

# THE 3.5 KEV CANDIDATE DARK MATTER DECAY SIGNAL - CURRENT STATUS AND NEAR-FUTURE PROSPECTS

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*With*

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# DECAYING DARK MATTER



## WIMPs

- Interaction strength at weak scale
- Correct  $\Omega_{DM}$  for masses GeV - TeV
- Would have short lifetime
- Made stable with new physics

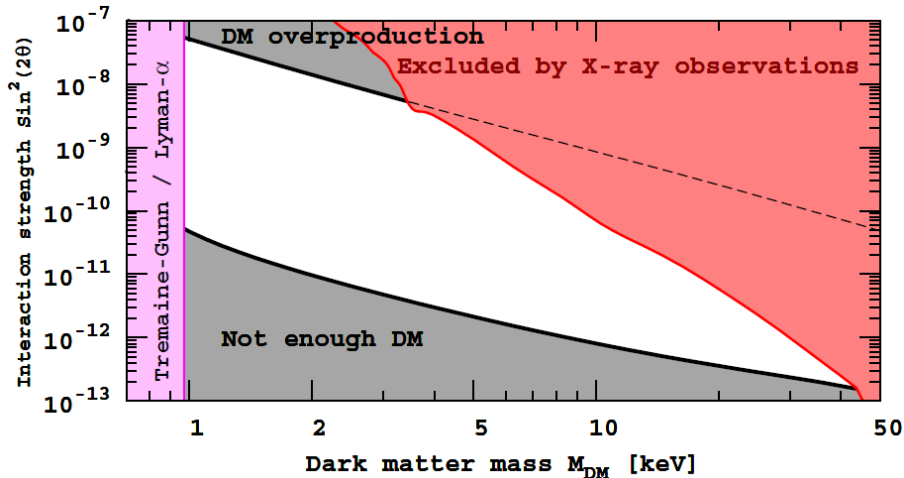
## SUPERWIMPs

- Interaction strength weaker-than-weak
- Correct  $\Omega_{DM}$  for masses of order keV
- Lifetime longer than age of universe
- Allowed to be decaying DM

## STERILE NEUTRINOS IN X-RAYS



Decaying DM should decay into monochromatic X-rays

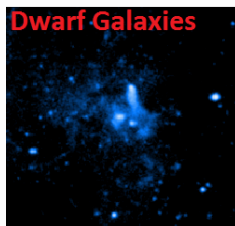
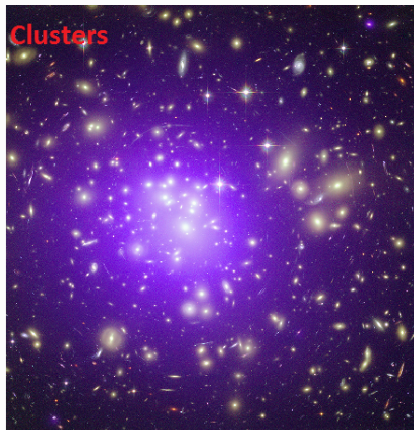
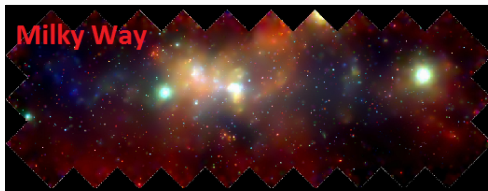


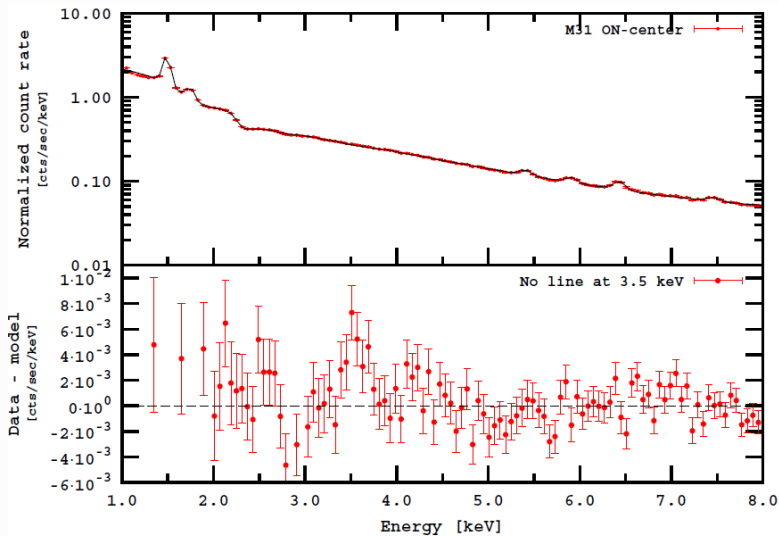
# TARGET SOURCES



Good targets are dark matter dominated. Specifically, sources with high expected decay signal strength

