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# Optical Scattering Methods Applicable to Drops and Bubbles

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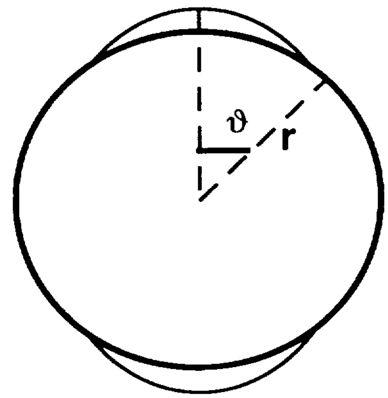
An overview of optical scattering properties of drops and bubbles will be given. The properties lead to unconventional methods for optically monitoring the size or shape of a scatterer and are applicable to acoustically levitated objects. Several of the methods are applicable to the detection and measurement of small amplitude oscillations. Relevant optical phenomena include: (1) rainbows, (2) diffraction catastrophes from spheroids, (3) critical angle scattering, (4) effects of coatings, (5) glory scattering, and (6) optical levitation. [Research partially supported by the Office of Naval Research.]




**OPTICAL PSEUDO-EXTINCTION METHOD FOR MEASURING** $\varepsilon_2(t)$

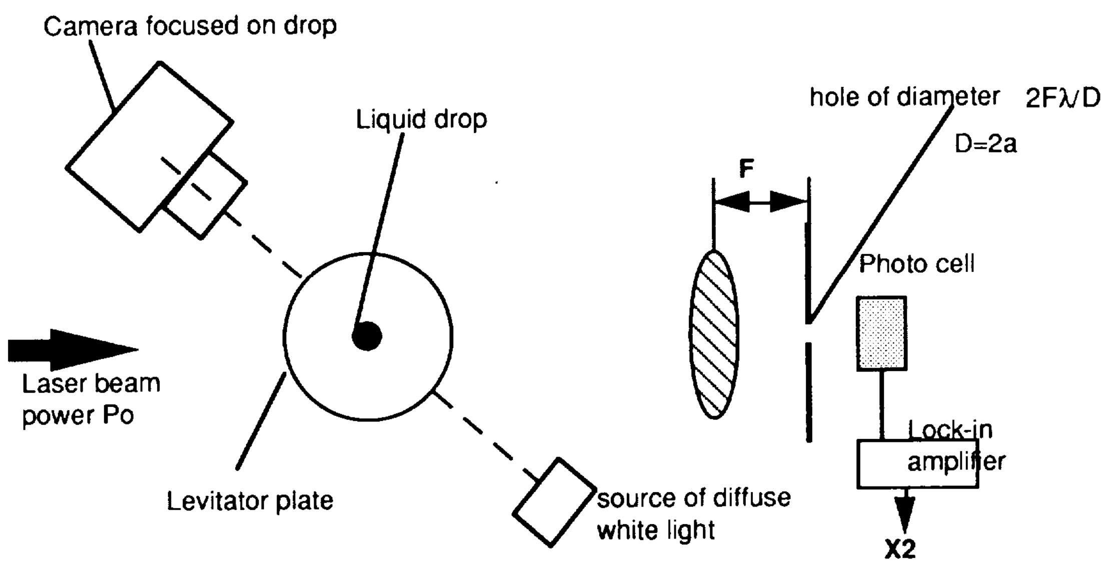
**R=a**

$$r(\vartheta,t) = R + \varepsilon_1(t)\cos\vartheta + \varepsilon_2(t)(3\cos^2\vartheta - 1)$$

$$A(t) = 1/2\int_0^{2\pi} r^2 d\vartheta = \pi R^2 + \varepsilon_2(t)\pi R + O(\varepsilon^3)$$

