The Durham Static Differential Image Motion Monitors (SDIMMs)

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Overview

The Static SDIMMs are Differential Image Motion Monitor (DIMM) systems developed to investigate two distinct methods for characterising atmospheric turbulence and seeing using a fixed, non-tracking setup. They were installed on the ING DIMM tower at the Observatorio del Roque de los Muchachos (ORM) in La Palma in 2025.

Motivation

The motivation behind this project is develop a robust and cost-effective method for monitoring atmospheric turbulence. Traditional Differential Image Motion Monitors (DIMMs) rely on sophisticated telescope mounts to track bright target stars, and motorised domes or enclosures to house them. Instruments such as the R2D2 DIMM of the Isaac Newton Group (ING) in La Palma provide reliable seeing measurements for astronomers. However, the substantial construction, running costs and complexity limit the widespread repeatability and deployment of such setups.

The SDIMMs (Static DIMMs), developed at Durham University and deployed at ORM, La Palma, investigate the efficacy of a static setup through two similar instruments with fixed pointing, designed to eliminate the need for tracking. One instrument is fixed to point at Polaris, which remains in the field of view as it circles around the North Celestial Pole. The other is fixed to point at the zenith, where stars transit across the field of view. As both instruments are static, they derive the seeing value from moving sources.

This project will investigate their performance relative to R2D2 to assess their scientific validity and potential for wider deployment.

Methods

The SDIMMs operate on the same fundamental principle as traditional DIMMs: measuring atmospheric turbulence by analysing the differential motion of stellar images formed through two sub-apertures of a small telescope. The primary metric derived from this technique is the Fried parameter, r_0, which quantifies the coherence length of atmospheric turbulence and serves as a direct indicator of seeing quality.

A DIMM provides a measure of the total atmospheric optical turbulence strength, and hence the seeing. By exploiting measurements of differential image motion, the seeing estimate is not biased by the effects of telescope shake, guiding errors or defocus - as would be the case for a direct measurement of the seeing directly from the FWHM of star images.

In this project, two SDIMM units are deployed to evaluate different observational strategies. One monitors Polaris, which remains within the field of view due to its proximity to the North Celestial Pole, while the other observes stars transiting across the zenith. Unlike conventional DIMMs that track targets, these static units must extract r_0 from sources that drift across the detector. This introduces new challenges in centroiding accuracy and temporal sampling.

The scientific performance of the SDIMMs is assessed through direct comparison with the R2D2 DIMM. By validating SDIMM measurements against both established instruments and through simulations, this study explores the viability of static DIMM architectures for future atmospheric turbulence monitoring.

Instrumentation

1. Location

The instruments are mounted on the ING DIMM Tower at ORM, alongside the existing R2D2 DIMM. Placing the DIMMs on the tower, 5m above ground level, aims to reduce the effects of surface-level turbulence (which does not contribute to the seeing for large telescopes) on the DIMM instruments. The Serrurier truss-type structure of the DIMM tower also has an independent central column, which mechanically isolates the instruments from the dome structure, in order to reduce the effects of wind-shake on the measurements.

Figure 1: View of ING DIMM Observing Tower, showing the R2D2 (left) and SDIMM (right) instruments.