$$\text{signal} \propto \text{DM mass in FoV} / \text{distance}^2$$



DETECTION AT  $\sim 3.55$  keV IN ANDROMEDA (M31)

Boyarsky et al. 2014a [1402.4119]

## DETECTIONS OF THE UNIDENTIFIED 3.5 KEV LINE

**BOYARSKY ET AL. 2014A** [1402.4119]

M31 galaxy	XMM-Newton, center & outskirts	<b>4.4<math>\sigma</math></b>
Perseus cluster	XMM-Newton, outskirts only	

**BULBUL ET AL. 2014** [1402.2301]

73 clusters	XMM-Newton (MOS & PN), centers only, up to $z = 0.4$	<b>5<math>\sigma</math> &amp; 4<math>\sigma</math></b>
Perseus cluster	Chandra, center only	<b>3.5<math>\sigma</math></b>

Estimated global significance  **$\sim 6.6\sigma$**

# INSTRUMENTAL ORIGIN?



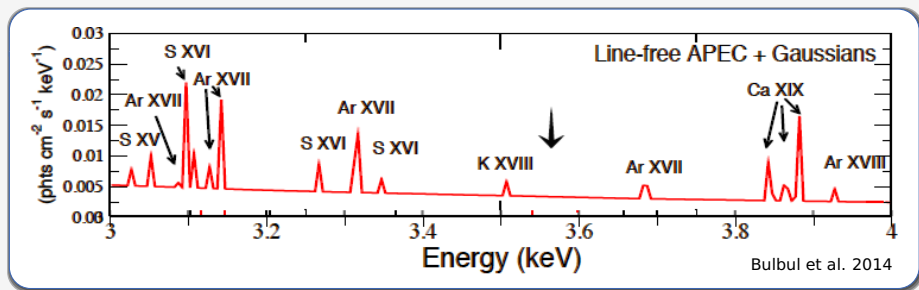
Instrumental origin **unlikely**

1. Detected in 5 different detectors
  - XMM-Newton MOS and PN detectors
  - Chandra ACIS-S, ACIS-I
  - Suzaku XIS
2. Line redshifts correctly with sources
  - Clusters stacked in object restframe (Bulbul et al. 2014)
  - Line in Perseus redshifted correctly at  $\sim 2\sigma$
3. Not detected in blank sky dataset
  - 16 Msec with XMM
  - $\sim 8$  Msec with Suzaku (Sekiya et al. 2015 [1504.02826])

## ATOMIC LINE?



**Unlikely:** can not explain consistently all observations



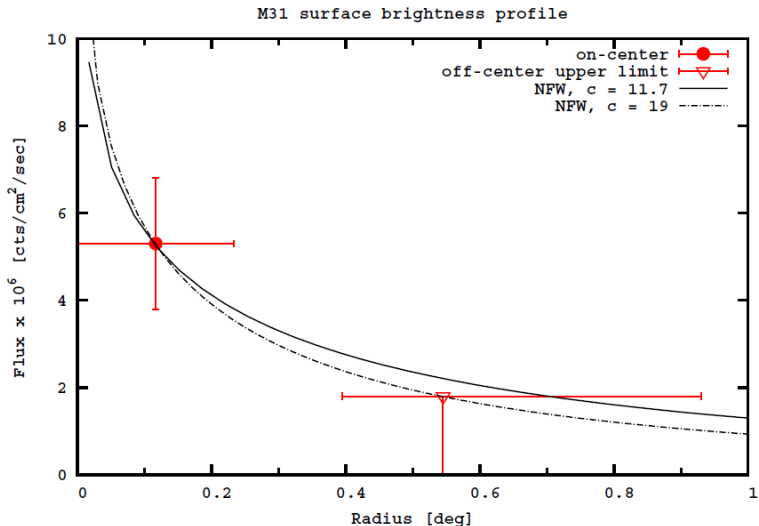
M31 line is **stronger** than other atomic emission  
 CLUSTERS need **anomalous line ratios** of a factor  $\sim 10 - 20$