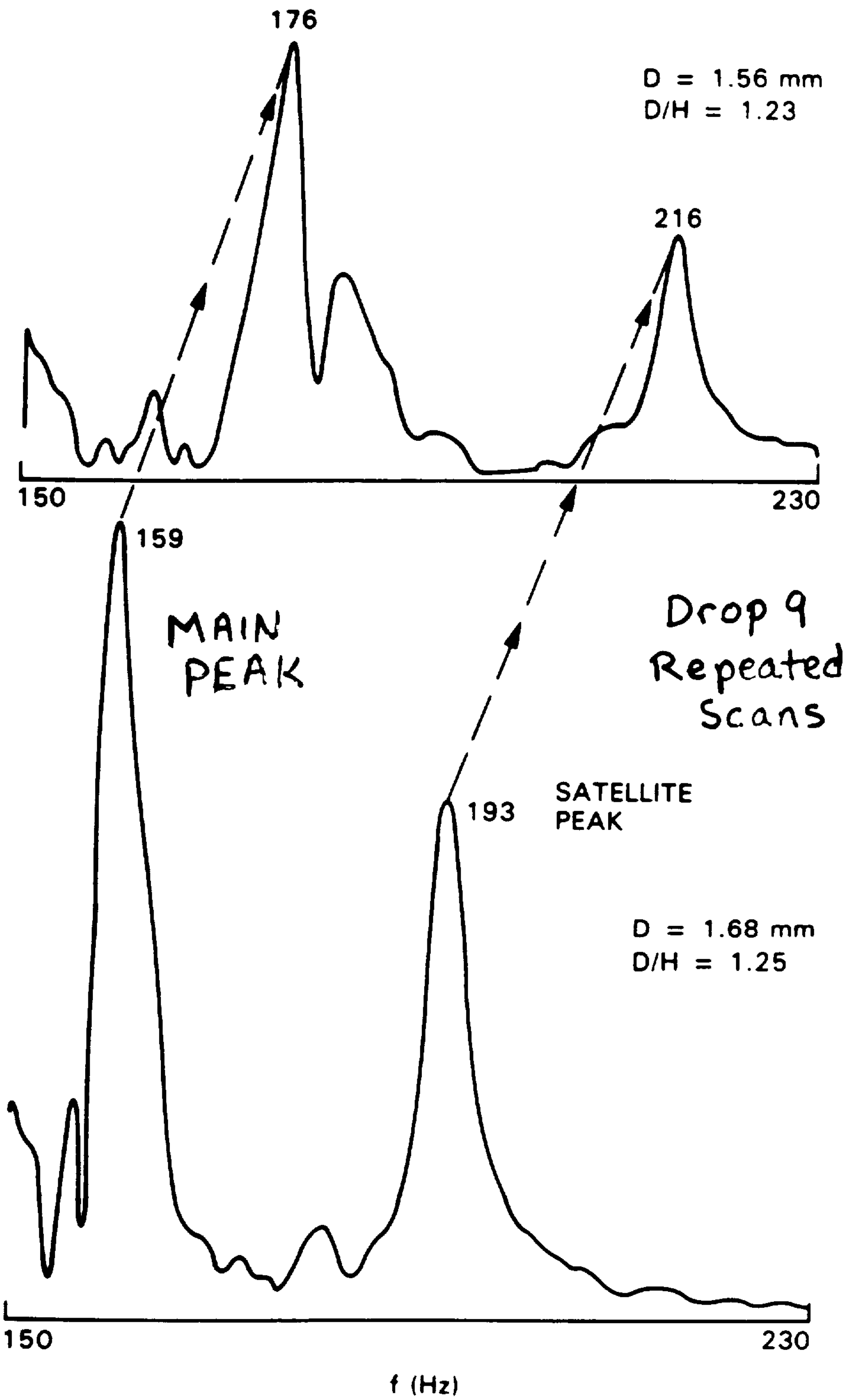
**A(t)**: cross sectional area

**POWER TO PHOTOCELL = Po - IA(t)**




$$\varepsilon_2(t) = x_2(f)\cos(2\pi f t + \psi) + \varepsilon_2(\text{equilibrium})$$

