

Contents

Foreword	xvii
<i>Hannes Alfvén</i>	
Preface	xix
1 Comets	1
<i>Fred L. Whipple</i>	
1 Introduction	1
2 Comet motions and the Oort cloud	6
3 Non-gravitational motions of comets	12
4 Cometary luminosity, bursts, and splitting	20
5 The radiators in comets	26
6 Physical processes in the head of a comet	33
7 Dust tails and grains	40
8 Plasma tails	50
9 The nucleus	58
10 Cometary origin	66
Acknowledgements	70
References	70
2 Zodiacal Light as an Indicator of Interplanetary Dust	75
<i>J. L. Weinberg and J. G. Sparrow</i>	
1 Introduction	75
(a) Scattering	75
(b) Thermal emission	76
2 Observational parameters and observing geometry of zodiacal light	77
3 Methods of observation	79
4 Errors and absolute calibration	83
4.1 Units of surface brightness	83
4.2 Precision and accuracy	84
5 Results	84
5.1 Brightness and polarization	85
(a) Observations in the ecliptic	85
(b) Observations off the ecliptic	87
5.2 Orientation of the plane of polarization	88
5.3 Colour and thermal emission	89
5.4 Gegenschein	90
5.5 Position and symmetry of the zodiacal cone	91
5.6 Doppler shifts	93
5.7 Heliocentric dependence	93
5.8 Temporal variations	96
5.9 Summary	98
6 Information content on the nature and distribution of the dust	99
6.1 Properties of the dust	100
6.2 The use of zodiacal light observations to infer the properties of the dust	100

6.3	A panel discussion	106
7	Additional requirements	111
7.1	Zodiacal light observations	111
7.2	Laboratory measurements, scattering theory, model calculations	111
7.3	Complementary observations of interplanetary dust	111
8	Concluding remarks	112
	Acknowledgements	112
	References	113
3	Meteors	123
	<i>David W. Hughes</i>	
1	Introduction	123
2	Meteor streams	124
2.1	Production from the decay of a cometary nucleus	124
2.2	Formation of the sporadic background	126
3	Meteors and micrometeoroids	130
4	Meteor observation techniques	133
4.1	Visual	133
4.2	Photographic and telescopic	133
4.3	Television	133
4.4	Spectroscopic	135
4.5	Radar—overdense and underdense echoes	136
5	Results obtained	140
5.1	Time variations in the observed rate for sporadics	140
5.2	Meteor stream observations	141
6	Meteor size distribution	145
6.1	Mass distribution indices	145
6.2	Influx mass in specific mass intervals	146
6.3	Factors which change the mass distribution index	146
7	Meteor influx	148
7.1	Influx as a function of magnitude and line density	148
7.2	Influx as a function of particle mass	150
7.3	Influx from meteor streams	155
8	Orbital parameters of meteoroids	157
8.1	Inclination, eccentricity, perihelion distance, and semimajor axis	157
8.2	Meteoroid geocentric velocity	160
9	Meteoroid densities	161
10	The meteor in the earth's atmosphere	163
10.1	The meteor region	163
10.2	Meteors and the ionosphere	166
10.3	Meteors and super-rotation	167
10.4	Meteoroid deceleration in the atmosphere; the classical theory	167
10.5	Height of maximum mass loss	171
10.6	The variation of luminosity along the train	171
10.7	The effect of thermal conduction, radiation, and heat capacity on the ablation process	172
10.8	Dissipation of meteor ionization	176
10.9	Other atmospheric effects caused by meteors	179
	References	180