## DARK MATTER DECAY?



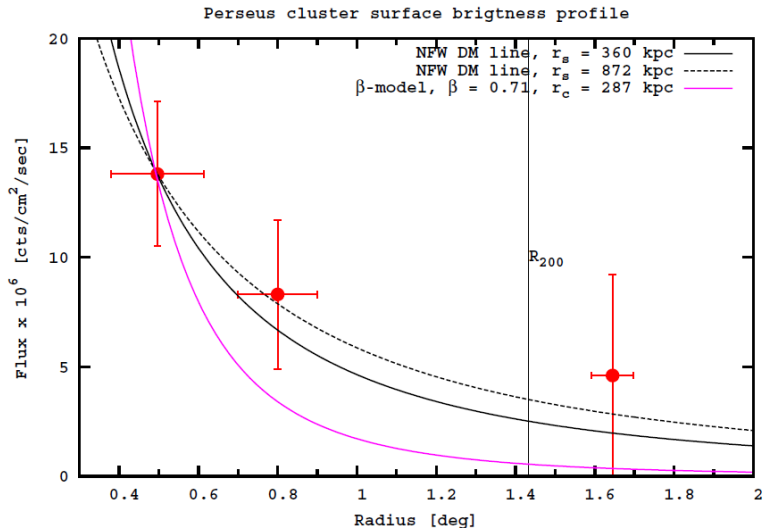
The line flux should be proportional to mass / distance<sup>2</sup>



## DARK MATTER DECAY?



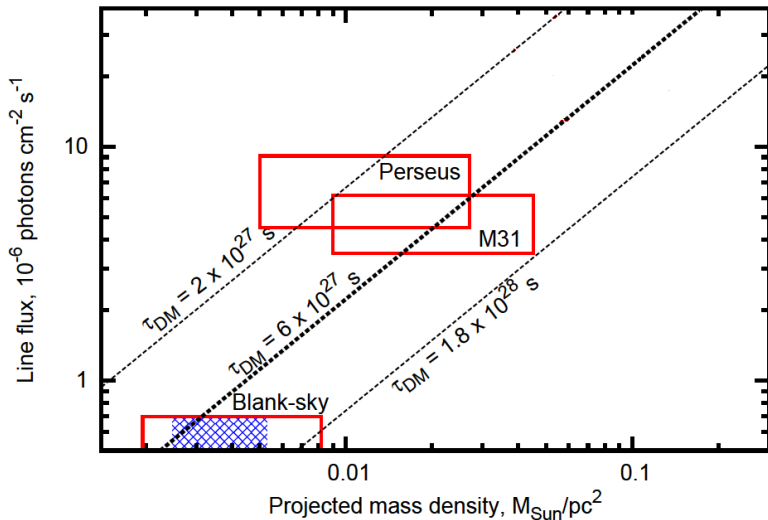
The line flux should be proportional to mass / distance<sup>2</sup>



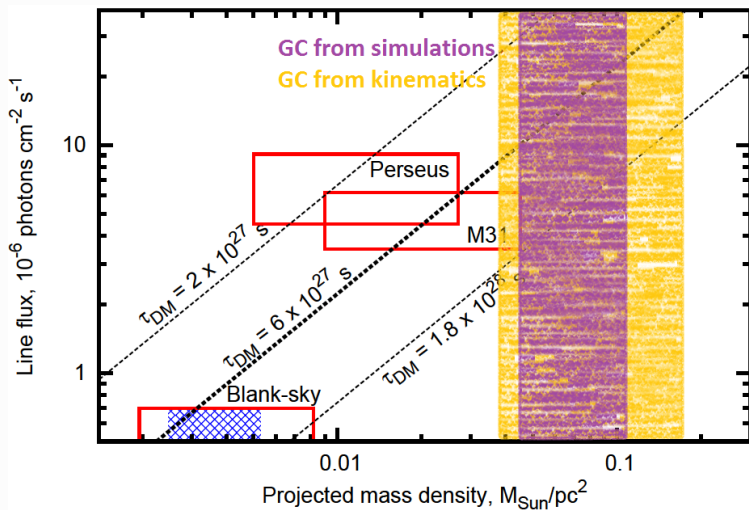
## DARK MATTER DECAY?