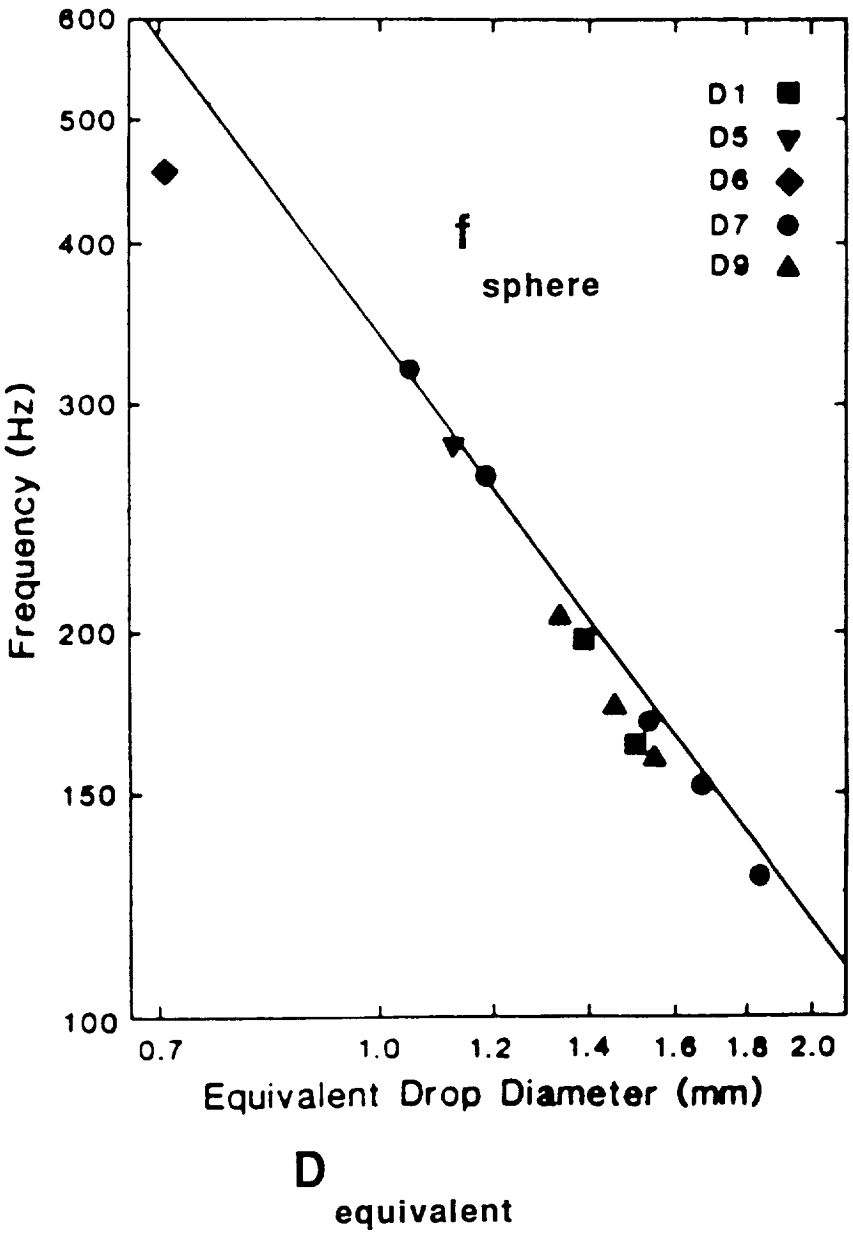
**INSENSITIVE TO THE POSITION OF THE DROP**