4 Interstellar Dust	187
<i>J. M. Greenberg</i>	
1 Introduction	187
2 Basic observations	188
2.1 Extinction	188
2.2 Linear Polarization	192
2.3 Circular Polarization	192
2.4 Interdependence of extinction and linear and circular polarization	195
2.5 Distribution of dust and correlation with gas	196
2.6 Radio and optical polarization	198
2.7 Infrared absorption and emission bands	199
2.8 Structure in the extinction curve	205
2.9 Scattering by dust	206
3 The interstellar medium	207
3.1 Cosmic abundance	208
3.2 Gas distribution	208
3.3 Radiation field	208
3.4 Magnetic field	210
4 Basic scattering relationships	210
4.1 Optics of materials	210
4.2 Scattering definitions	212
4.3 Extinction and polarization by clouds of particles	213
4.4 Some scattering examples	216
(a) Spheres: arbitrary size	216
(b) Cylinders: arbitrary size	216
(c) Non-spherical smooth particles: arbitrary size, $ m'-1 \ll 1$	221
(d) Very small particles: $x \ll 1$, $ mx \ll 1$	223
(e) Inhomogeneous and irregular particles	225
4.5 Absorption spectra in small particles	226
5 The basic grain model	228
5.1 Grain size	228
(a) Polarization	229
(b) Extinction	229
5.2 A simple unified dust model	231
5.3 Chemical composition and cosmic abundance	235
5.4 A bimodal grain model	238
(a) Coremantle grains	239
(b) Very small bare grains	241
(c) Comparison with observations	242
6 Physical problems	244
6.1 Grain temperatures	245
(a) H I regions	245
(b) H II regions	249
6.2 Growth and destruction	250
(a) Sources of refractory particles	250
(b) Growth and destruction of mantles	252
6.3 Alignment	256
(a) Alignment by paramagnetic relaxation	256
(b) Other alignment mechanisms	262
6.4 The uniform law of wavelength-dependence of polarization	264
6.5 Far-ultraviolet polarization	266

7	Photochemistry of dust grains	267
7.1	Free radicals in interstellar grains	267
7.2	Interstellar molecules	270
8	Evolution of dust	271
8.1	Evolution of the small dust grains	271
8.2	Evolution of classical grains	274
	(a) Accretion in collapsing clouds	274
	(b) Proto-stellar nebula—comets	276
	(c) After star formation	277
9	Infrared emission by galactic dust	279
9.1	Cool interstellar regions	280
9.2	Dark clouds associated with H II regions	282
9.3	Circumstellar dust	283
10	Concluding remarks	283
	Acknowledgements	284
	References	284
5	Microparticle Studies by Sampling Techniques	295
	<i>D. E. Brownlee</i>	
1	Introduction	295
2	Space collections	296
3	Atmospheric collection	301
3.1	Rocket collections	303
3.2	Balloons	306
3.3	Aircraft collections	310
3.4	Classification of stratospheric micrometeorites	313
	(a) Chondritic—(Chondritic elemental abundances)	315
	(b) Iron-sulphur-nickel—(An iron-sulphur mineral with a few per cent nickel)	319
	(c) Mafic silicates—(Olivine or pyroxene)	320
	(d) Other particle types	320
4	Surface collections	323
5	Analytical techniques and contamination problems	327
	Element ratios	328
	Isotope ratios	328
	Mineral content	328
	Cosmic ray tracks	329
	Morphology	329
	Contamination problems	329
6	Physical properties of interplanetary dust	329
7	Future experiments	331
	References	332
6	Microparticle Studies by Space Instrumentation	337
	<i>J. A. M. McDonnell</i>	
1	Introduction	337
2	Detection techniques in space	337
3	Measurements in space	348
3.1	Impact craters and foil penetrations	348
	Near earth	349
	Deep space at ~1 AU heliocentric distance	357
	Lunar sample studies	358