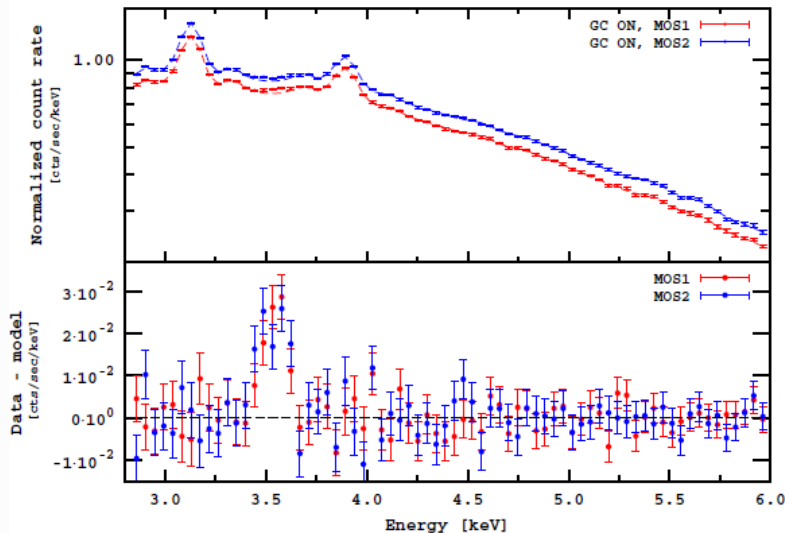
The line flux should be proportional to mass / distance<sup>2</sup>



