A prototype low cost disdrometer by using 3D print and Raspberry PI

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Motivation and objective:

- Measurements of size distribution of hydrometeors are important to understand the cloud microphysics process and to improve the remote sensing of precipitation.
- However, disdrometers are usually expensive (in thousands) and not affordable by general community. Also, most disdrometers are too heavy to be balloon borne. Existing videosondes are still too expensive to be disposable.
- With the new technology of 3D printing and cheap Raspberry PI computers, it is possible to build a light and relatively low cost disdrometer.

Instrument design:

- Using the optical scattering of hydrometeors, Disdro-TAMUCC positions a flat surface laser with an angle relative to the vertical path that hydrometeors fall through the collection chamber (Figure 1). When one or multiple hydrometeors intercept the laser beam, area of scatter of light is directly related to the size of the hydrometer. A global shutter camera is used to collect the scattered light signal, with a minimum smearing by the falling hydrometers, by taking the images with 60 fps.
- The light scattering area from hydrometeors increase with the distance to the camera. Using the slant laser beam, the vertical position where a hydrometeor encounter the beam is directly related to the distance to the camera.
- A Raspberry PI 4 is used to drive the camera and complete the real time image processing and calculate the light scatter area, position, and size of particles. Using VNC, whole instrument can be remotely controlled.

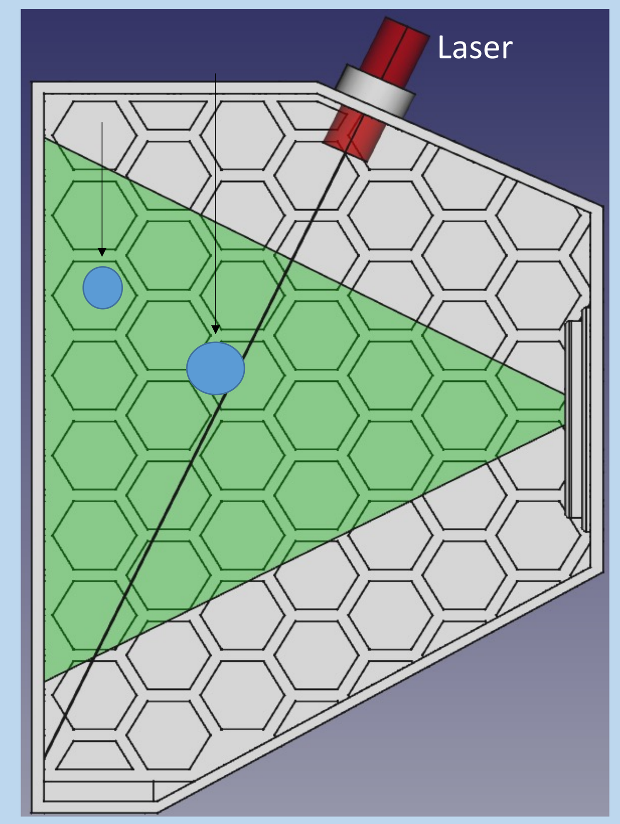

Figure 1: Schematic diagram of Disdro-TAMUCC. A laser flat surface beam is positioned with an angle relative to the fall of rain drops. A camera takes the images of scattered light by rain drops.

Low cost and light weight

- Cost of the disdrometer include Raspberry PI4 ($45) for realtime imagine processing; a low-end global shutter camera ($20-30); 3D printing material ($10-15) ; a flat line laser ($10) ; in total around $100
- Current version of Disdro-TAMUCC weigh only 570 g, including frame, raspberry pi, and laser. Adding batteries, this payload can certainly be balloon borne.

