

# GAPS: A Novel Indirect Search for Dark Mater

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- 1 Introduction
  - Indirect Detection of Dark Matter
  - Antideuterons as a DM Signature
- 2 The General Antiparticle Spectrometer
  - Exotic Atoms
  - Antiproton and Antideuteron Identification
  - GAPS Si(Li) Detectors
- 3 GAPS Balloon Project
  - bGAPS
  - Simulation Work
  - GAPS Balloon Flight
  - Prototype GAPS Flight
- 4 The GAPS Collaboration
- 5 Conclusions

# Indirect Detection of Dark Matter

WIMP Dark Matter could decay or self-annihilate (if it is a Majorana fermion) to standard model particles.

This could be anywhere DM is concentrated: in the galactic halo, dwarf spheroidal galaxies, the sun, etc.



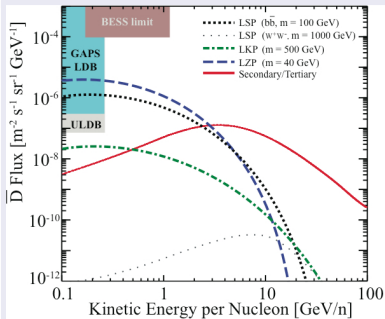
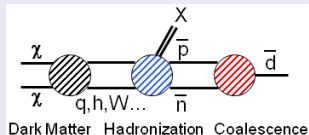
Could search for charged species or  $\gamma$ 's.

- $\gamma$ 's: Promising, see FERMI, VERITAS, etc.
- Protons,  $e^-$ : Hopeless
- Antiprotons,  $e^+$ : Promising, but large backgrounds
- Antideuterons: Promising, probably small backgrounds

# Antideuterons as a DM Signature

## Antideuterons from DM

Antideuterons could be (rarely) produced from DM in the galactic halo, and thus present in cosmic rays.

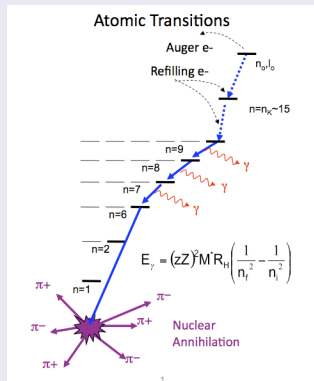
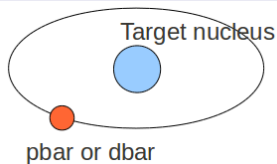


At low energy, antideuterons from DM-DM annihilation could vastly outnumber those produced from normal astrophysical processes (secondary/tertiary).

# GAPS: The General Antiparticle Spectrometer

Most experiments use magnetic deflection to distinguish antimatter species (HEAT, AMS, PAMELA, BESS, etc).

Light antinuclei can form excited exotic atom states with normal matter.



Atomic transition x-rays, charged pion multiplicity, and possible other products provide distinct signature for antinuclei.

# Antiproton and Antideuteron Identification

## Time-of-Flight

- Identify charge of primary.
- Measure particle  $\beta$ .
- Veto heavy cosmic rays/showers.

## Target/Tracker/x-ray Detector

- Slow down antiparticles and form exotic atoms.
- Measure x-ray energies.
- Track annihilation products.

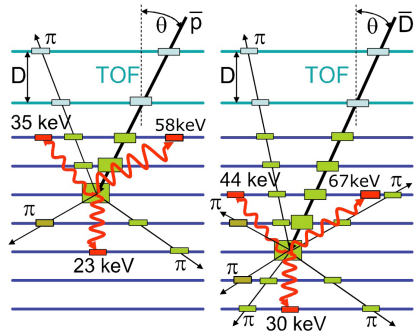


Figure: GAPS with Si target material.

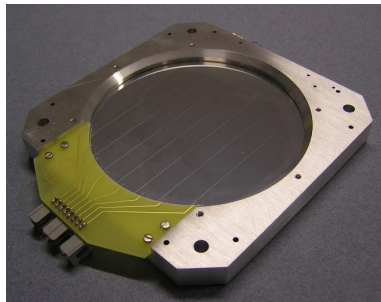
Exotic atom technique successfully tested in 2004 KEK test beam.

# GAPS Si(Li) Detectors

Lithium drifted silicon provides:

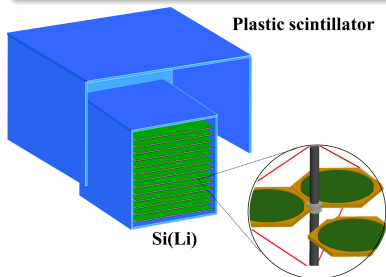
- Both degrader, target and detector.
- Excellent x-ray energy resolution ( $\sim 3\text{keV}$ ).
- Tracking of primary particle.
- Tracking of annihilation products.

