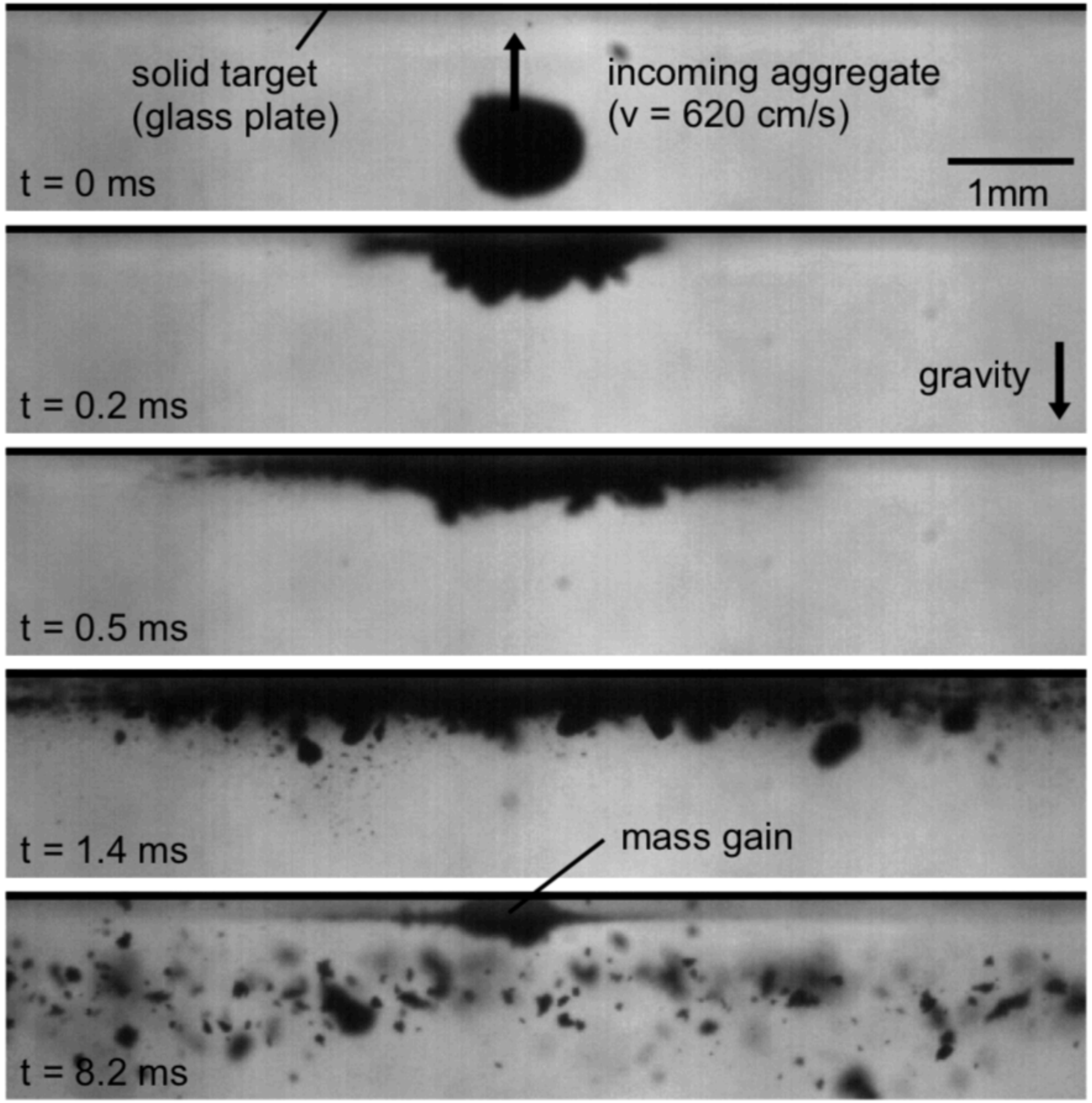
