Scattering Calculations for Rain Drops Undergoing Asymmetric, Mixed Mode, Oscillations and their Impact on Polarimetric Radar Variables

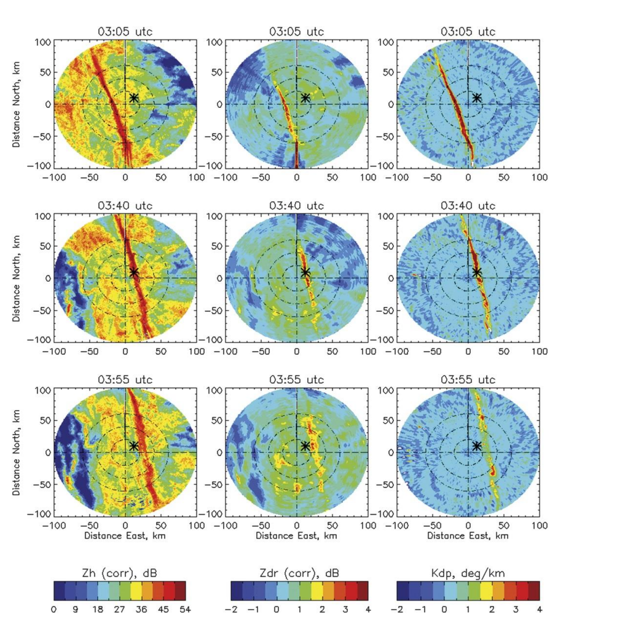
M. Thurai [1], E. Chobanyan [1], B. Notaroš [1], M. Schönhuber [2], and V. N. Bringi [1]
[1]Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, Colorado
[2]Joanneum Research, Graz, Austria

1. Introduction

Knowledge of drop shapes, oscillations, are of central importance for deriving retrieval algorithms for drop size distribution (DSD) parameters and rain rates as well as for attenuation-corrections for polarimetric radars. Previous work has shown that drop collisions can give rise to mixed mode oscillations and that for high collision rate scenarios, a significant % of drops can become 'asymmetric' at any given instant (Thurai et al., 2014). Here we present examples of scattering calculations for (a) simulated drop shapes and (b) reconstructed drop shapes from 2D video disdrometer (2DVD) measurements, with particular emphasis on asymmetric drop shapes.

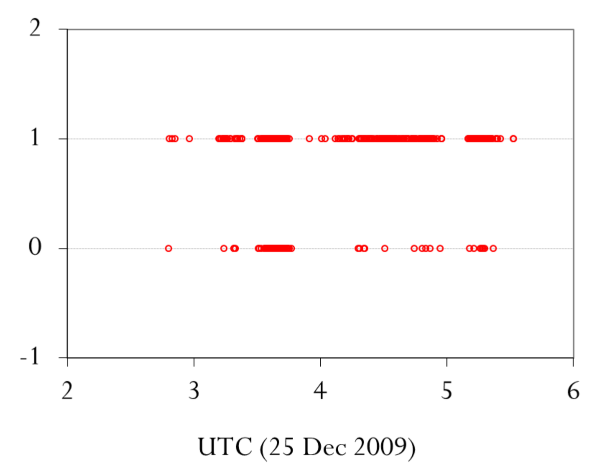
2. Experimental Evidence: Huntsville, Alabama, 25 Dec 2009

C-band ARMOR (UAH)



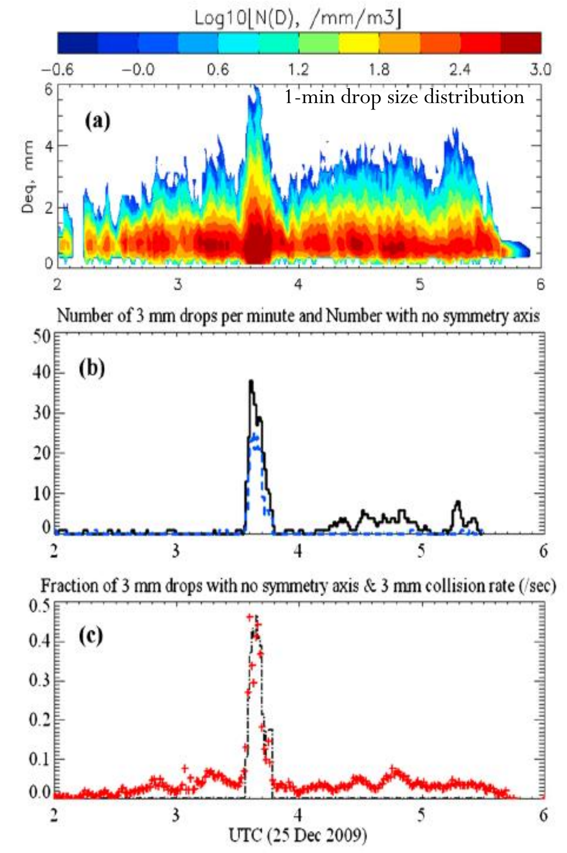
PPI scans of (left) attenuation-corrected Z_h, (middle) attenuation-corrected Z_{dr}, and (right) K_{dp}, taken at (top to bottom) 0305, 0340, and 0355 UTC. The 2DVD site is marked with an asterisk sign along 52° azim and 15 km range