In-house effort to produce detectors in quantity (lithium drifting, etching, passivation of surfaces, etc) underway.



# bGAPS: A GAPS Balloon Payload

A balloon-born GAPS payload (bGAPS) is under active development, with a first flight planned for 2014 in Antarctica.



- Overall acceptance of  $\sim 2.7 m^2 sr$ .
- Overall width of  $\sim 3 m$ .
- 13 layers of Si(Li) detectors ( $\sim 200$  kg of silicon).
- Plastic scintillator based time-of-flight system.



# Simulation Work

## Atmospheric Simulations

Development of GEANT4 based simulation to better understand backgrounds and event rate. Validated by excellent agreement with previous measurements.

## Optical Simulation of TOF System

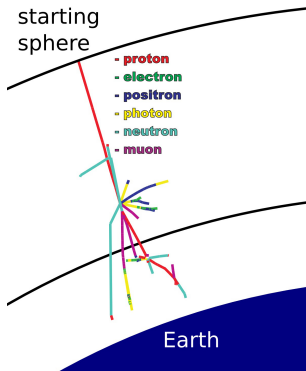
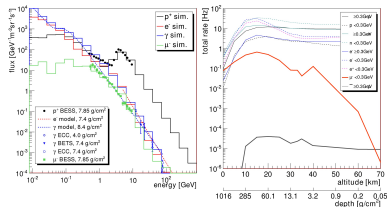
GEANT4 optical simulation for time-of-flight scintillator paddle design optimization.

## Exotic Atom Studies

Ongoing work on understanding the exotic atom physics.

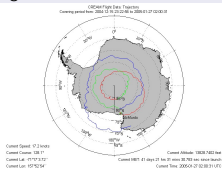
## Whole Instrument Simulation

Integration of all detectors and payload structure to product whole-instrument simulation.

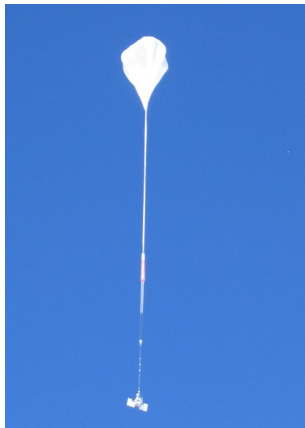
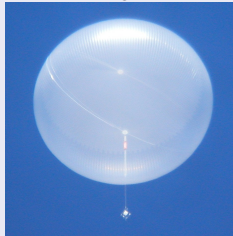


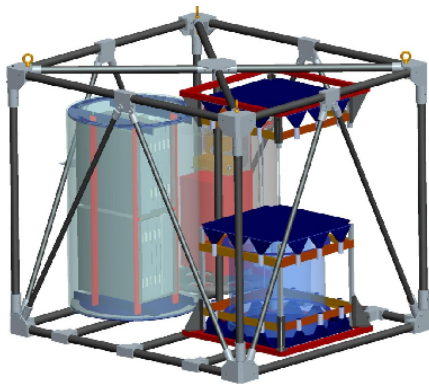
# GAPS Balloon Flight

Antarctic LDB flights can provide up to  $\sim 40$  day flights.

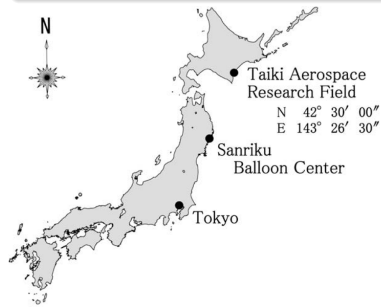


Future ULDB flights to be  $\sim 100$  day.





An engineering test payload known as pGAPS is scheduled to fly in 2011 from the JAXA/ISAS balloon launch facility in Taiki, Japan. This payload will consist of a plastic-scintillator based time-of-flight system and 6 commercially purchased Si(Li) detectors.



- JAXA / ISAS: Fuke, Bando, Takada, Yoshida
- Columbia Univ.: Aramaki, Gahbauer, Hailey, Koglin, Madden, Mori, Tajiri
- UC Berkeley: Boggs, von Doetinchem
- Tech. Univ. Denmark: Christensen
- LLNL: Craig
- ORNL: Fabris, Ziock
- UCLA: Mognet, Ong, Zhang, Zweerink

pGAPS is funded by NASA grants in the US and by MEXT-KAKENHI grants in Japan.

- Antideuteron provide a potentially background free signature for dark matter.
- GAPS is a promising approach to antideuteron searches.
- Detector development ongoing.
- Science flight in  $\sim 2014$ .
- Test flight this year!