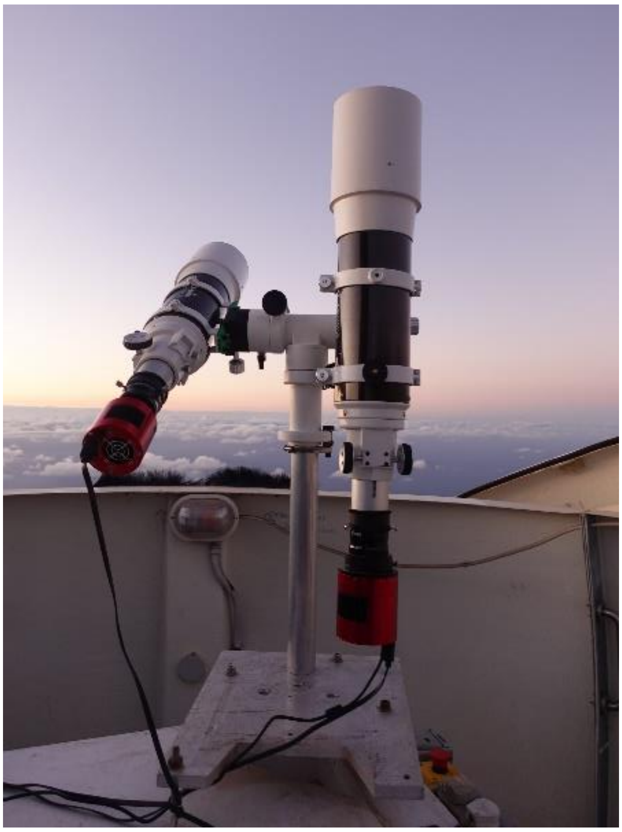


Figure 2: SDIMMs Dual Telescope Setup. Left: Polaris DIMM, Right Zenith DIMM.

2. Telescopes

The SDIMMs are constructed largely from commercially available components. Some additional custom mechanical parts manufactured at Durham University, specifically a pier for the fixed mounting, and a telescope aperture mask with mounting for a wedge prism. Both S-DIMM instruments are supported on a single Alt-Az mounting which provides independent manual alignment of the two telescopes, for the Polaris- and Zenith-pointing DIMMs. The setup has static pointing (after initial alignment) with no tracking or motorized axes. One of the DIMM telescopes is aligned to an elevation of 29 degrees, to point at Polaris, while the other points approximately to the Zenith.

Both telescopes are Skywatcher 120mm aperture, F/4 refractors. Each is fitted with a StellaMira 0.8x focal reducer / field-flattener, to optimise the image scale and provide constant focus across the large field of view of the detector.

3. Cameras

The SDIMMs employ large format CMOS cameras manufactured by ZWO. The Polaris DIMM is fitted with a ZWO ASI1600MM camera. This provides close to Nyquist sampling of the images at the diffraction limit, whilst also yielding a field of view of 1.5 degrees. This is large enough to encompass the full sideral motion of Polaris around the celestial pole, so that Polaris always remains within the field of view of the camera.

The Zenith-pointing DIMM is fitted with a ZWO ASI6200MM camera, which provides an increased field of view of approximately 3 degrees, at the same pixel scale.

Instrument	Polaris SDIMM	Zenith SDIMM
Camera	ZWO ASI1600MM	ZWO ASI6200MM
Sensor Resolution	4656 × 3520 (16 MP)	9576 × 6388 (61 MP)
Pixel Size	3.8 μm × 3.8 μm	3.8 μm × 3.8 μm
Pixel Scale	1.6 arcsec per pixel	1.6 arcsec per pixel
Field of View	2.1x1.6 degrees	4.3x2.9 degrees

4. Aperture Masks

The DIMM technique requires that images of a bright star two sub-apertures with the telescope pupil are formed separately in the focal plane. This is usually achieved by forming an aperture mask for the telescope, containing two sub-apertures, and placing a narrow-angle wedge prism over one of the sub-apertures. For the SDIMMs, aluminium aperture masks were created with a pair of sub-apertures with 48mm diameter and 60mm separation. One of the sub-apertures is fitted with a 50mm optical window, selected for non-parallelism of approx. 10-20 arcsec.

The format of the SDIMM mask is illustrated below. The SDIMM sub-apertures are smaller and closer together than those of the R2D2 setup, which is also shown for comparison.

