Technology Development for the Whipple Mission Concept - Present Status and Future Work

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Studying the Outer Solar System

- Only a small volume of the Solar system has been studied in detail
- Remnant of formation of Solar system present in Kuiper belt, Sedna region, Oort cloud
- The rocky population of these regions could provide key inputs to models of formation and early history of Solar system
- Planetary prizes given for work on outer Solar system
Whipple Concept - Blind Occultation Survey

Detect occultations of stars by solar system objects

Occulting object 1km diameter at 42 AU

Distant Star

2D Diffraction pattern
Impact parameters $b=0$, 1.0, & 2.0 km
Whipple Concept - Blind Occultation Survey

D.3

Infer the history of the solar system from the architecture of minor planet populations
## Whipple Concept - Blind Occultation Survey

<table>
<thead>
<tr>
<th></th>
<th>Min.</th>
<th>Max.</th>
<th>Best Est.</th>
</tr>
</thead>
<tbody>
<tr>
<td>KBO</td>
<td>12,000</td>
<td>40,000</td>
<td>25,000</td>
</tr>
<tr>
<td>SRO</td>
<td>15</td>
<td>90,000</td>
<td>1,300</td>
</tr>
<tr>
<td>OCO</td>
<td>100</td>
<td>650</td>
<td>260</td>
</tr>
</tbody>
</table>

**Detection of occultations of stars by solar system objects**

**2D Diffraction pattern**

*Impact parameters b=0, 1.0, & 2.0 km*

**Diameter at 42 AU**
Whipple Concept - Blind Occultation Survey 2010 Discovery - Consolation Prize - Technology Development
The Problem

• Need to continuously monitor tens of thousands of stars at 40 Hz
• Occultations occur in less than a second - MUCH faster than Kepler
• Can’t telemeter light curves - require massive onboard processing
• Onboard detection of occultation - Equivalent Width algorithm (Roques+2003)

\[ EW = \sum_{i=1}^{7} \left( 1 - \frac{F_i}{F} \right) \]
Simulated Whipple Lightcurve

\[ EW = \sum_{j=\text{short}} \left| \frac{F_j - F}{F} \right| \]

Time (sec)
Instrumentation - The Whipple Photometer

- Teledyne H2RG HyVISI sensor + SIDECAR ASIC - 700 windows per sensor at 40 Hz (w/ CDS) - TRL 9

- Lightcurves processed by FPGA using EW algorithm - only candidate occultations sent to telemetry

- Whipple Technology Development - Marry the two! Prove that it works.
3 Key Goals of WTD

• Demonstrate 700 windows at 40 Hz in H2RG
• Demonstrate 700 data streams at 40 Hz in FPGA
• Demonstrate detection of simulated occultations in complete systems
Laboratory Setup
Laboratory Setup - Schematic
Current Status

• H2RG + SIDECAR fully operational (15 e- readnoise)
• Occultation simulator fully operational
• Windowing software delivered and operational - under evaluation
• EW algorithm tested (simulated and real/noisy data) and confirmed in Virtex 5 FPGA
• Multiple data streams confirmed - 2000+ stars per sensor at 40 Hz (Whipple req is 700 stars at 40 Hz)
Whipple Occultation Lightcurves - Lab Data Processed by FPGA
Future Work - We’re Almost There!

• Interface FPGA development kit with SIDECAR ASIC - in progress
• Construct PCB board for FPGA and command interface
• Laboratory evaluation of EW alg., sensitivity, S/N performance, stability, etc.
Shameless Plug - X-ray Imaging Spectroscopy (Poster Gallery #4 - Kenter+ 2012)

- Monolithic CMOS X-ray imaging spectrometer
- Microchannel plate optic
- X-ray studies of rocky bodies, planetary magnetosphere

Chandra image of Jupiter in four bands (Branduardi-Raymont+ 2007)

Simulated spectra of NEO