Estimate rain dorp diameter based on lab results:

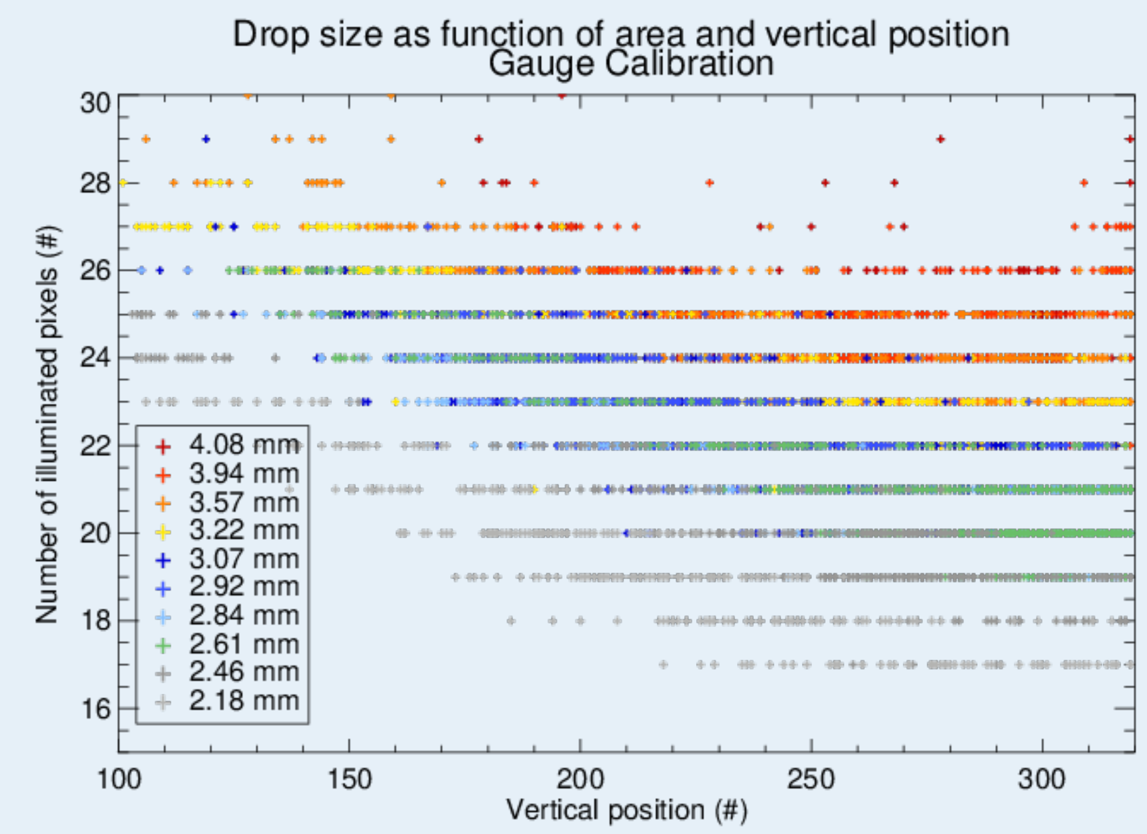

Figure 6: After collecting the objects from images for drops from needle different gauges. The size of particle can be shown as a function of vertical position and illuminated area from the camera image.

The equation to derive the particle diameter D is following:

$$D = a \cdot \text{Area}^{0.5} (b \cdot Y + c)$$

Using data in Figure 6, the constants a, b, c, can be derived. Note that these constants need to be calibrated for each instrument

