

EXPERIMENTAL STUDY OF THE RADIATION PRESSURE FORCES ON ISOLATED MICRON-SIZE DUST PARTICLES. O. Krauß, and G. Wurm, Institute for Planetology, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (okrauss@uni-muenster.de).

Introduction: Dust particles in circumstellar disks as well as in planetary systems are subject to the radiative forces of the central star. The radiation pressure can have a significant effect on the dynamical evolution of the dust grains in such a system, depending on the particle properties and on the characteristics of the radiation field. The most straight forward effect of radiation pressure is its radial force component on dust particles opposing the stars gravitational attraction. However, the non-radial components of motion of dust grains can also be affected, leading to a damping or acceleration in their orbital direction. This can be due to the Poynting-Robertson effect or the transversal components of the radiation pressure force, which can reach considerably high values for irregularly shaped particles [1-3].

There is strong evidence that dust particles in astrophysical environments like the ones mentioned above can be characterized as rather porous aggregates built from (sub)-micron-size particles in various forms. The optical properties of such aggregates do not only depend on their size and the material they consist of but they are also a function of their morphology and the size of their constituents [4,5].

The experimental set-up that we have developed allows measuring the radiation pressure forces on arbitrarily shaped particles in the directions parallel and perpendicular to the incident light. Studies of dust analog particles using this apparatus should help to gain more insight in the effect of radiative forces on dust grains as a function of various parameters. In the near future the technique presented here will also be applicable to the investigation of more delicate individual samples like e.g. stratospheric interplanetary dust particles (IDPs).

Measurement Technique and Experimental Set-up: In our experiment the radiation pressure force is measured by the observation of the momentum transfer from a high-power laser pulse to a particle under force-free conditions. The particle is levitated by an electrodynamic quadrupole trap in a vacuum chamber. However, during the measurement process the electric fields of the trap are turned off for a period of several ms so that the particle is under the conditions of free fall. Radiation is provided by an optical parametric oscillator (OPO) that emits pulses of about 8 ns length and is tunable from 220 to 2550 nm with typical energies of a few mJ per pulse. The wide tuning range of this laser

system enables us to perform radiation pressure spectroscopy as a function of the size parameter over a range of more than one order of magnitude with a single particle. Each laser pulse used for a measurement is analyzed with respect to its wavelength, total energy, and the spatial energy distribution over its cross section. The particle is observed from a direction perpendicular to the incident laser beam using a color CCD camera, equipped with a long distance microscope objective. Stroboscopic illumination with a flash lamp and a modulated laser diode from the back yields snapshots of the momentary position of the particle at a given time and particle trajectories, respectively, within one video frame of the camera.

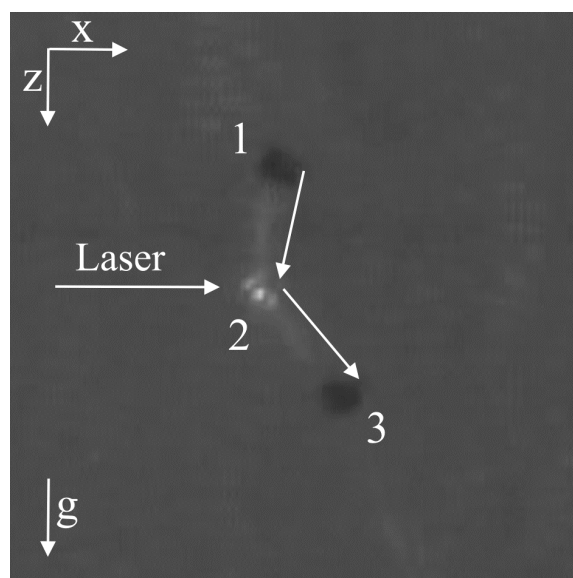


Fig 1: Typical microscope image ($260 \times 260 \mu\text{m}$) of the radiation pressure measurement process in the x - z -plane. The laser beam is directed along the x -axis and hits the particle in position 2. The gravitational force acts along the z -axis.

As a result we obtain microscope images like the one shown in Fig. 1. The numbers and arrows in this image indicate the temporal sequence of the particle positions and motion. By analyzing the particle motion from position 1 to 2 before the laser pulse and from position 2 to 3 after the laser pulse the momentum transfer from the laser pulse to the particle in x and in z direction is determined. From this we can directly infer the ratio of one perpendicular to the parallel compo-

ment of the radiation pressure cross section of the particle for its current orientation with respect to the incident laser beam in position 2. If, in addition, the absolute amount of radiative energy at this position and the particle mass are measured we can obtain absolute values for the radiation pressure cross section.

Results and Discussion: First measurements using the here presented method were done with micron-size graphite grains of highly irregular shape that serve as analog particles for carbonaceous dust grains in various astrophysical environments. As can be seen from Fig. 2 these graphite particles are aggregates consisting of flake-like elements of different sizes.

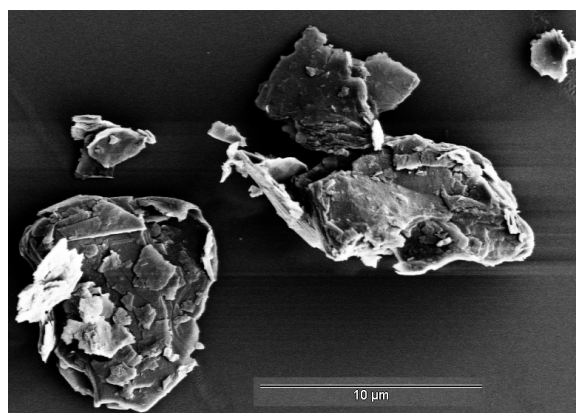


Fig 2: Scanning electron microscope image of typical graphite grains as they were used for radiation pressure measurements.

In a first step we performed measurements with the laser wavelength fixed at 550 nm varying the energy from 1.1 to 1.6 mJ per pulse. The radiation pressure effect in the direction parallel to the incident light can be seen directly from the microscope images like the one in Fig. 1. Since the laser pulse hits the particle from the left, there is always an alteration of the particle trajectory to the right. The influence on the particle motion in the z direction is not so obvious because it is superimposed on the accelerated motion due to gravity.

The analysis of the data reveals that the radiation pressure forces on such a particle vary dramatically with its orientation at the moment it is hit by the laser pulse. This is true for both components that are observable in the 2-dimensional images that we obtain. It is also visualized by strong variations in the intensity of the light scattered at 90° that is detected in these images.

Our observations suggest that for the investigated graphite grains the ratio of the perpendicular to the parallel component of the radiation pressure cross section can reach values as high as predicted by Il'in and Voshchinnikov [2] or even higher. In their calculations

for oblate spheroids of amorphous carbon, which are still more symmetric than the particles investigated here, they found maximum values for this ratio of more than 0.2.

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References: [1] Kimura H. et al. (2002) *Icarus*, 157, 349-361. [2] Il'in V.B. and Voshchinnikov N.V. (1998) *A&A SS*, 128, 187-196. [3] Klačka J. and Koci-faj M. (2001) *JQSRT*, 70, 595-610. [4] Gustafson B.Å.S. (1989) *ApJ*, 337, 945-949. [5] Mukai T. et al. (1992) *A&A*, 262, 315-320.