

A Comet's Tail Is Not One Tail but Two, Pulled by Different Forces

— Radiation Pressure Balances Gravity at a Grain Radius of **0.2296** μm — The Ion Tail Leans Only **5.7106**

Degrees in the Solar Wind, While the Dust Tail Fans Out by Grain Size — [Paper 339]

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— *From thinking to syncing.* —

Abstract

A comet trails its tail away from the Sun. This paper asks whether that tail is one thing—the answer is that there are two, and the forces pulling them are different. No new mathematical theorem and no new law is claimed. First, computing where radiation pressure balances gravity gives a grain radius of **0.2296** μm (Section 2). Second, this is the core of the paper. Across that boundary the same Sun turns from pulling to pushing (Section 2). Third, the ratio β goes as the reciprocal of grain size. A grain ten times larger is pushed a tenth as hard (Section 2). Fourth, the ion tail is dragged by the solar wind and leans only **5.7106** degrees (Section 3). Fifth, halve the wind speed and the lean becomes **11.3099** degrees. The tail is an instrument for measuring a wind one has not visited (Section 3). Sixth, the separator is whether the material is ionised (Section 5).

Scope of this paper (scope note): No new mathematical theorem and no new law is claimed—the ratio β of radiation pressure to gravity, the sweeping of ionised gas by the solar wind, and the curvature of dust tails are all standard. We do not build the physics of the nucleus—sublimation, ejection speeds, and nuclear structure are not entered. They are mentioned and no more. We compute no syndynes or synchrones—reconstructing the shape of a dust tail from grain size and ejection time is not entered. Only the boundary size and the direction of force are looked at. We do not treat magnetohydrodynamics—field draping and disconnection events are not entered. We treat no individual comet—observations of particular objects are not the subject; standard values are used. We do not treat Poynting-Robertson drag—long-term orbital evolution is not entered. Relation to earlier papers: Paper 328 showed that the same ellipse being three months out was evidence of a different cause—there two identical shapes were separated by phase; here two things that look like one tail are separated by lean and curvature. Both are “it looks the same and is not”. Paper 300 showed whether two things share a root is decidable—by that test the two tails here have distinct roots. Paper 325 showed the size of the drop is not in the angle of the rainbow—this is the converse: in a dust tail, grain size decides everything. A pair: the case where it does not enter and the case where nothing else does. Paper 337 showed the edge of the solar system to be five edges—there and here alike, one name covers several physical quantities. What is added is computing the $\beta = 1$ size with the assumed density stated, showing in numbers that the direction of force reverses across it, deriving the ion tail’s lean from the wind speed and giving its response to a change of wind, and putting the separator on ionisation.

1. Notation and the Question

Setting: As a comet nears the Sun, gas and dust stream from its nucleus. Both flow away from the Sun and form a tail.

Observation 1.1

Look closely at a photograph and there are two tails. One is blue and straight, the other white and curved—issuing from the same nucleus at the same time, and shaped differently.

Observation 1.2

The Sun exerts two forces. Gravity, which pulls, and radiation pressure, which pushes—both go as $1/r^2$, so their ratio β does not depend on distance.

Observation 1.3

The way of measuring is fixed first. Dust density $\rho = 2500 \text{ kg/m}^3$, radiation pressure efficiency $Q = 1$ (full absorption), solar luminosity $L = 3.828 \times 10^{26} \text{ W}$ — β goes as the reciprocal of density, so the size is undetermined unless the density is stated.

Question: What separates the two tails?

2. The $\beta = 1$ Grain Has a Radius of $0.2296 \text{ }\mu\text{m}$

Setting: For a spherical grain of radius s , radiation pressure goes with the cross-section πs^2 and gravity with the volume $\frac{4}{3}\pi s^3$. Their ratio is

$$\beta = \frac{3LQ}{16\pi GM_{\odot}c\rho s},$$

so β goes as the reciprocal of s —and distance cancels because both forces go as $1/r^2$.

Calculation 2.1: Solve for the size at which $\beta = 1$ (computed in this paper).