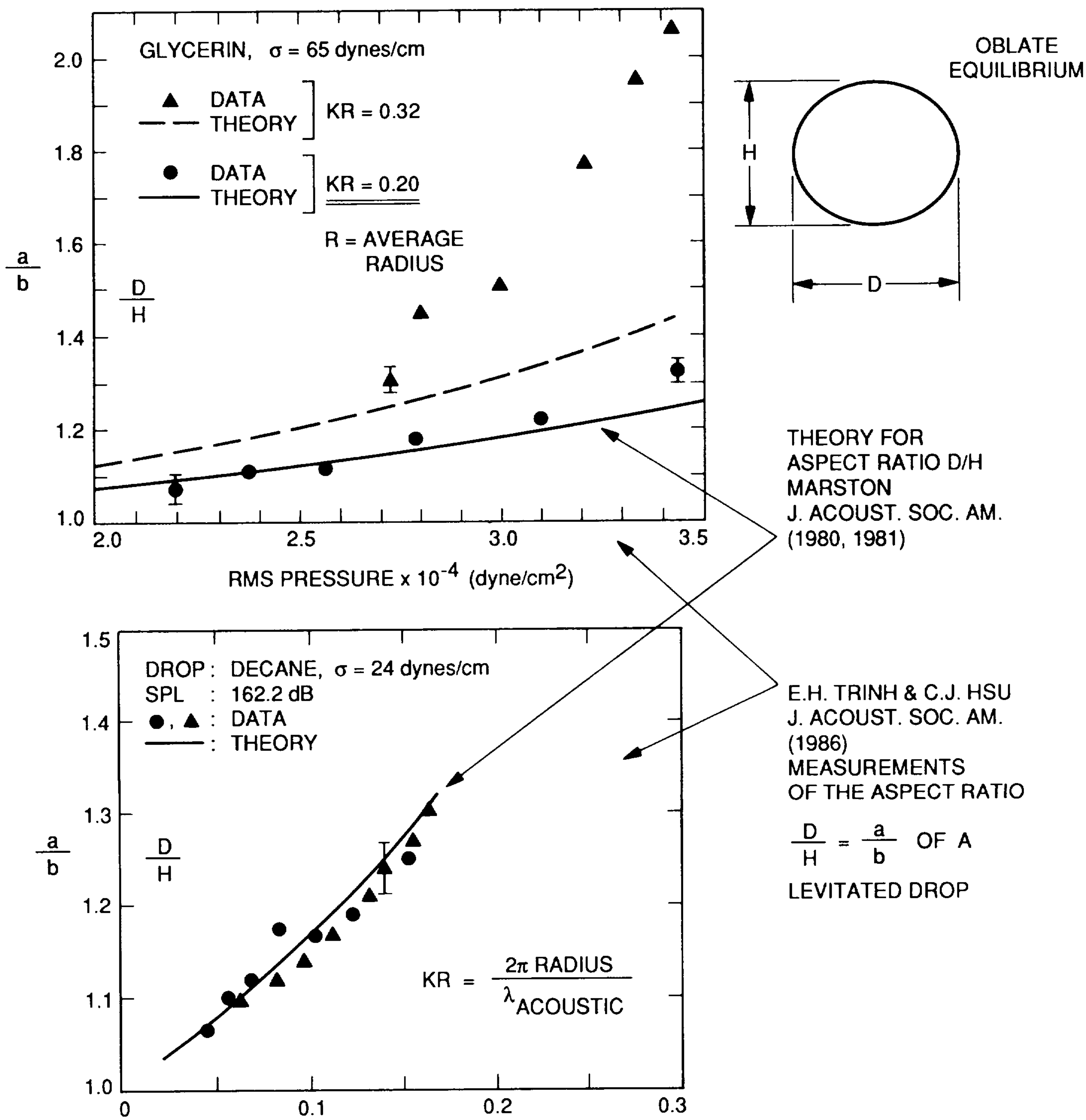

176
D = 1.56 mm
D/H = 1.23
216
150
230
159
MAIN PEAK
Drop 9 Repeated Scans
193
SATELLITE PEAK
D = 1.68 mm
D/H = 1.25
150
230
f (Hz)