Deskewability of 3 mm drop images from 2DVD



Significant fraction of the moderate-to-large sized drops did not possess rotational symmetry when convection line passed over the 2DVDs.

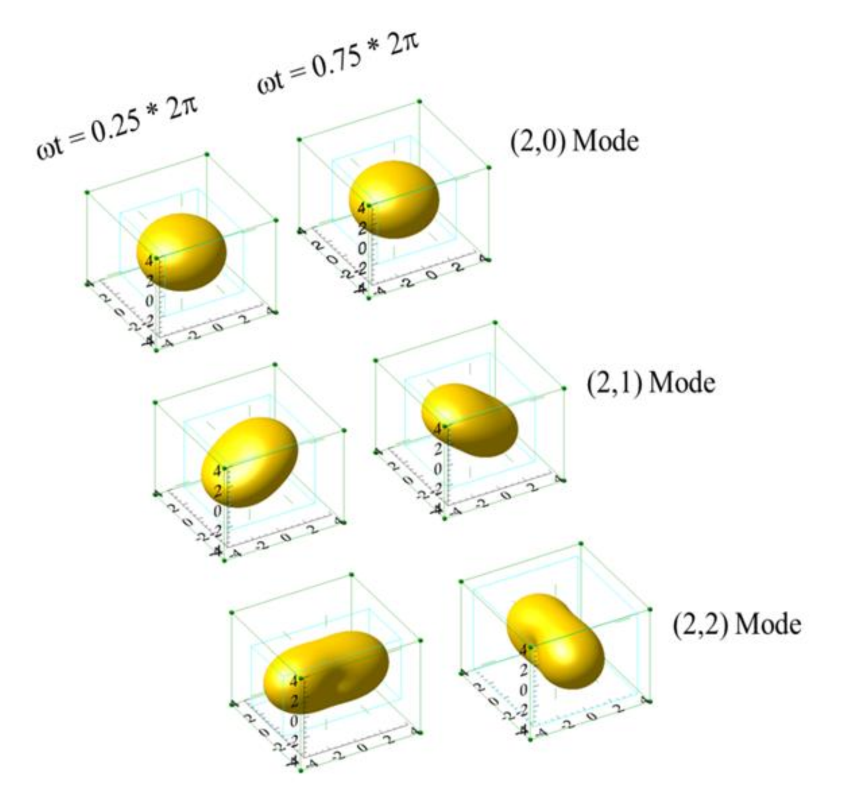
2DVD measurements and collision probability



Thought to be due to sustained drop collisions occurring within the convection line → causing a significant fraction to be undergoing mixed-mode oscillations at any given instant in time.

