A Nulling AO Coronagraph on a Sounding Rocket
Design & Implementation Considerations

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Technical Issues for Sounding Rockets

There may be some overlap with S. Charabarti's talk

- Initially, B.U., MIT(draper), and JPL looked at both Balloon borne and sounding rocket platforms for our nulling coronagraph experiment.
- We looked at the following issues and concluded that sounding rockets were significantly more likely to work.
  - Thermal stability (of the optics and nuller/coronagraph)
  - Residual atmosphere
- In addition there were other less "fundamental" issues but still important
  - Time to "phase up" the AO system (favor space)
  - High vibration levels during launch (favor Balloon)
  - Pointing accuracy and stability (Covered in Sup's talk)

Optics Stability/Residual Atm

- Based on conventional space based design
  - Use Zerodur/ULE optics (zero CTE @ 25C)
  - Heat optics to 25 C, make up for radiation into 3K space
    - In space there are no thermal plums from heating optics
- Sounding rocket specific issues
  - Thermal shock from opening mirror cover. Telescope optics is looking at 300K thermal environment before launch. This changes to 3K when mirror cover is opened. Have minutes to reach thermal equilibrium.
    - Initial calculations showed that the mirror would not reach thermal equilibrium before the sounding rocket mission was over.
  - Solution was to use a LN_2 mirror cover. Before launch, the telescope is looking into a 77K black body. So the thermal shock of removing the mirror cover is significantly reduced, (by 200X)~6mW. If we pump on the Nitrogen (50K) the thermal shock is reduced by (1200X) heat load changes by ~ 1mW.

Optics Stability vs Gravity

- The Picture primary mirror (60cm) is a very light weight mirror, (from SBIR)
- It is known to sag ~200nm when tilted from vertical to horrizontal
- In 1 G, a 0.1nm change in the figure can result with a gravity vector change of 1arcmin, 4 seconds of time tracking a star from a balloon.
- The mirror we had could only be used in 0G.

Residual Atmosphere

- If we use conventional designed space optics (heat ULE to 25C) the heat will cause "residual" atmospheric turbulence inside the telescope.
  - 1K * 1m @1Atm ~ 1um OPD. We want OPD fluctuations < 0.1nm.
  - If the temperature of the optic is 30K above the ambient air, the residual air must be < $3x10^{-6}$ atmospheres to limit "internal self generated seeing" to be < 0.1nm. This was one of the main reasons why BU, MIT, JPL chose to go with a sounding rocket vs Balloon.
    - With a balloon, one might not heat the mirror, but live with ~ $1x10^{-5}$ instead of 10^{-8}.
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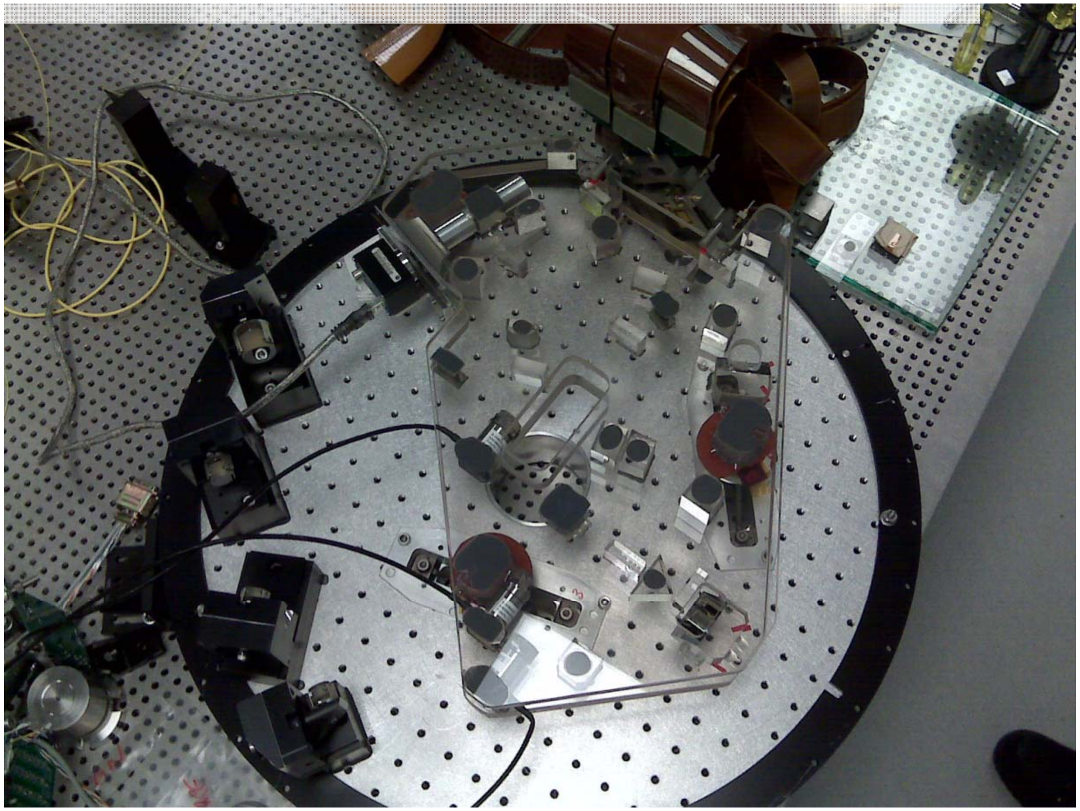
Nulling Interferometer Thermal Issues

Essentially same as in Space

- The two arms of the nulling interferometer have to be equal to ~0.1nm. Also they can't "drift" by more than ~0.1nm.
- Our approach is to use a "glass sandwich". Optics are directly attached to "top/bottom" ULE plates. A PZT actuated mirror is used to set final OPD, PZT has a strain gauge reference to the low CTE reference.
- Extreme care must be used when building glass structures to survive launch conditions.
  - Damp resonances to limit max G forces
  - No direct glass-glass or glass-metal contact that can "chatter".
  - Mechanical strength can not be at the expense of thermal stability.



Conclusions

- We (BU, MIT, JPL) initially looked at both balloon payloads and sounding rocket payloads. Finally deciding that sounding rockets were the lesser of two evils.
- Zero G and space, is a plus
  - Lower vibration environment, better pointing
  - No time variable gravity vector
  - Better thermal environment (with LN2 mirror cover)
    - Can use normal space optics design (heat zerodur/ULE to 25C)
- 5 minutes of science time is very short, even for the small $$ spent.
  - But might be the best bet, for technology demonstration, and exo-zodi characterization.
  - Must have wavefront sensor that can "phase up" mirror on a bright star in 10~20 seconds.
- Cost credibility. If a payload survives a sounding rocket launch, it'll survive a regular launch. If you can build a 50cm telescope + coronagraph for space for $5M, you can more credibly propose a 1.5m telescope + instrument in space using the $D^{2.5}$ scaling law for ~$80M. (Instead of some missions that require the cost of a telescope in sq-meters to actually drop with larger telescope size.