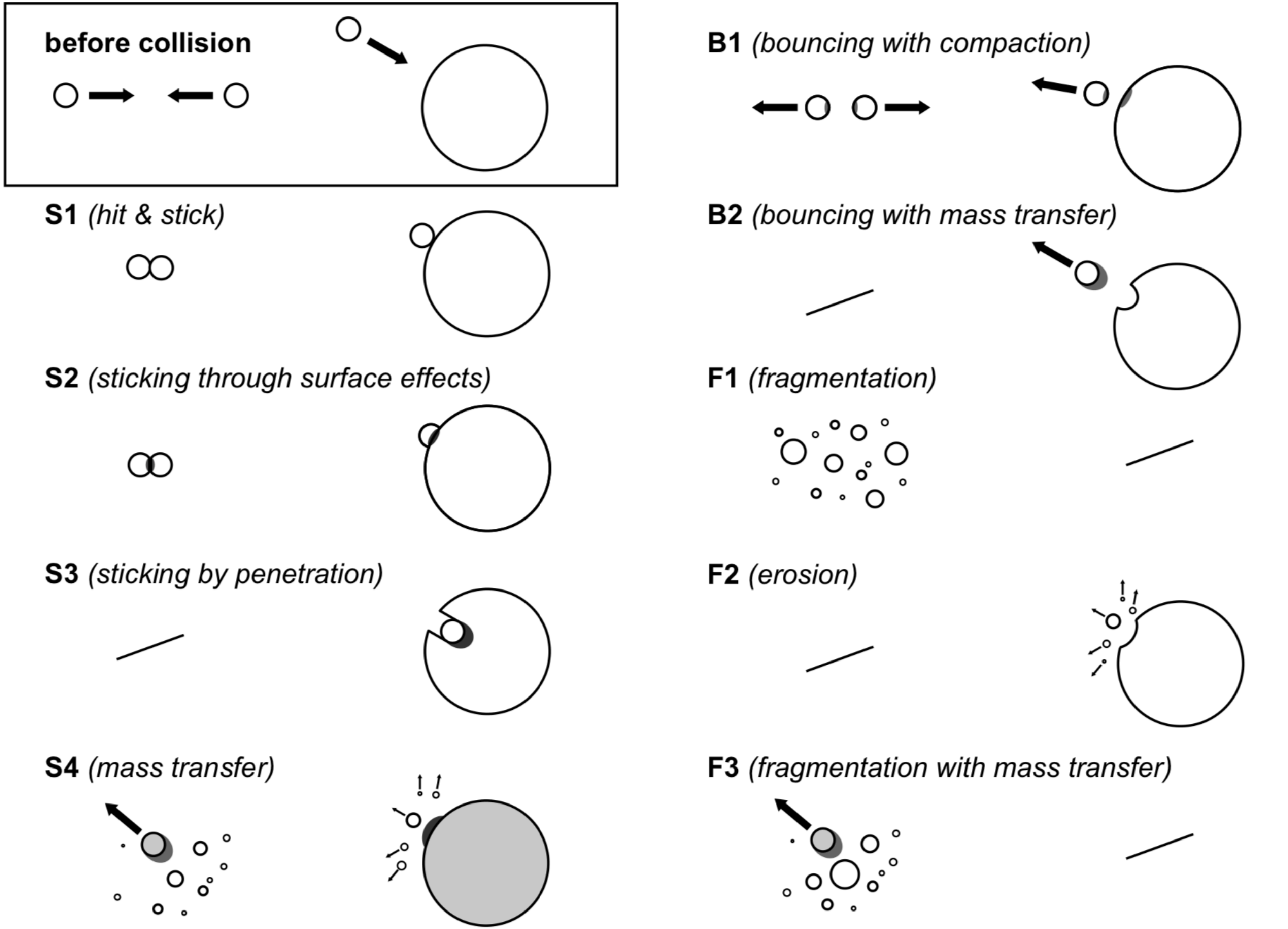