3. Simulated Drop Shapes

(a) Mixed Mode Oscillations

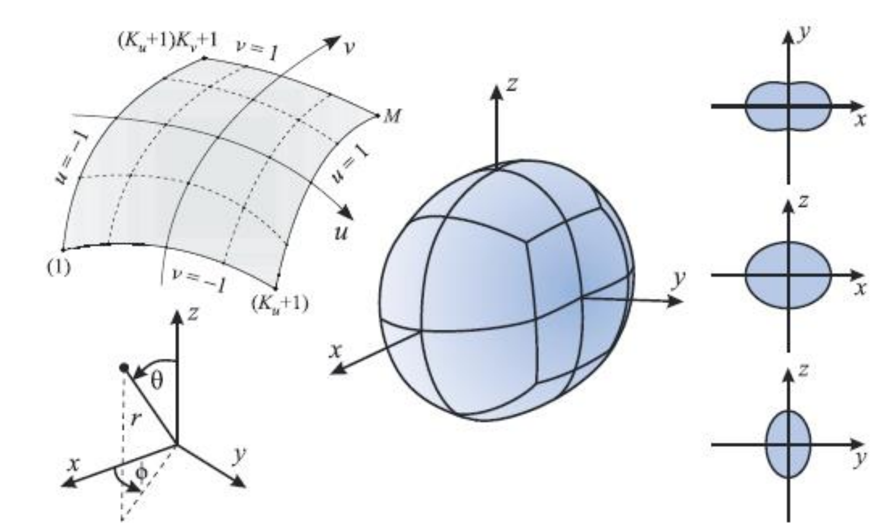


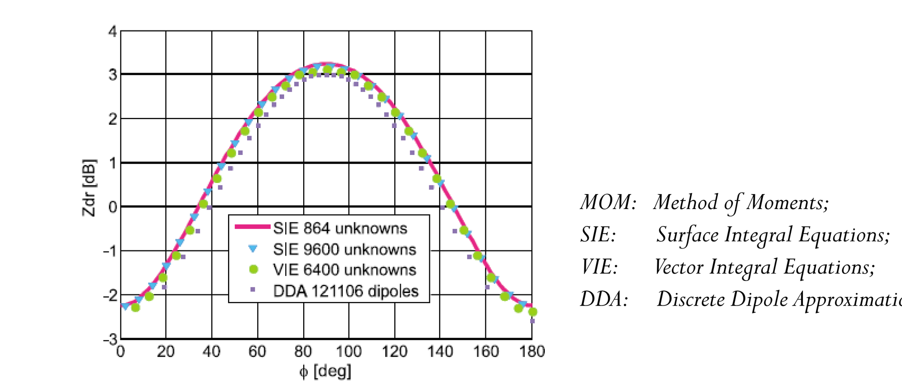
Three fundamental modes

$$r_{n,m}(t,\theta,\phi) = r_0 + A\sin(\omega t)P_{n,m}(\theta)\cos(m\phi)$$

$D_{eq} = 6mm;$ *oscillation amplitude = 10%*

(b) (2,2) Mode and Calculations

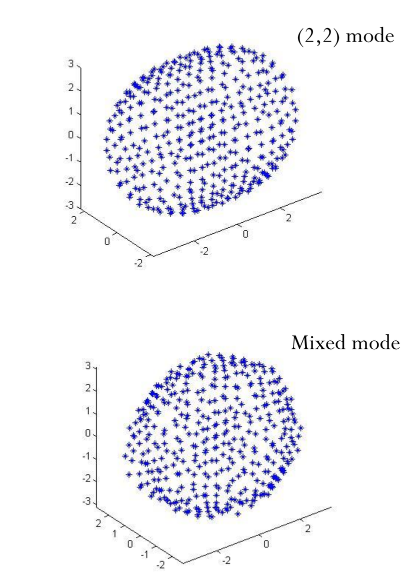


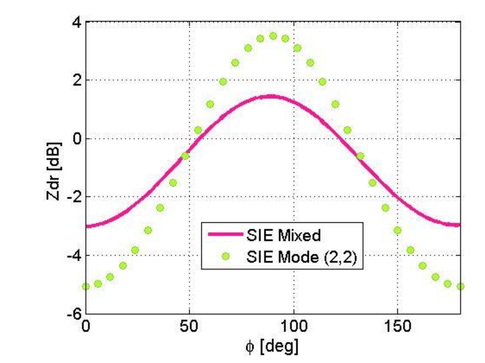


MOM: Method of Moments;
SIE: Surface Integral Equations;
VIE: Vector Integral Equations;
DDA: Discrete Dipole Approximation

Z_{dr} in the x-y plane for (2,2) mode; f = 3 GHz, $\varepsilon_r = 80 - j20$; Computed by the MOM-SIE on two models, MOM-VIE, and DDA code, with the first MOM-SIE solution being more than 1000 times faster than the DDA solution.