Expect large signal from GC  $\rightarrow$  “easy” cross-check

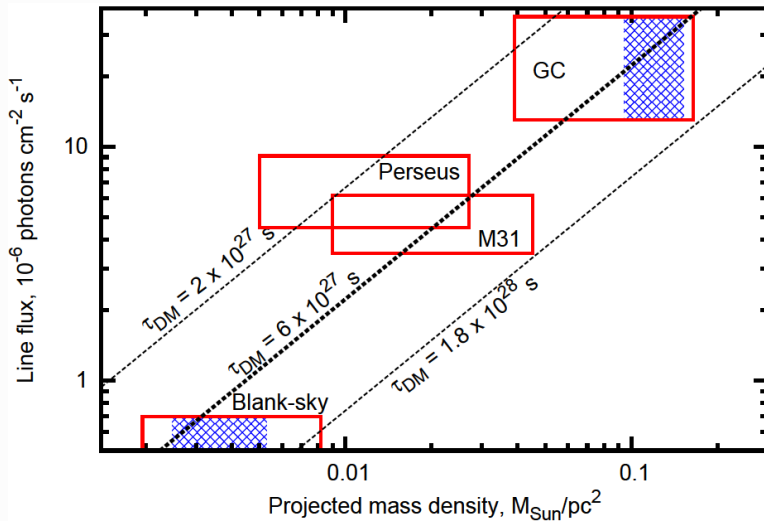


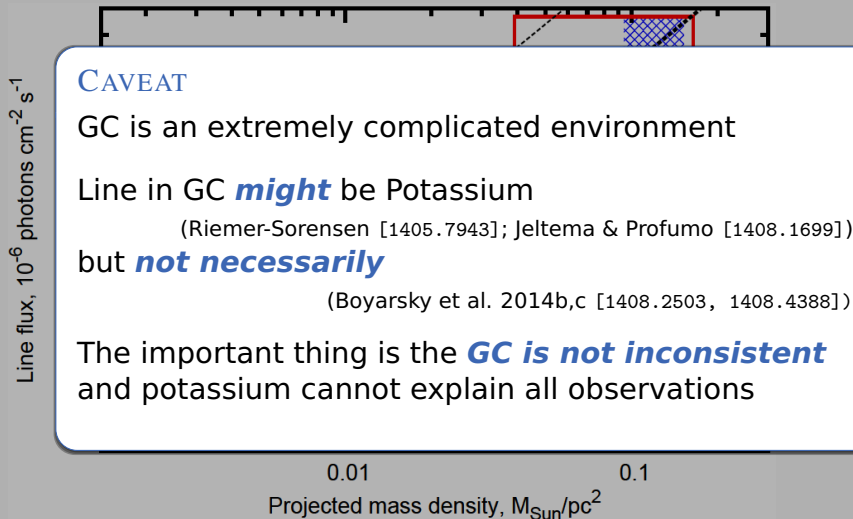
## GALACTIC CENTER



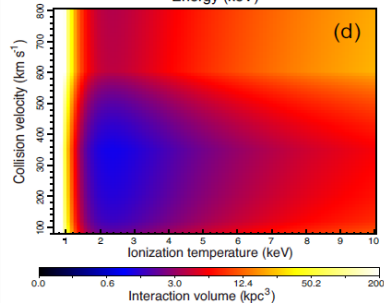
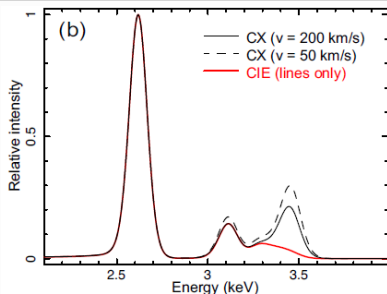
Boyersky et al. 2014b [1408.4388]

## GALACTIC CENTER





# POSSIBLE ALTERNATIVE: CHARGE-EXCHANGE



GU, KAASTRA, ET AL. 2015

[1511.06557]

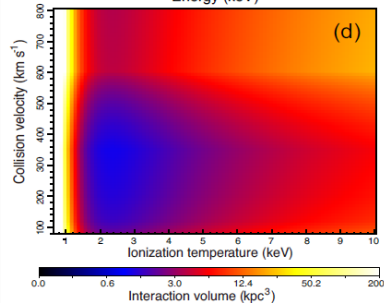
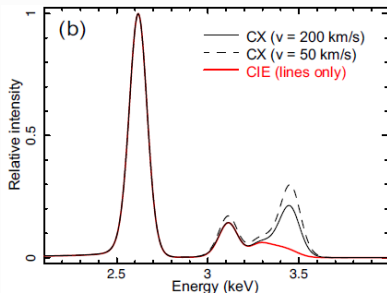
Colliding cold gas and hot gas  
 can emit lines through  
*charge-exchange*.

At **3.48** keV, possible S XVI  
 CX-line.

Depends on *amount* of cold  
 gas and *velocity*.



# POSSIBLE ALTERNATIVE: CHARGE-EXCHANGE



GU, KAASTRA, ET AL. 2015

[1511.06557]

Difficult to predict, but may be plausible in Perseus.

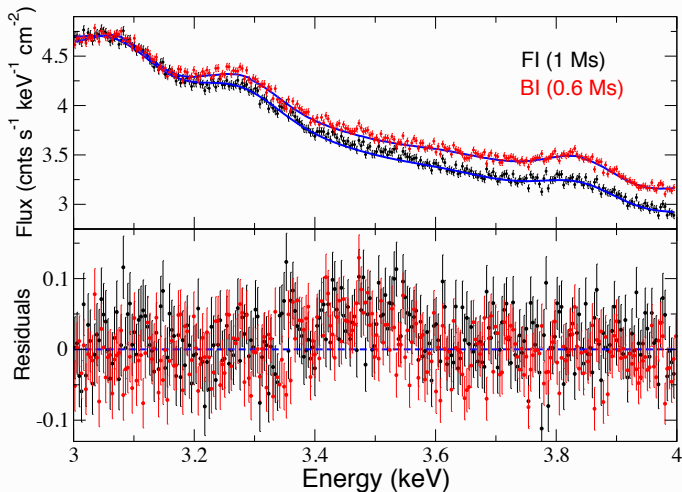
Not expected in *dSph's*.

*Astro-H* will be able to resolve line broadening.