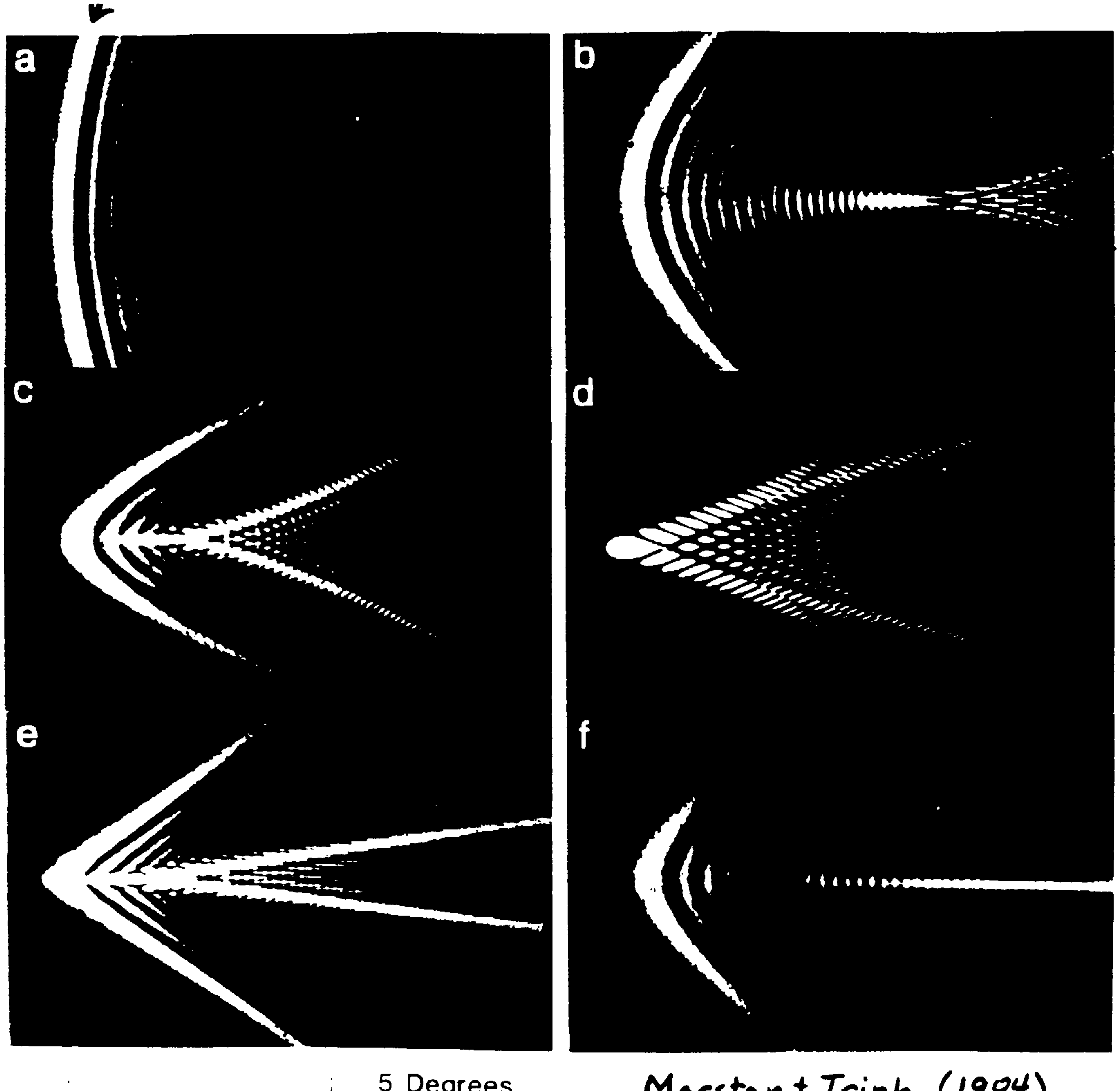
ADJUSTED DATA

D(equivalent) = DIAMETER OF SPHERE HAVING THE SAME VOLUME AS THE DROP:

$$D.D\left(\frac{D}{H}\right)^{-\frac{1}{3}}$$




GLYCERIN, σ = 65 dynes/cm
DATA
THEORY
KR = 0.32
DATA
THEORY
KR = 0.20
R = AVERAGE RADIUS
a/b
D/H
2.0
1.8
1.6
1.4
1.2
1.0
2.0
2.5
3.0
3.5
RMS PRESSURE x 10^-4 (dyne/cm^2)
OBLATE EQUILIBRIUM
H
D
THEORY FOR ASPECT RATIO D/H
MARSTON
J. ACOUST. SOC. AM. (1980, 1981)
DROP : DECANE, σ = 24 dynes/cm
SPL : 162.2 dB
●, ▲ : DATA
: THEORY
1.5
1.4
1.3
1.2
1.1
1.0
0
0.1
0.2
0.3
KR = 2π RADIUS / λ ACOUSTIC
E.H. TRINH & C.J. HSU
J. ACOUST. SOC. AM. (1986)
MEASUREMENTS OF THE ASPECT RATIO
D/H = a/b OF A LEVITATED DROP