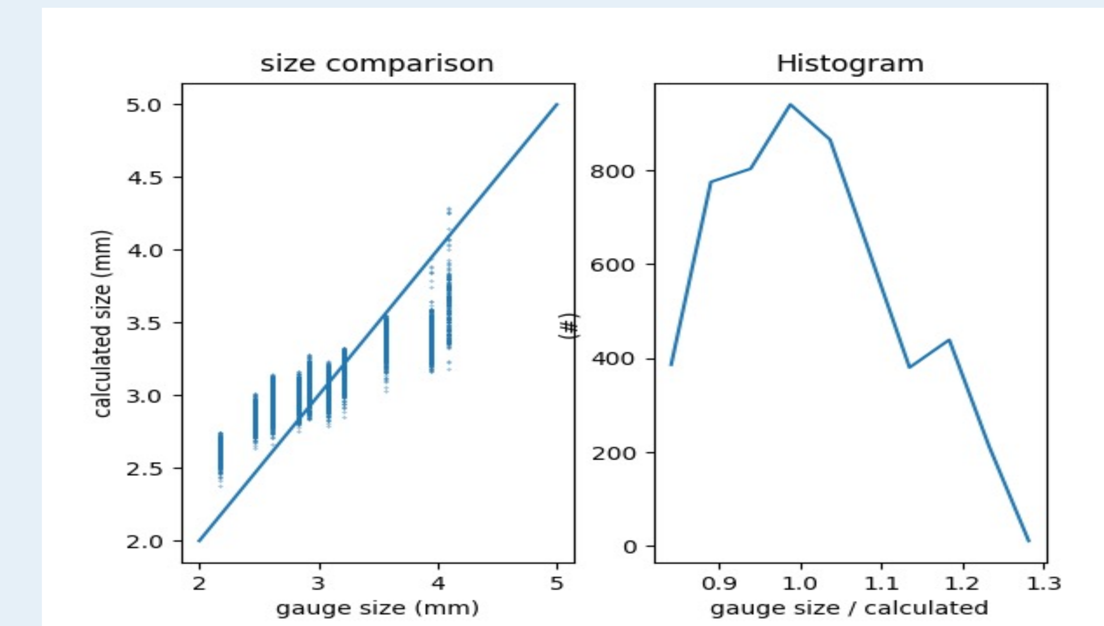

Figure 7: Using the equation, the particle sizes can be calculated from the area and vertical position of objects in images and compared to the gauge size. Note that the relationship can be extrapolated to smaller or larger sizes, though with large uncertainties.

3D printing

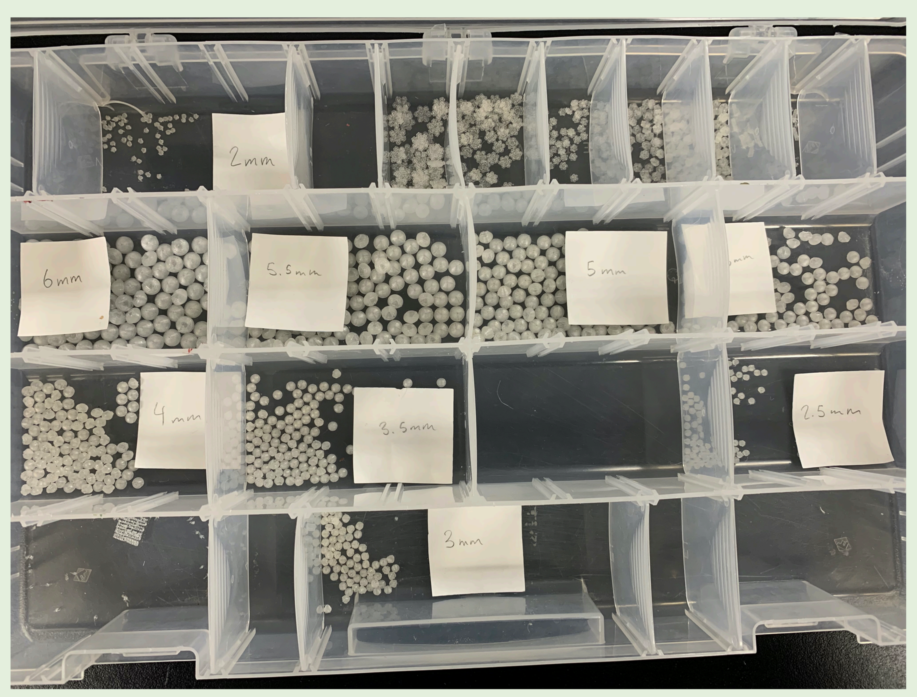

Figure 2: Rain drops and small snowflakes of various sizes (diameter > 2 mm) can be 3D printed with transparent PLA material. Note that PLA has a 25% higher density than water.