(c) Meshing and Mixed Mode Oscillations



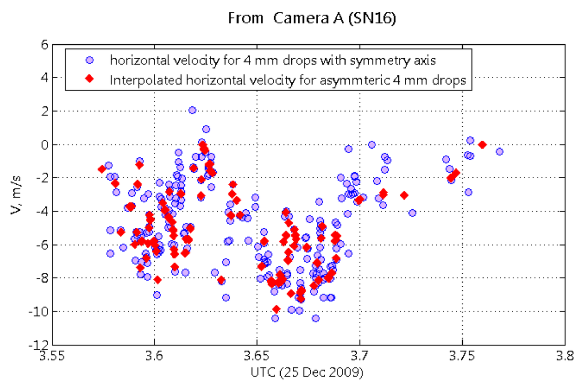


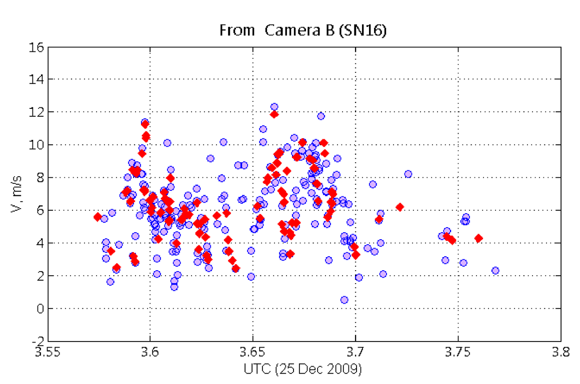
Z_{dr} in the x-y plane for (2,2) mode and mixed mode; f = 3 GHz

4. 2DVD Based Shapes in Natural Rain:

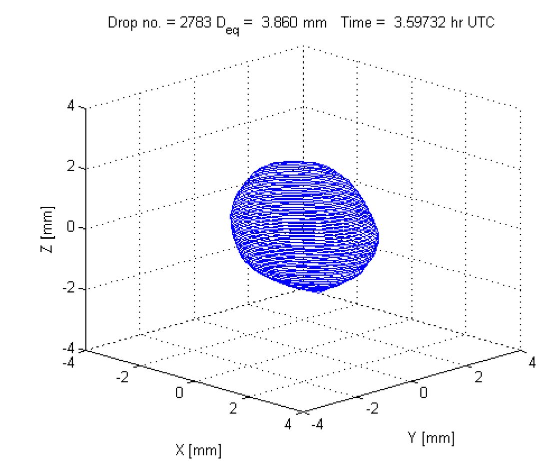
the shape measurements from the 2DVD for the abovementioned rain event in Huntsville are used. In order to reconstruct the shapes for drops which do not possess symmetry axis, we first need to know the horizontal velocity vector for each of these drops. To this end, we output all known horizontal velocities (from both 2DVD cameras) for drops of the same size that do have symmetry axis and for which the data processing algorithm can determine these velocities; this is then interpolated in time for the asymmetric drops. The velocity vectors so derived are then used for correcting the measured contours in the x-z and the y-z planes for each individual drop, and the corrected contours are subsequently used to construct the corresponding 3D shapes.

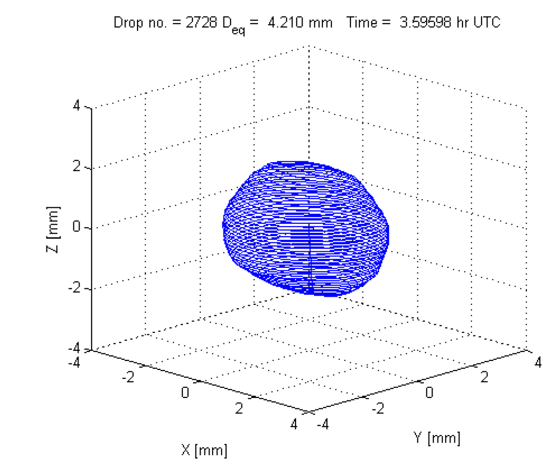
Interpolated horizontal velocities from cameras A and B images for $3.75 < D_{eq} < 4.25$ mm





Two examples:
(a) 4.2 mm drop and (b) 3.9 mm drop, both with no rotational symmetry axis, after being reconstructed using the interpolated horizontal wind velocities from cameras A and B





5. Ongoing Work:

We will continue with our two-fold approach for deriving shapes of drops undergoing asymmetric, mixed-mode oscillations as given in sections (3) and (4), i.e. theoretically simulated shapes and the reconstructed shapes from the 2DVD measurements in natural rain. Scattering calculations for such drops will also continue, using the efficient and accurate higher order method of moments in the surface integral equation formulation (Djordjević and Notaroš, 2004).

References:

Thurai, M., V. N. Bringi, A. B. Manić, N. J. Šekeljić, and B. M. Notaroš, 2014: 'Investigating raindrop shapes, oscillation modes, and implications for radio wave propagation', Radio Sci., **49**, 921–932, and some references therein.

Djordjević, M., Notaroš, B. M., 'Double higher order method of moments for surface integral equation modeling of metallic and dielectric antennas and scatterers', IEEE Transactions on Antennas and Propagation, 2004, **52**, (8), 2118-2129..

Acknowledgments: This work was supported by the National Science Foundation under grant AGS-1431127.