3.2	Impact plasma, microphone sensors, and combined sensors	362
	Near earth	362
	Cis-lunar and deep space	365
	Distant interplanetary missions	375
3.3	Space measurements reviewed	380
	Interplanetary flux	381
	Near-earth environment	382
	Lunar surface	383
	Characteristics of the interplanetary flux model	384
4	Characteristics of the cosmic dust complex measured by spacecraft . .	386
4.1	Directional anisotropy	388
4.2	Heliocentric radial dependence	397
4.3	Planetary enhancement	400
4.4	Temporal variations	406
4.5	Sources and sinks of microparticles in the solar system	411
	Appendix: Sensor calibration factors	413
	References	419
	Acknowledgements	419
7	Lunar and Planetary Impact Erosion	427
	<i>D. G. Ashworth</i>	
1	Introduction	427
2	The Moon	429
2.1	Erosion processes	433
2.2	Lunar crater morphology	433
2.3	Physical properties of micrometeoroids	435
2.4	Chemical properties of micrometeoroids	437
2.5	Velocity of micrometeoroids	438
2.6	Exposure ages of lunar samples	439
2.7	Micrometeorite mass-crater diameter relationships	440
2.8	Erosion processes on the lunar surface	441
2.8.1	Thermal erosion	441
2.8.2	Solar wind sputter erosion	442
2.8.3	Meteoroid impact erosion	444
2.9	Crater statistics	450
2.9.1	Craters with diameters in the range $1\text{ cm} < D < 3\text{ km}$	450
2.9.2	Craters with diameters in the range $300\text{ m} < D < 300\text{ km}$	454
2.9.3	Craters with diameters in the range $0.1\ \mu\text{m} < D < 1\text{ cm}$	459
2.9.4	Craters with diameters in the range $150\ \mu\text{m} < D < 1\text{ cm}$	461
2.9.5	Craters with diameters in the range $2\ \mu\text{m} < D < 150\ \mu\text{m}$	466
2.9.6	Craters with diameters in the range $0.1\ \mu\text{m} < D < 2\ \mu\text{m}$	469
2.9.7	Computer erosion models	472
2.9.8	Exposure ages derived from crater statistics	475
2.10	Destruction of lunar rocks	476
2.10.1	Small particle abrasion	477
2.10.2	Catastrophic rupture	481
2.11	Cratering in the lunar regolith	486
2.12	Flux of micrometeoroids and meteoroids	490
3	The planets	495
3.1	The Earth	495
3.2	Mars	504
3.3	Phobos and Deimos	507

3.4 Mercury	508
References	512
8 Particle Dynamics	527
<i>J. S. Dohnanyi</i>	
1 Motion of bodies in gravitational fields	527
1.1 The central force problem	527
1.1.1 Orbits	527
1.1.2 Lagrangian points	529
1.1.3 Gravitational focusing	530
1.2 Orbits of interplanetary objects	532
1.2.1 Comets	532
1.2.2 Asteroids	534
1.2.3 Meteors	536
1.2.4 Particle distribution from satellite observations	542
1.3 Perturbations	546
1.3.1 Resonant perturbations	546
1.3.2 Random perturbations	548
2 Interaction with the interplanetary environment	558
2.1 Solar radiation	558
2.1.1 Radiation pressure	558
2.1.2 The Poynting–Robertson effect	562
2.1.3 Influence of the solar wind	564
2.1.4 Influence of the Sun’s magnetic field	565
2.1.5 Radial distribution of meteoroids	566
2.2 Influence of collisions	567
2.2.1 Comminution	567
2.2.2 Erosive collisions	568
2.2.3 Catastrophic collisions	569
2.2.4 Population dynamics	570
2.2.5 β -meteoroids	573
2.2.6 Survival times of interplanetary particles	575
2.3 Meteor streams	580
2.4 Rotations	582
2.4.1 Influence of collisions	582
2.4.2 Influence of radiation pressure	583
2.4.3 Radzievski effect	585
Acknowledgements	587
References	587
9 Laboratory Simulation	607
<i>H. Fechtig, E. Grün, and J. Kissel</i>	
1 Introduction	607
2 Hypervelocity accelerators for simulation of micrometeoroids	608
2.1 Explosive accelerators	609
2.2 Rockets	611
2.3 The light-gas gun	611
2.4 Plasma drag accelerators	613
2.5 Electromagnetic accelerators	615
2.6 Electrostatic accelerators	616
2.7 Comparative remarks	621

3	High velocity impact processes	622
3.1	Initial partition of energy	623
3.2	Melting	625
3.3	Cratering	626
3.4	Ejecta	629
3.5	Impact light flash	629
3.6	Impact ionization	631
3.7	Energy balance	636
4	Impact ionization detectors	637
4.1	Description and calibration of detectors flown in space missions	637
4.1.1	The dust experiments on Pioneers 8 and 9	637
4.1.2	The micrometeoroid detector aboard Prospero	640
4.1.3	The micrometeoroid experiment on HEOS-2	641
4.1.4	The micrometeoroid analyser on Helios 1 and 2	642
4.1.5	The meteoroid flux detector on the Meteoroid Technology Satellite (MTS)	645
4.2	Comparison of the sensitivities of different impact ionization detectors	645
5	Penetration and impact phenomena	647
5.1	Penetration measurements	647
5.2	Crater phenomenology	652
5.3	Crater sizes	655
5.4	Projectile structure and chemistry measurements	657
6	Future developments	663
	References	664
	Author Index	671
	Subject Key	687
	Subject Index	689