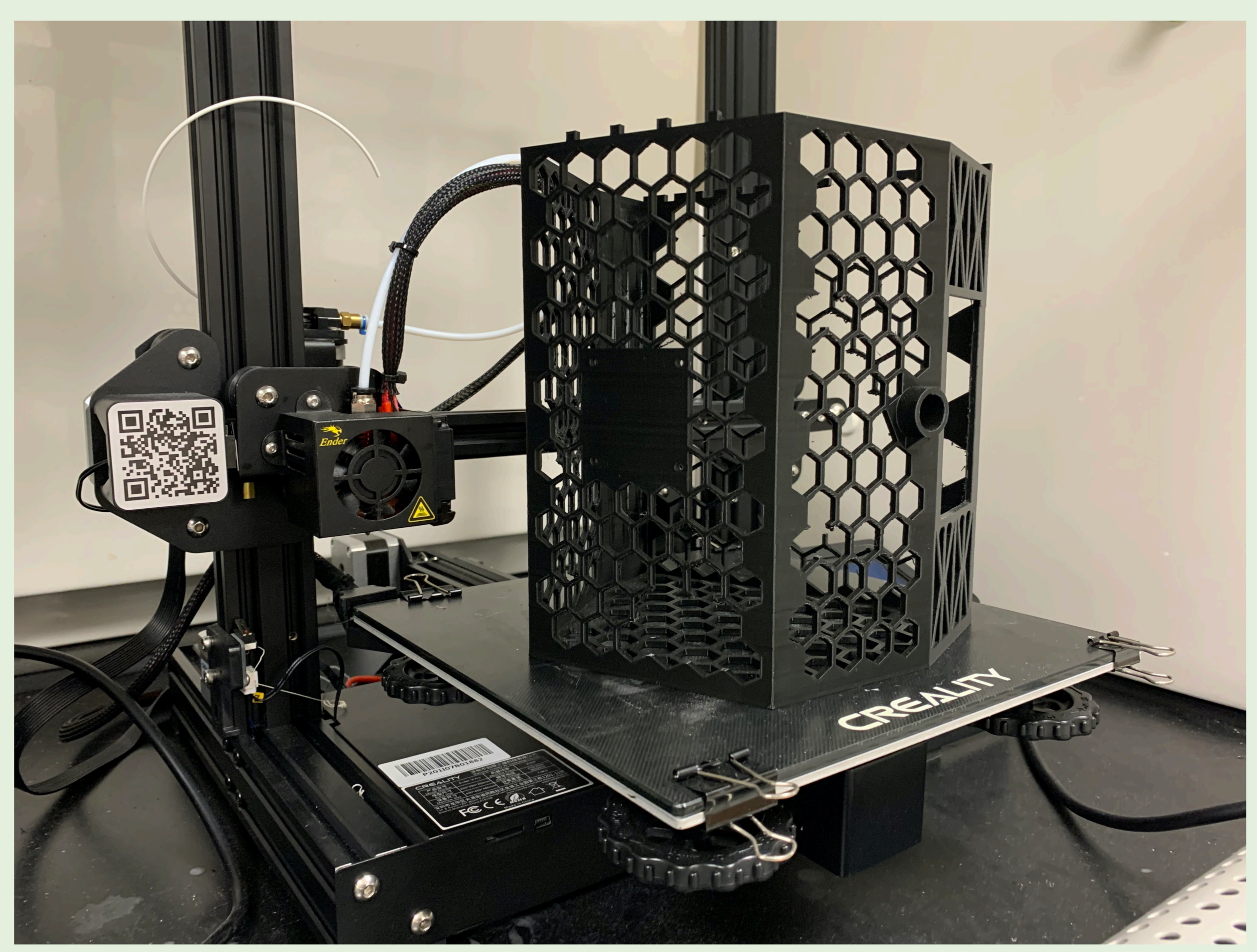

Figure 3: (Right) shows the setup of the 3D printer. Note that the frame of the instrument is designed to maximum the strength of the frame and saves the material and weight.