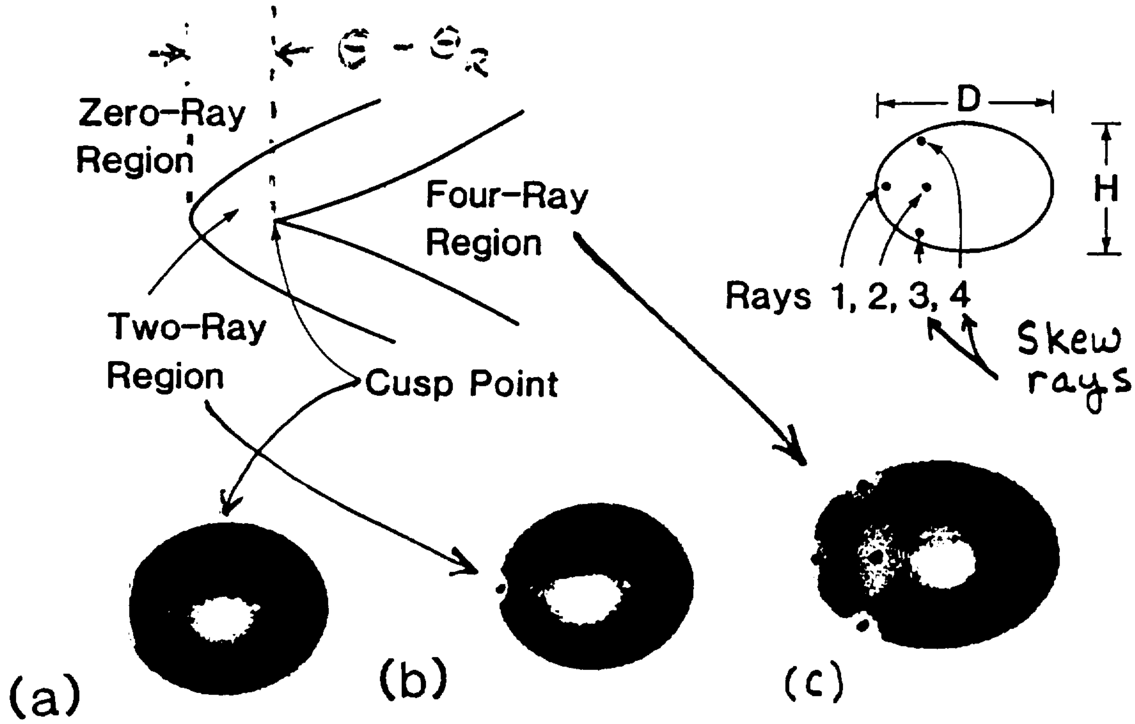



Transverse Cusp

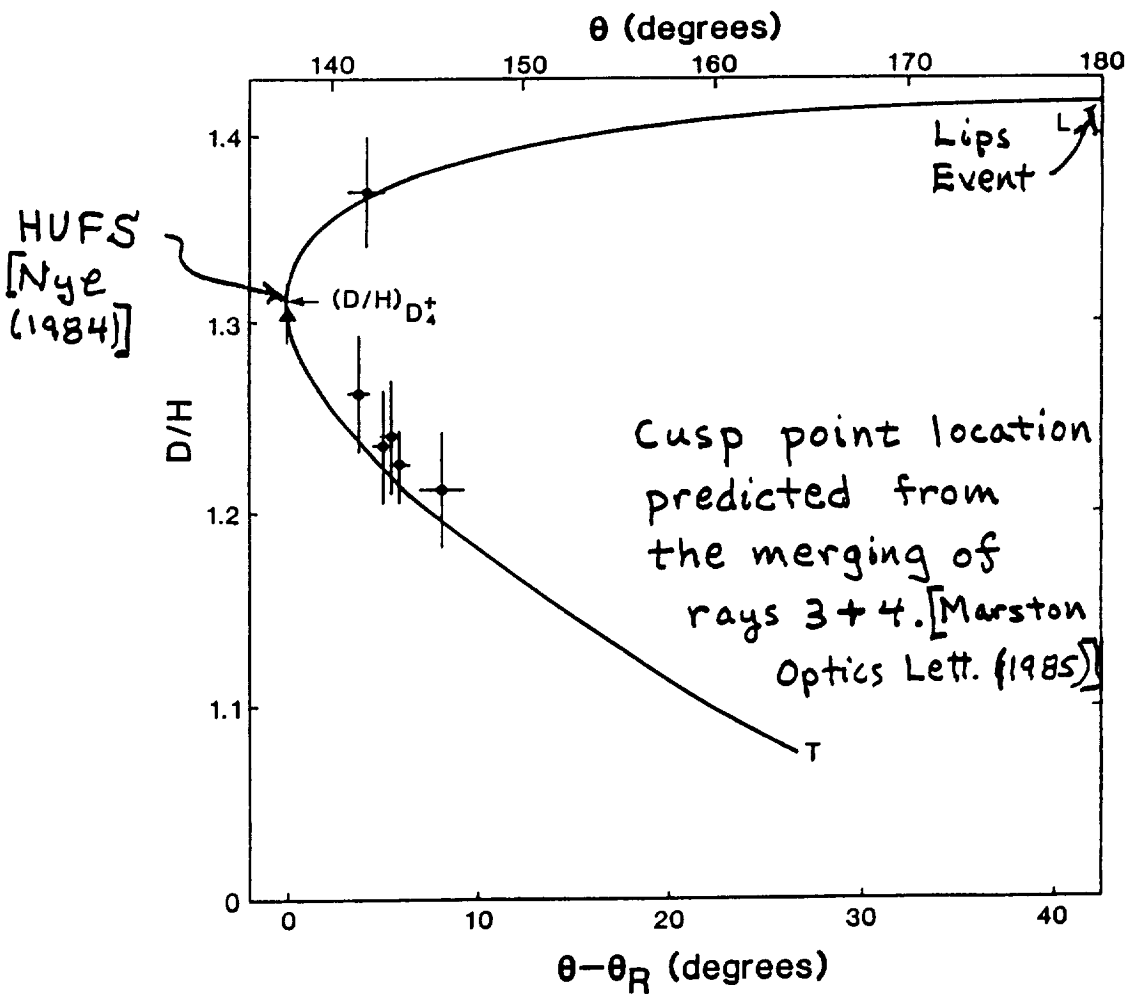
Hyperbolic Umbilic Focal Section

Marston + Trinh (1984)