Quantity	Value
Radius at $\beta = 1$	$2.296358 \times 10^{-7} \text{ m} = 0.2296 \text{ }\mu\text{m}$
the same as a diameter	$0.4593 \text{ }\mu\text{m}$

Observation 2.2

A check—the boundary is usually said to be sub-micron, and $0.2296 \text{ }\mu\text{m}$ falls there. Change the density to 1000 kg/m^3 (ice) and the boundary moves by a factor of 2.5, so this figure carries its density assumption with it.

Calculation 2.3: Tabulate β against grain size (computed in this paper).

Radius [μm]	β	Effective force
0.05	4.5927	repulsion wins
0.1	2.2964	repulsion wins
0.2296	1.0000	balance
1.0	0.2296	attraction wins
10.0	0.0230	attraction wins
100.0	0.0023	attraction wins

Observation 2.4

This is the core of the paper. The same Sun falls on the pulling side or the pushing side according to the size of the grain alone—a 0.2 μm grain flies away from the Sun and a 1 μm grain falls toward it.

Observation 2.5

Since β goes as the reciprocal of s , a grain ten times larger is pushed a tenth as hard. 0.229636 against 0.022964—larger grains follow gravity and stay along the comet's orbit.

Observation 2.6

So the dust tail spreads out by grain size. Small grains are pushed far, large ones stay near the nucleus—what looks like one tail is a continuous band sorted by size.

3. The Ion Tail Leans 5.7106 Degrees in the Solar Wind

Setting: Gas molecules are ionised by solar ultraviolet. Ions are caught by the magnetic field of the solar wind and carried with it.

Calculation 3.1: With the comet moving at orbital speed v_o , the tail leans against a wind of speed v_{sw} (computed in this paper).

Solar wind v_{sw} [km/s]	Comet v_c [km/s]	Lean $\arctan(v_c/v_{sw})$
400	40	5.7106°
200	40	11.3099°

Observation 3.2

5.7106 degrees is small. The ion tail points almost exactly anti-sunward——whichever way the comet is travelling, the tail runs straight away from the Sun.

Observation 3.3

This lean has exactly the form of aberration. The arctangent of the ratio of the observer's speed to the speed of what arrives——it is the $\tan \alpha = v/c$ of Paper 328 with c replaced by the wind speed.

Observation 3.4

Halve the wind and the lean roughly doubles. From 5.7106 to 11.3099 degrees——so measuring the lean reads off the speed of the wind. The tail is an instrument for measuring a wind one has not visited.

Observation 3.5

The dust tail curves for an entirely different reason. Dust is not caught by the field; it keeps the orbital velocity it had when released and is pushed according to its β ——each grain traces its own orbit, and together they make a curved fan.

Observation 3.6

The two ways of bending, side by side.

Dragged by		Why it bends	Dependence on grain size
Ion tail	the solar wind	the comet's motion (5.7106°)	none
Dust tail	radiation pressure	β per grain	everything

4. Separating What Looks Like One Tail, by the Criterion of Paper 300

Calculation 4.1: Apply the three criteria of Paper 300.

Criterion	Result
Is there a correspondence preserving an identity	No. Electromagnetic entrainment and radiation pressure are different equations
Does the same quantity appear	No. v_c/v_{sw} against $\beta(s)$
Do they keep agreeing as variables move	No. Change the grain size and only the dust moves

Observation 4.2

All three point to distinct roots. Change the grain size and the ion tail does not stir; change the wind speed and the dust tail does not stir—two things that move independently.

Observation 4.3

Even their colours differ. The ion tail is blue from carbon monoxide ion emission; the dust tail is white from scattered sunlight—emission against scattering; even how the light comes out is different.

Observation 4.4

To be stated honestly—the β used here assumes full absorption ($Q = 1$). Real efficiency oscillates with the ratio of grain size to wavelength, and below a micron it can be either less or more than 1— $0.2296 \mu\text{m}$ shows the decade, not a precise boundary.

Observation 4.5

It pairs with Paper 325. Paper 325 wrote that the size of the drop is not in the angle of the rainbow—here the shape of the dust tail is decided by grain size and nothing else. A pair: the case where it does not enter and the case where nothing else does.

5. The Separator: Ionised, or Not?

Observation 5.1

The separator—whether the material carries a charge.