Comparison to Parsivel disdrometer

Figure 8: The Disdro-TAMUCC is setup side-by-side with a Parsivel disdrometer to compare the results. We have only collected a few events since September 2021.

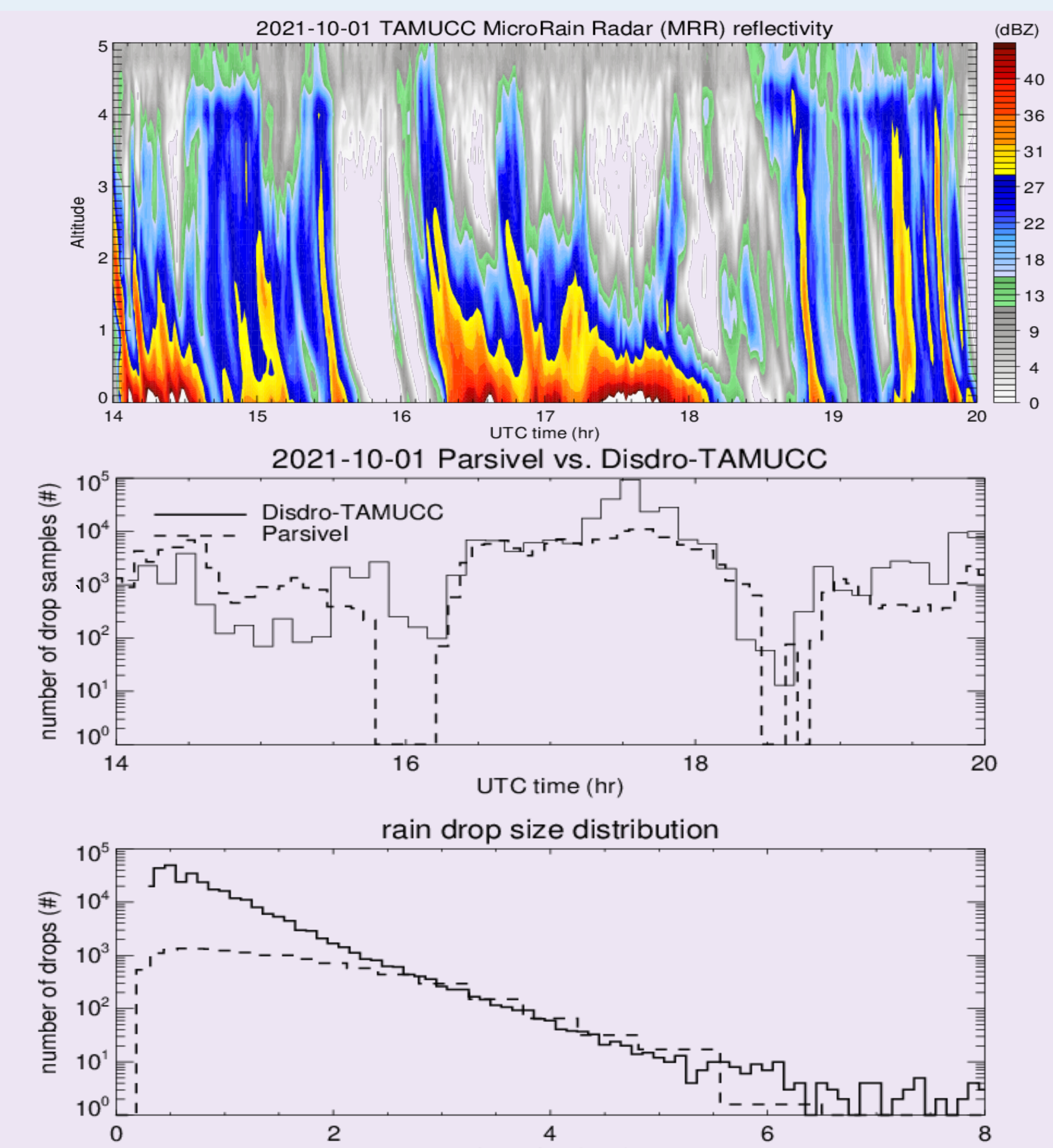

Figure 9: (right) Top panel shows a shallow rain event with episodes of rainfall at TAMUCC in the afternoon of October 1st captured by the Micro Rain Radar (MRR) reflectivity. Middle panels shows the number of particles collected by Disdro-TAMUCC and Parsivel during the event. Bottom panel shows the size vs. number distribution from Parsivel and Disdro-TAMUCC. The difference in the total samples collected is likely due to the different sample volumes by Parsivel and Disdro-TAMUCC. More work is needed to normalize number to number density with sample volume. Note that Disdro-TAMUCC collected some small particles during the non-raining periods. This could be due to the unrealistic background light noise.