Fig. 2. Example for a collision of a porous ($\phi = 0.35$) aggregate with a solid target at a velocity of 620 cm s^{-1}. The aggregate fragments according to a power-law size distribution and some mass sticks to the target (bottom frame).


before collision
S1 (hit & stick)
S2 (sticking through surface effects)
S3 (sticking by penetration)
S4 (mass transfer)
B1 (bouncing with compaction)
B2 (bouncing with mass transfer)
F1 (fragmentation)
F2 (erosion)
F3 (fragmentation with mass transfer)

LARGE-SCALE EXPERIMENTS TO DETERMINE THE COEFFICIENT OF RESTITUTION FOR METER-SCALE GRANITE SPHERES.
D. D. Durda[1], N. Movshovitz[2], D. C. Richardson[3], E. Asphaug[2], A. R. Rawlings[4], and C. Vest[4]. [1]Southwest Research Institute, 1050 Walnut Street Suite 300 Boulder CO 80302, durda@boulder.swri.edu, [2]University of California Santa Cruz, Santa Cruz CA 95064, [3]University of Maryland, College Park MD 20742, [4]Lousiana Crane Company, LLC.

Introduction: The fast *N*-body code `pkdgrav` [1] is used to study many problems in planetary science, ranging from the collisional and dynamical evolution of planetary ring systems [2], to planetesimal accretion [3,4], to the outcomes of disruptive asteroid collisions [5,6]. Within the code is the assumption of a coefficient of restitution (often chosen to have a value of 0.5) characterizing the outcomes of ~10 m/s inelastic collisions between ~10-m size bodies. Previous work by other researchers [7-10] has already established that the coefficient of restitution varies with size and impact speed for ~1 cm/s impacts between ~1–10-cm diameter water ice spheres, but little or no work has been done to characterize the coefficient of restitution for rocky bodies or for larger ice bodies. Since large rocky bodies tend to have larger and more numerous structural flaws (that fail at lower stress levels and strain rates) than small bodies, collisions between larger bodies may be more dissipative than impacts at the same speeds between smaller bodies. Without the necessary experimental data, however, we have no reliable basis for setting the coefficient of restitution

lowing significant open rock face for unobstructed rock-on-rock contact during the experiments (Fig. 1).

Figure 1. A 1-meter-diameter granite sphere suspended for the large-scale ‘pendulum’ experiments. Left: Placement of support strapping and lifting from forklift. Right: Sphere suspended in place for experiment with 1-meter scale bar and experiment run number marker shown.

Figure 2. Granite spheres in equilibrium position. Left: Headache balls low near the spheres. Right:

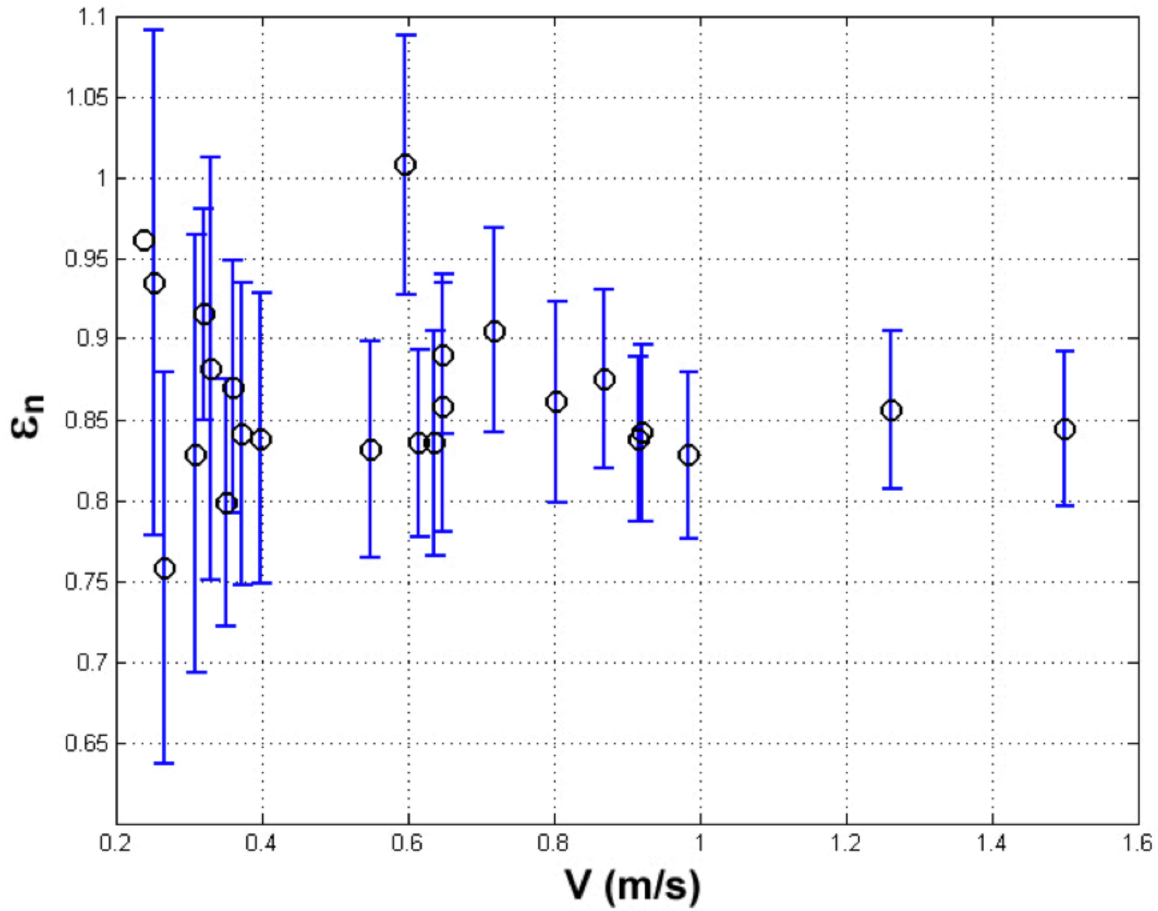


Figure 3. Coefficient of restitution as a function of impact speed for 1-meter diameter granite spheres.