A Study of Evolving Optical Caustics Formed by Evaporating Water Droplets

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INTRODUCTION

OPTICAL CAUSTICS
• Optical caustics are concentrated envelopes of light rays reflected or refracted by a curved surface of an object, or the projection of that envelope of rays on another surface
• Familiar examples of caustics: rainbow, bright lines in water droplets and on the bottom of a swimming pool, and the sharp light curves formed by a wine glass or coffee mug (Fig. 1)

CATASTROPHE THEORY
• Catastrophe theory, developed by the French mathematician Rene Thom in the 1970s, is the study of how changing control variables leads to qualitative changes in the solutions of an equation
  - It has been applied to different phenomena, such as the stability of ships and bridge collapses, optical caustics, however, are one of the best visual illustrations of how it can be applied
  - Berry [7] first applied the theory to caustics seen by evaporating water droplets

EXPERIMENTAL METHODS

MICROSCOPE SLIDE SETUP
• Microscope slide was placed vertically for the far field viewing method (Fig. 3)

FAR FIELD VIEW
• When laser light passes through a water droplet the perturbations produce a far field caustic, known as the parabolic umbilic in the catastrophe theory classification
• Laser beam (λ = 633nm) was expanded to about 1mm in diameter with two lenses
• When rays from a distant point source of light pass through an evaporating water droplet the perturbations produce an envelope of light rays reflected or refracted by the surface of the droplet (Fig. 4)

DATA

RESULTS
Table 2

<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>Observations</th>
<th>Picture number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Fold caustic present</td>
<td>2.f</td>
</tr>
<tr>
<td>600</td>
<td>Elliptic umbilic forming</td>
<td>2.P</td>
</tr>
<tr>
<td>960</td>
<td>More pronounced elliptic forming</td>
<td>2.e</td>
</tr>
<tr>
<td>1380</td>
<td>Triangle pattern (elliptic umbilic) pronounced</td>
<td>2.d</td>
</tr>
<tr>
<td>1800</td>
<td>Elliptic moves towards fold</td>
<td>2.e</td>
</tr>
</tbody>
</table>

ANALYSIS

• Entire evolution observed shows parabolic umbilic caustic unfolding, not every step is seen visually because some are blurred out by diffusion (Fig. 6)
• Parabolic umbilic caustic unfolding can be observed by manipulating the generating function (the first three have been studied so far)
• Goal was to derive the caustic curve for each catastrophe by deriving the generating function (the first three have been studied so far)

FUTURE STUDIES
• Study of far field caustic behavior of evaporating water droplets (Fig. 8)
• A clearer understanding of the caustic curves for higher dimension catastrophes
• Investigation of caustics of higher order singularities (ex: symbolic umbilic $E_3$)

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REFERENCES