Light scattering from oblate drop of water



$\theta - \theta_R$
Zero-Ray Region
Four-Ray Region
Two-Ray Region
Cusp Point
D
H
Rays 1, 2, 3, 4
Skew rays
(a)
(b)
(c)

θ (degrees)
140
150
160
170
180
D/H
1.4
1.3
1.2
1.1
0
Lips Event
L
HUFS [Nye (1984)]
$(D/H)_{D_4^+}$
Cusp point location predicted from the merging of rays 3 + 4. [Marston Optics Lett. (1985)]
T
0
10
20
30
40
$\theta - \theta_R$ (degrees)

# Rainbow scattering from spheroidal drops—an explanation of the hyperbolic umbilic foci

J. F. Nye Nature 312, 531 (Dec. 1984)

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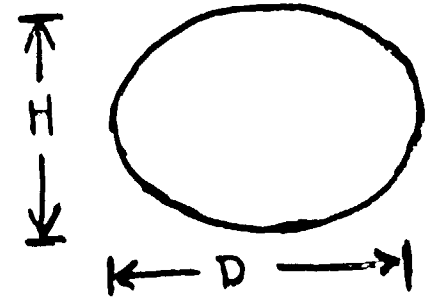


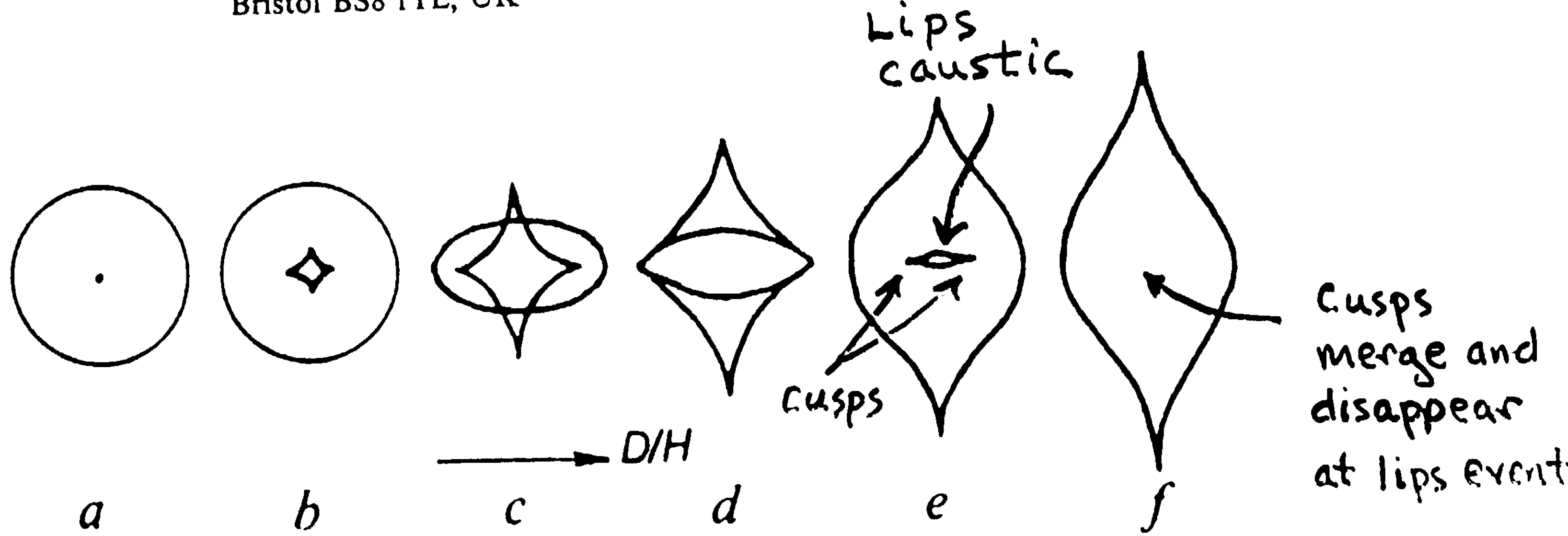
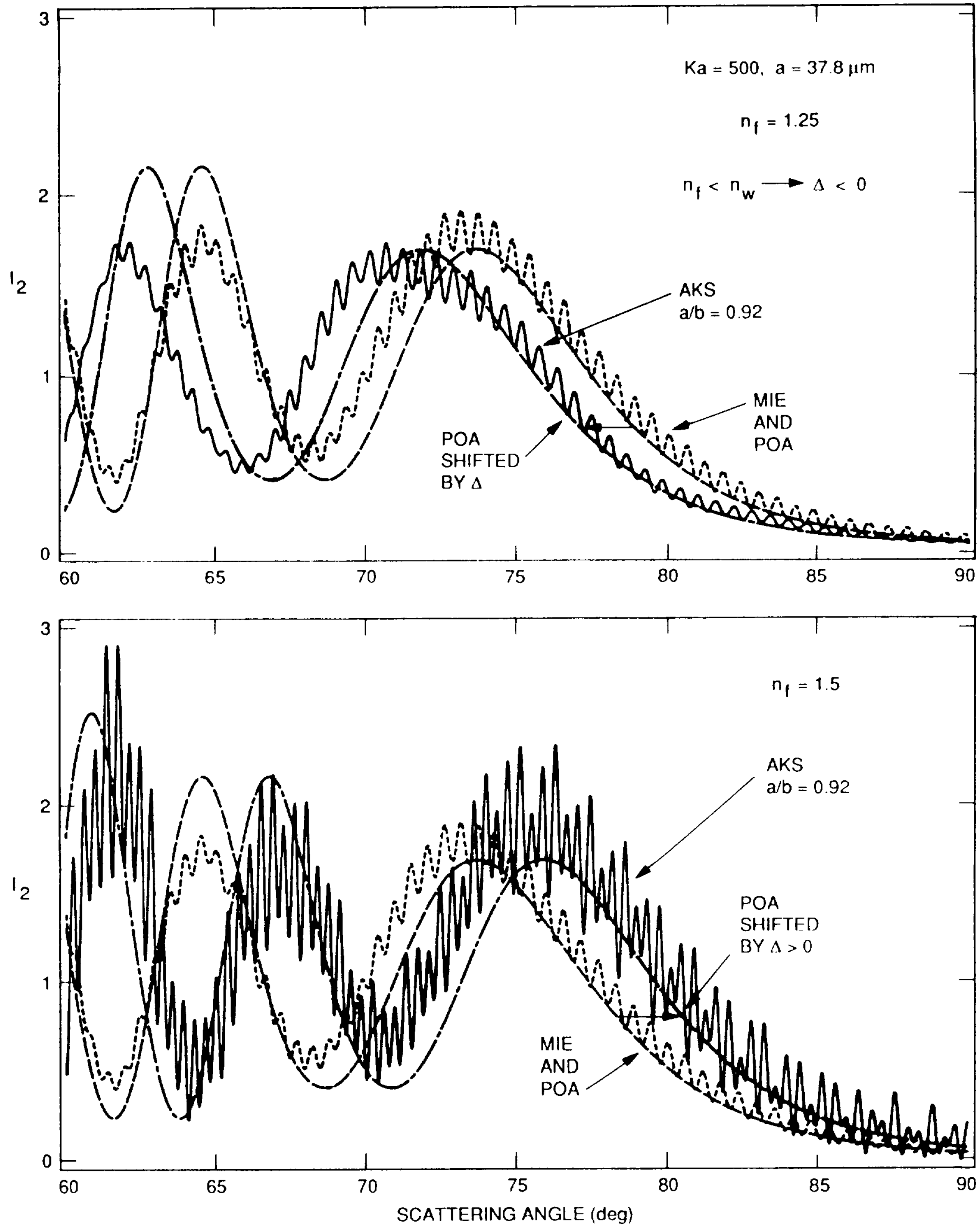




**Fig. 2** Sequence of caustics in the far field as $D/H$ increases from 1. *a*, The circular rainbow with a singular point at its centre. On perturbation the point breaks up (*b*, *c*) into an expanding four-cusped figure. At *d*, two hyperbolic umbilic foci occur. On further increase of $D/H$, the inner figure contracts (*e*), and then disappears (*f*) in a lips event. The angular width of the complete figure is the same throughout.


3
2
1
0
$I_2$
Ka = 500, a = 37.8 μm
$n_f$ = 1.25
$n_f < n_w \longrightarrow \Delta < 0$
AKS
a/b = 0.92
MIE
AND
POA
POA
SHIFTED
BY Δ
60
65
70
75
80
85
90
3
2
1
0
$I_2$
$n_f$ = 1.5
AKS
a/b = 0.92
POA
SHIFTED
BY Δ > 0
MIE
AND
POA
60
65
70
75
80
85
90
SCATTERING ANGLE (deg)