## MORE PERSEUS WITH SUZAKU (SOON)



**Preliminary** 1 Ms with *Suzaku*,  $8\sigma$  detection in the center

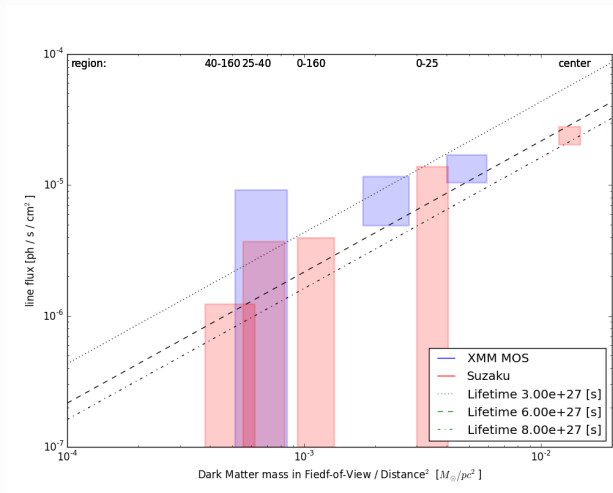


Fransé, Bulbul et al. (in prep)

# MORE PERSEUS WITH SUZAKU (SOON)



**Preliminary** No detection in outskirts with *Suzaku*



Franse, Bulbul et al. (in prep)

# IMMINENT: LOTS OF DRACO



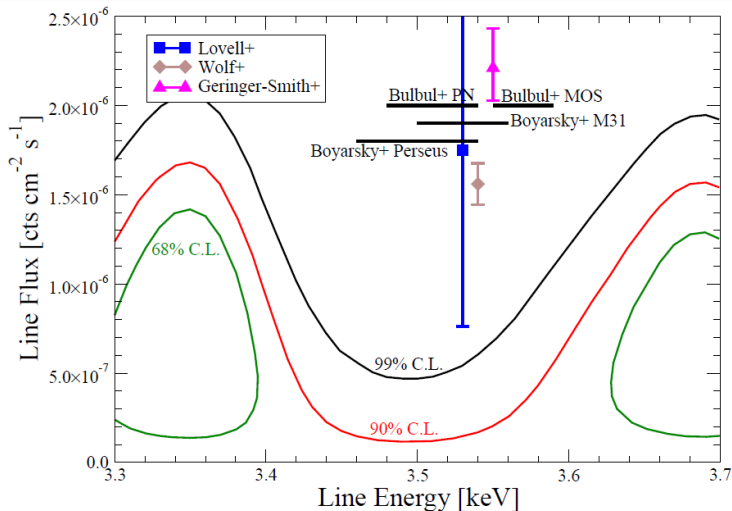
We have been **awarded 1.4 Ms** of XMM observations of the Draco dwarf galaxy this year

- Highest expected signal of all dwarf galaxies (Geringer-Sameth+ 2014, Lovell+ 2014)
- Very gas-poor (**do not expect any atomic lines**)
- We will be able to **confirm or deny the DM origin** of the 3.5 keV line **in early 2016**.

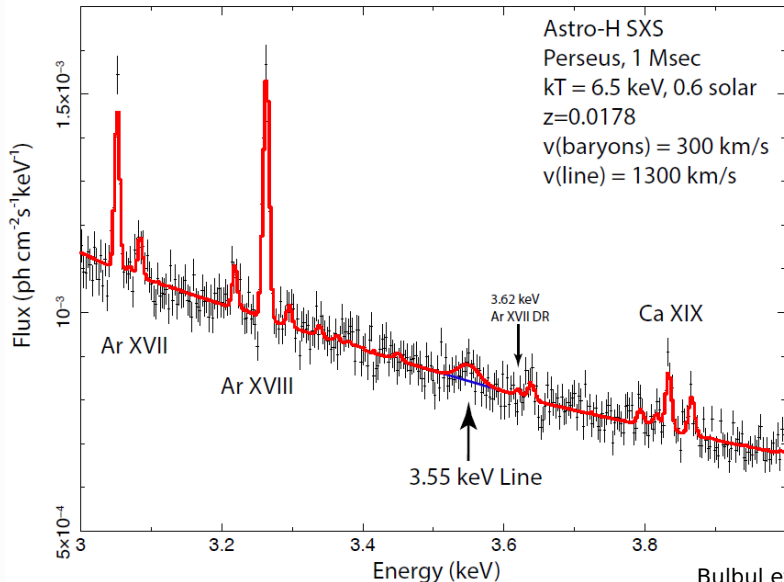
## DRACO BY PROFUMO &amp; JELTEMA



Full 1.6 Ms analysed by Profumo & Jeltema [1512.01239]



## FUTURE: ASTRO-H MICRO-CALORIMETER



Bulbul et al.(2014)

## SUMMARY

