THE TERAHERTZ INTENSITY MAPPER (TIM)

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INTRODUCTION

TIM is a balloon-borne telescope experiment designed to study galaxy formation. We want to answer two big questions:

1. How do galaxies form and evolve? Why do the kinds of galaxies change over time?
2. Why has star formation slowed over the past 8 billion years?

Our gondola is designed to answer these questions by looking at dusty galaxies through a far-infrared telescope. Emission lines from ionized carbon act as a "tracer" of star formation. To detect these emission lines, we must put our telescope outside the atmosphere-- hence the balloon!

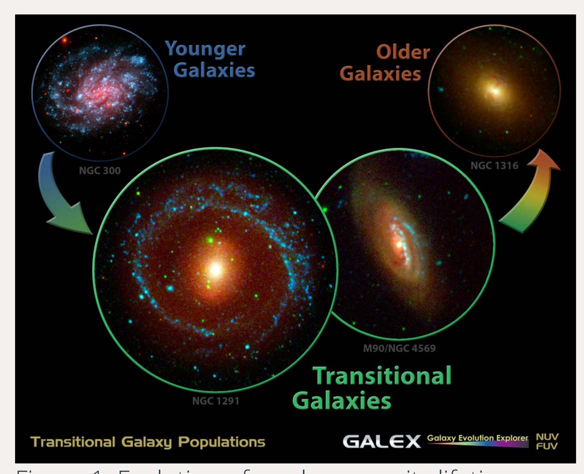

Figure 1: Evolution of a galaxy over its lifetime, Galaxy Evolution Explorer NASA

Figure 2: Example of a balloon-borne telescope, BLAST 2009

OBJECTIVE

We need to be able to point our telescope, but being on a balloon presents some challenges. We must be able to measure our environment and control all aspects of motion remotely. The elevation drive and the reaction wheel, two elements of motor control I designed this summer, play an important role in rotating the inner and outer frame. The goal for Summer 2021 was to design and manufacture these elements of the gondola and place them on a TIM prototype to test our pointing sensors, e.g. star cameras and magnetometers.

METHODOLOGY

All designs for the elevation drive and reaction wheel were created and tested in SolidWorks before being sent to the machine shop. Briefly, I will describe the functionality of both elements.

1. The elevation drive
   a. Powered by a Kollmorgen rotary motor which uses a magnetic field to turn the shaft (pictured below)
   b. Responsible for rotating TIM's inner frame approximately 60 degrees
   c. Inner frame holds star cameras, telescope, and other electronics; its rotation allows cameras to map a complete picture of our sky's stars
2. The reaction wheel
   a. 6 spokes attached to a central hub with brass weights at outer edge
   b. Acts on the principle of conservation of angular momentum
   c. Responsible for controlling azimuth velocity of the outer frame
   d. Needs a high moment of inertia to work efficiently, which is why mass is concentrated as far away from the center of mass as possible

RESULTS

The TIM prototype is on its way to completion. As of August 2021, a modified design of the reaction wheel has been assembled onto the outer frame and its motor has been programmed to spin the wheel. My design for the elevation drive is complete, and we are currently in the process of ordering the necessary raw materials and getting it manufactured in David Rittenhouse Laboratory. In the upcoming months, we anticipate that we will have a TIM prototype that contains a fully functioning reaction wheel and elevation drive (as pictured in Figure 3).

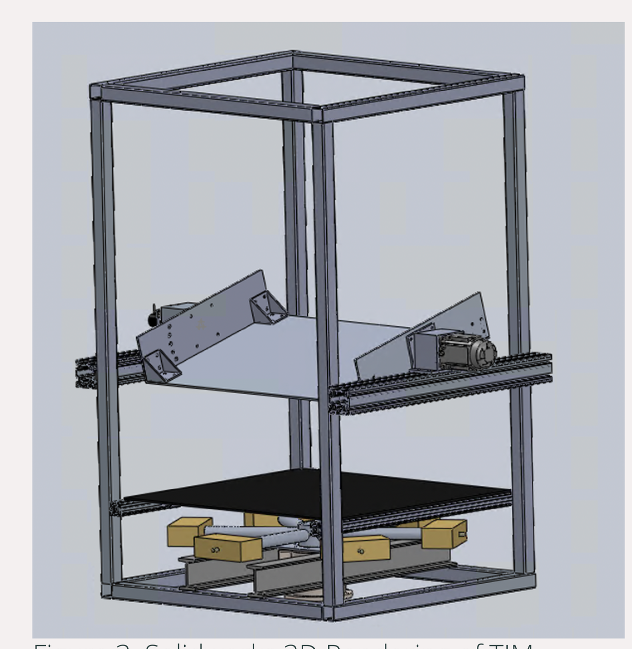

Figure 3: Solidworks 3D Rendering of TIM Prototype, Mena 2021

TECHNOLOGY & DESIGN

Figures 4 and 5 display 3D drawings of the reaction wheel and elevation drive created in SolidWorks 2020. Figures 6 and 7 show the motors necessary for each structure to rotate.