Charge		What it follows	Shape of the tail
Ions	yes	the magnetic field (solar wind)	straight
Dust	no	radiation pressure and gravity	curved

Observation 5.2

The separator is not the kind of substance. The same molecule goes to the ion tail if ionised and behaves like dust if not—the presence or absence of one electron decides where it goes.

Observation 5.3

The separator can be moved. Move away from the Sun, the ultraviolet weakens, ionisation stops and the ion tail disappears—leaving the dust tail alone. The two can be extinguished independently.

Observation 5.4

On the dust side there is a further division. Grains with $\beta > 1$ are expelled from the solar system and those with $\beta < 1$ stay in orbit—inside one dust tail, fates part at a radius of 0.2296 μm .

Observation 5.5

To be stated honestly—a third tail, of sodium, has been reported. Only two are treated here—“there are two” is a claim about the principal two, not an exhaustive count of kinds of tail.

Observation 5.6

One last thing—that the tail points away from the Sun was itself the evidence for the solar wind. Because the tail runs anti-sunward whichever way the comet travels, it was inferred that something streams out from the Sun—long before any spacecraft went there, the direction of a tail was measuring a wind.

6. The Census and the Close

1. The $\beta = 1$ radius is $0.2296 \mu\text{m}$ (Calculation 2.1): assuming 2500 kg/m^3 .
2. $\beta = 4.5927$ at $0.05 \mu\text{m}$ (Calculation 2.3): repulsion wins.
3. β goes as the reciprocal of size (Observation 2.5): ten times larger, a tenth as hard.
4. The ion tail leans 5.7106 degrees (Calculation 3.1): almost exactly anti-sunward.
5. Exactly the form of aberration (Observation 3.3): c replaced by the wind speed.
6. 11.3099 degrees at half the wind (Calculation 3.1): the tail is an anemometer.
7. Distinct roots on all three criteria (Calculation 4.1): they move independently.
8. Emission against scattering (Observation 4.3): why the colours differ.
9. One electron decides where it goes (Observation 5.2): not the kind of substance.
10. Fates part at $0.2296 \mu\text{m}$ (Observation 5.4): a further division inside the dust.

Closing: A comet trails its tail away from the Sun, and that tail is not one but two, pulled by different forces—one blue and straight, one white and curved, issuing from the same nucleus at the same time and shaped differently. What decides the dust is β , the ratio of radiation pressure to gravity—both go as $1/r^2$, so the ratio is independent of distance and goes as the reciprocal of grain size. Balance falls at a radius of $0.2296 \mu\text{m}$ (assuming 2500 kg/m^3), and across it the same Sun turns from pulling to pushing. A $0.2 \mu\text{m}$ grain flies away from the Sun and a $1 \mu\text{m}$ grain falls toward it. So what looks like one dust tail is a continuous band sorted by size. The ions are dragged by the solar wind instead—ionised molecules are caught by the field and carried with it. The lean from the comet’s own motion is $\arctan(40/400) = 5.7106$ degrees, so the tail points almost exactly anti-sunward. This is the $\tan \alpha = v/c$ of aberration in Paper 328 with c replaced by the wind speed. At half the wind the lean is 11.3099

degrees, so the lean of a tail reads off a wind one has not visited. All three criteria of Paper 300 point to distinct roots——change the grain size and the ion tail does not stir; change the wind and the dust tail does not. Even the colours differ for different reasons: emission for the ions, scattering for the dust. One thing separates them——whether the material carries a charge. And the separator is not the kind of substance——the same molecule goes to the ion tail if ionised and behaves like dust if not; the presence or absence of one electron decides where it goes. It can be moved, too——move away from the Sun, the ultraviolet weakens, and the ion tail alone disappears. To be said honestly——the β here assumes full absorption, while real efficiency oscillates with the ratio of size to wavelength; $0.2296\ \mu\text{m}$ shows the decade, not a precise boundary. A third tail, of sodium, has also been reported, so “there are two” is a claim about the principal two. One last thing——that the tail points away from the Sun was itself the evidence for the solar wind. Because it runs anti-sunward whichever way the comet travels, it was inferred that something streams out from the Sun. Long before any spacecraft went there, the direction of a tail was measuring a wind.

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