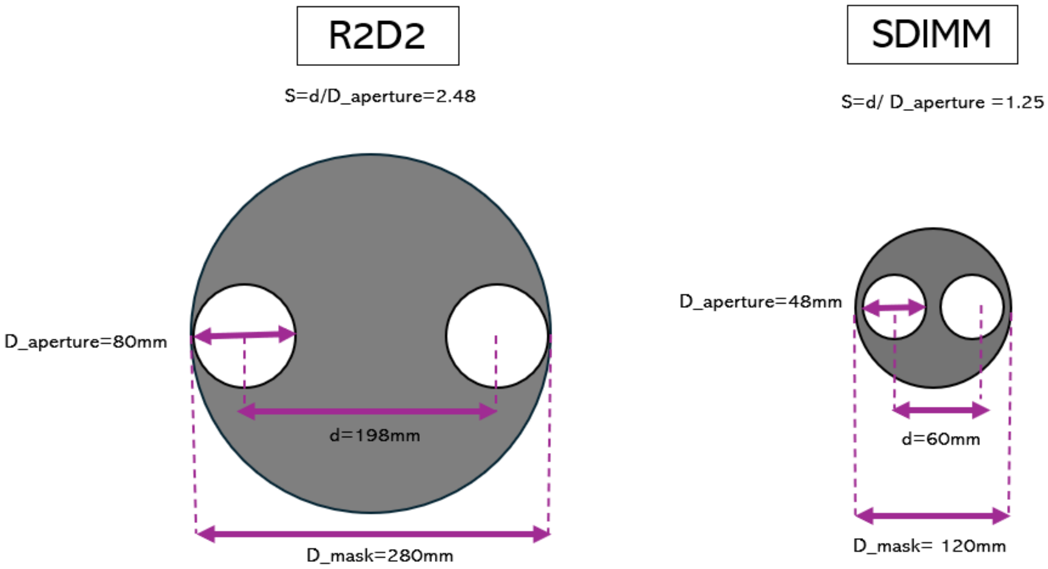


Figure 3: Diagram of DIMM Mask of R2D2 and SDIMM

Data Acquisition and Analysis

Both the cameras are connected to a PC running Linux. The control PC is connected to the ING internal network to permit remote operation.

Software Architecture

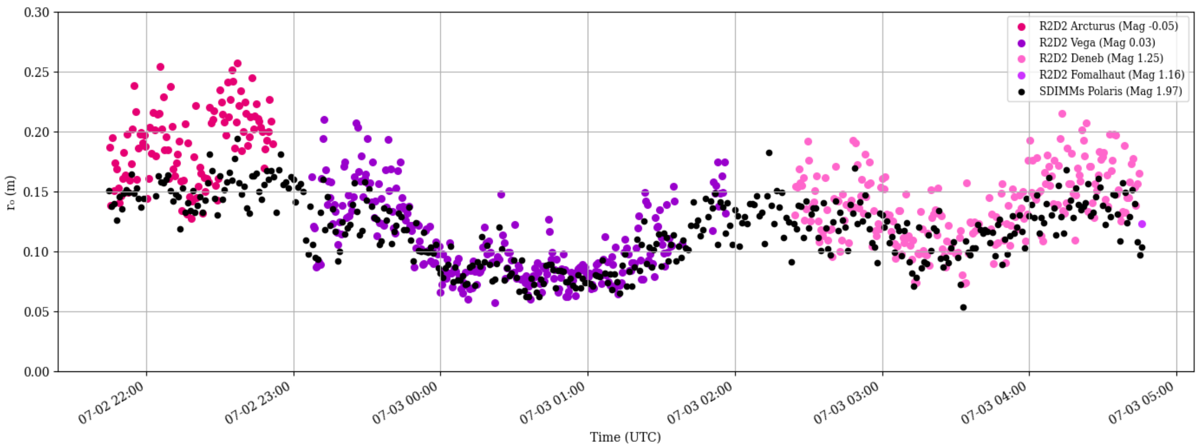
The Polaris instrument code begins by capturing a single 0.5 second reference frame to locate the brightest star in the field of view, assumed to be Polaris. It then collects a packet consisting of 200 short-exposure frames, each 2 milliseconds in duration. A single r_0 value is derived from 10 packets of data, yielding one seeing value every 45 seconds on average.

The Zenith instrument code similarly begins by capturing a reference frame to locate the brightest star in the field of view. It then finds the total counts produce by the star and using that information it calculates the exposure time needed to reach a minimum required flux level. Using this adjusted exposure time, the system collects a packet of 200 frames. This star is then tracked until it leaves the field of view. The acquisition process then repeats for a new reference star. An r_0 value is derived from each sequence of 10 data packets for a given reference star.