Calibration in lab

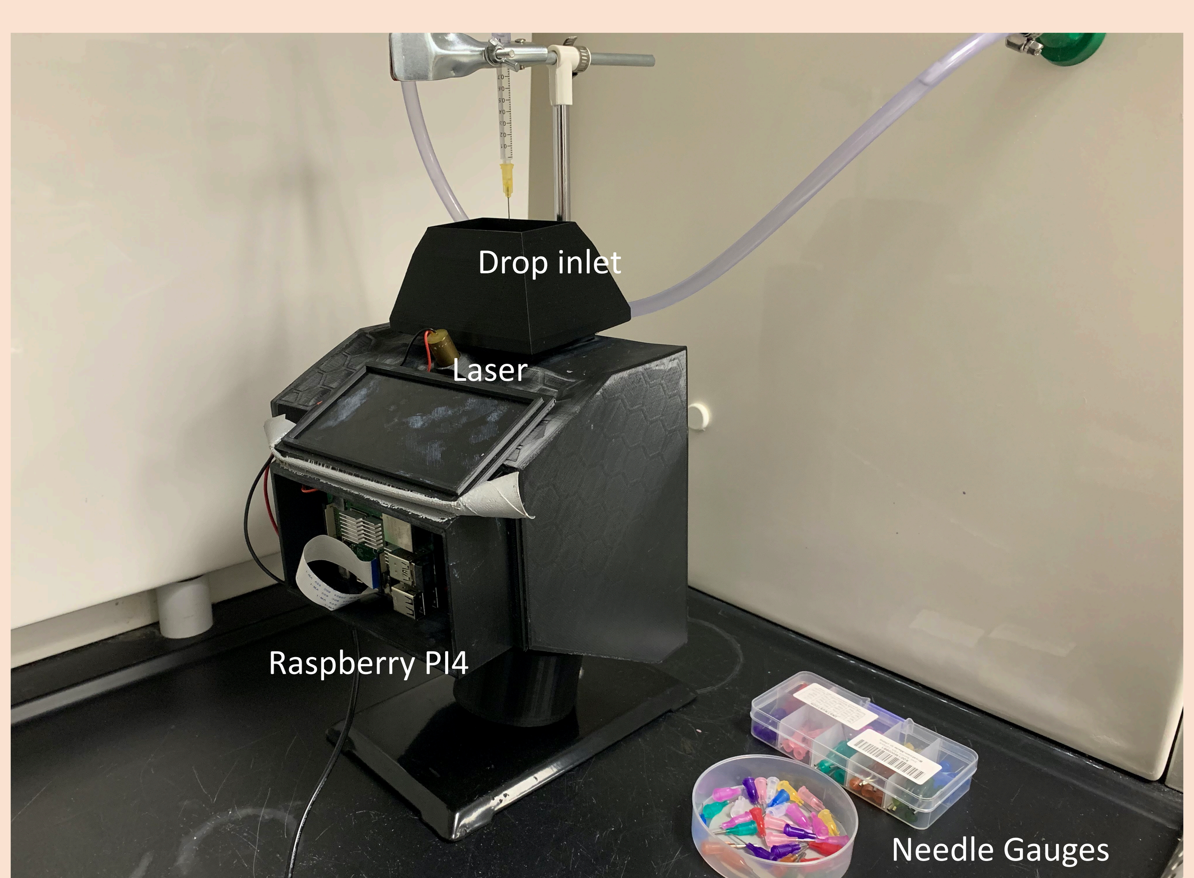

Figure 4: There are several ways to calibrate the instrument in the lab, including 3D printed hydrometeors, commercial gauged steel balls, and needle gauges to create small water drops of different sizes (shown here).

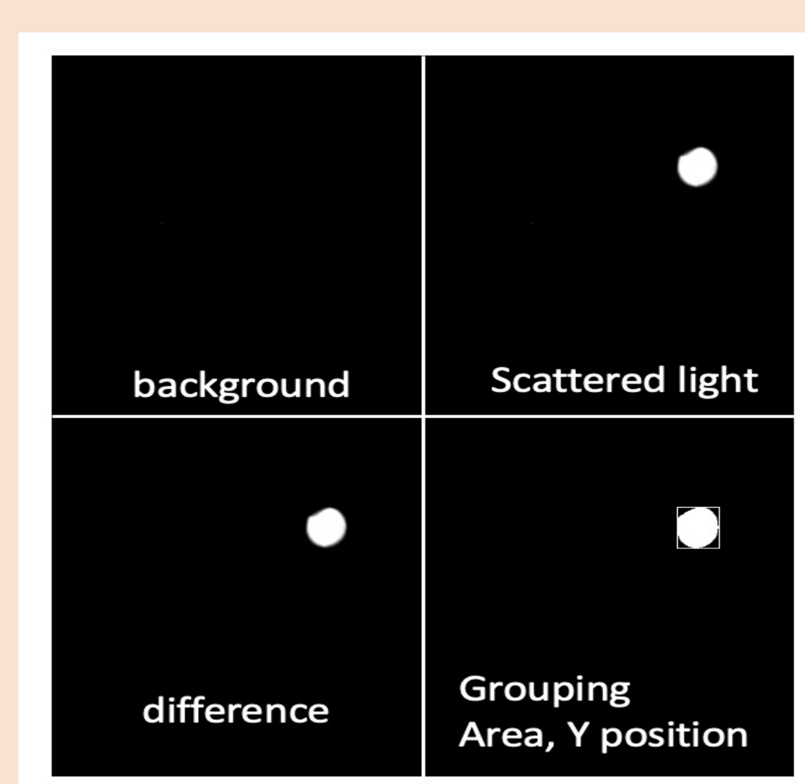

Figure 5: To estimate size of a hydrometeor, camera takes background image fist (top left). When a hydrometer intercepts the laser beam, scattered light is captured by the camera (top right). Then the background will be subtracted to estimate the real scatter signal (bottom left). The last step is to process image with OpenCV package in python on Raspberry PI. The objects are grouped and summarized.

Summary:

- A low-cost disdrometer is created by using 3D printed frame, a flat surface laser pointer, a global shutter camera, and a Raspberry PI 4.
- The calibration is conducted by using 3D printed rain drops, steel balls, and water drops from different needle gauges.
- Side-by-side comparison to Parsivel disdrometer of a few cases collected at TAMUCC shows the promising result from the instrument to measure the realistic distribution of rain drops with size greater than 2 mm.

Challenges:

- Not enough resolution. Current global shutter camera has 640x480 resolution with 60 fps. A better resolution is needed to be able to detect particles smaller than 2 mm
- Difficulty in calibration of particle smaller than 2 mm in lab. Needle Gauges can only make drops greater than 2 mm. We have tried small size commercial steel balls. However, the reflection from the shining surface of steel balls introduce a lot of noises.
- The current instrument does not operate under a cold temperature. Both laser and raspberry PI need above freezing temperature to operate normally. Therefore, an improved design is needed to make it truly balloon borne.