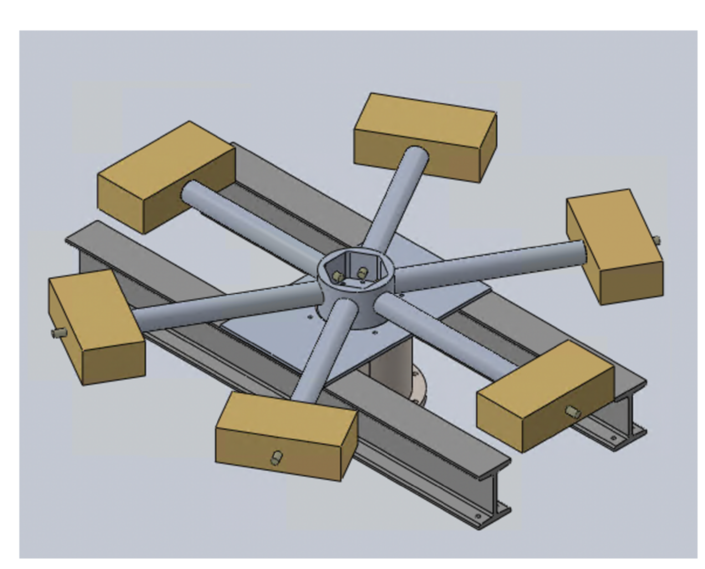

Figure 4: Reaction wheel design, Mena 2021

Figure 6: Reaction wheel motor, Kollmorgen D063M

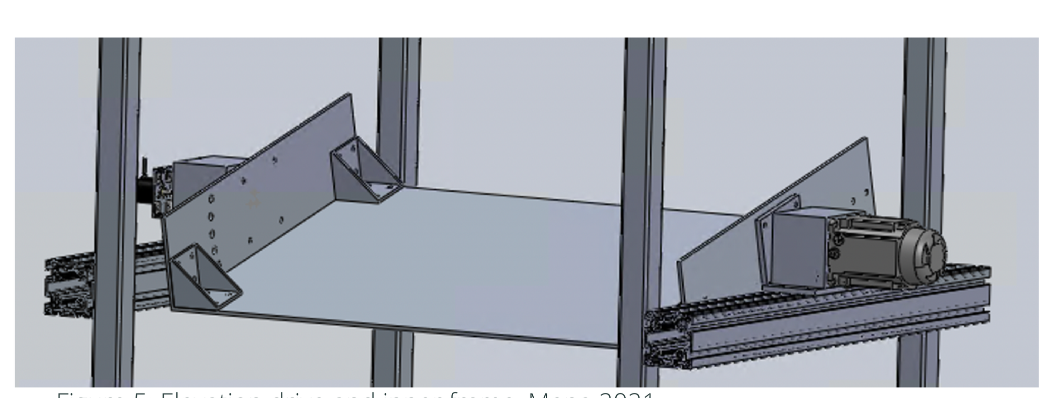

Figure 5: Elevation drive and inner frame, Mena 2021

Figure 7: Elevation drive motor, Kollmorgen C041A

CONCLUSION

Having a TIM prototype with a functional inner and outer frame gives us a greater understanding of how our pointing sensors (e.g. magnetometers, star cameras, etc.) will operate in-flight. This prototype brings us one step closer to the construction of a full scale gondola which will be launched in Antartica in several years. The completion of this project allows us to use our far-infrared telescope to answer the big questions about galaxy evolution and star formation.

Figure 8: BLAST-TNG ready for launch in Antarctica, 2019

RELATED LITERATURE

1. Fissel, L.M. (2013)Probing the Role Played by Magnetic Fields in Star Formation with BLASTPol [Doctoral dissertation, University of Toronto]
2. Shariff, Jamil A. et al. (2014) Pointing control for the SPIDER balloon-borne telescope, Proc. SPIE Int. Soc. Opt. Eng., vol. 9145
3. Lourie, N.P. et al. (2014/11) The next generation BLAST experiment, Journal of Astronomical Instrumentation, World Scientific Publishing Company, vol. 3