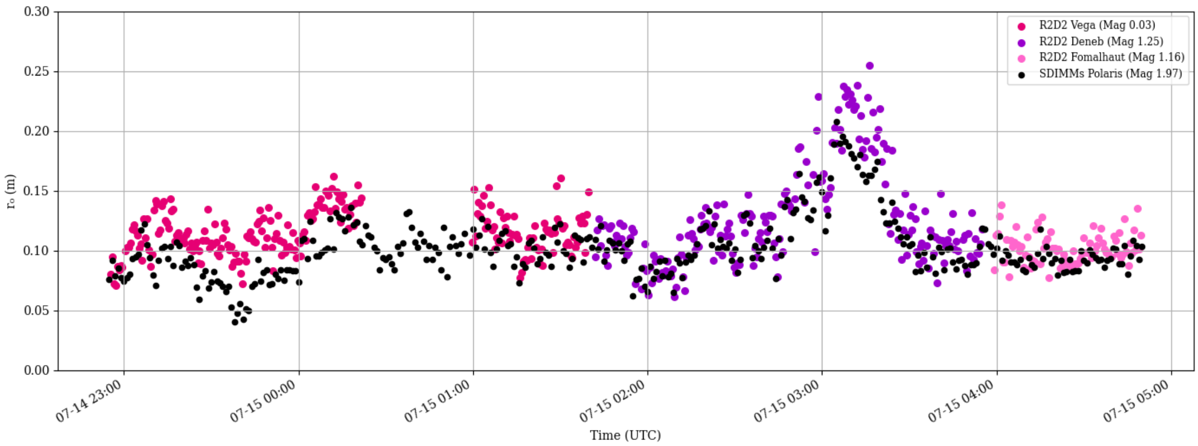
Results

Sample data has so far been recorded on 11 nights since installation of the instruments. For the majority of nights, we find generally good agreement with the R2D2 instrument, such as the following examples on 02/07/2025, 14/07/2025 and 20/07/2025.

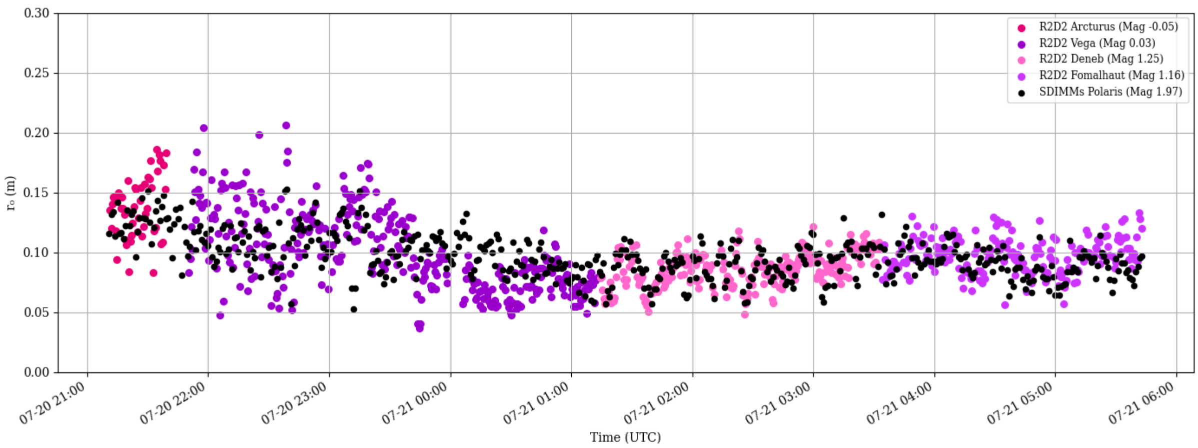
Comparison of SDIMM Polaris with R2D2 for night of 02/07/2025



Comparison of SDIMM Polaris with R2D2 for night of 14/07/2025



Comparison of SDIMM Polaris with R2D2 for night of 20/07/2025



There are also some periods when there are consistent offsets between seeing values from the Polaris SDIMM and R2D2. We are currently investigating possible causes, including wind shake of the instrument, and the effects of variable extinction and thin cirrus clouds on the SNR. We are also exploring the effect of high turbulence wind speeds in biasing the DIMM measurements. During high wind speeds, there can be significant smearing of the image motions during each exposure. Using longer exposure times could result in measuring higher r_0 values (better seeing) on nights characterised by high winds speeds. We are using simulations to investigate the expected magnitude of this effect given the different exposure times employed by the Polaris SDIMM and R2D2.