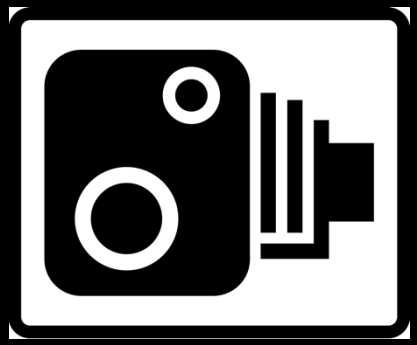
Dark Matter Velocity Spectroscopy: A Speed test for Dark Matter



Speckhard, KCYN, Beacom, Laha
PRL 116 (2016) no.3, 031301

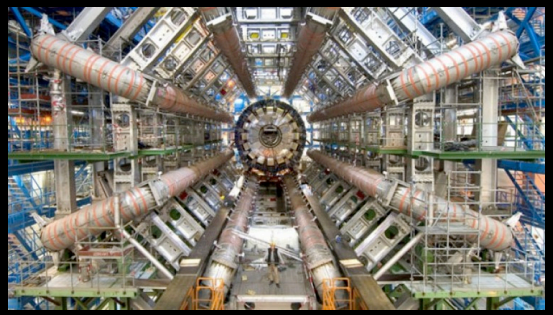
Kenny, Chun Yu NG

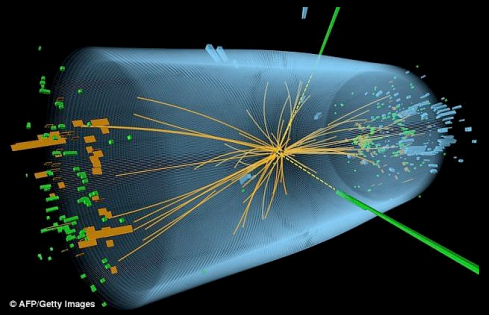
CCAPP, The Ohio State University

How to detect Dark Matter?

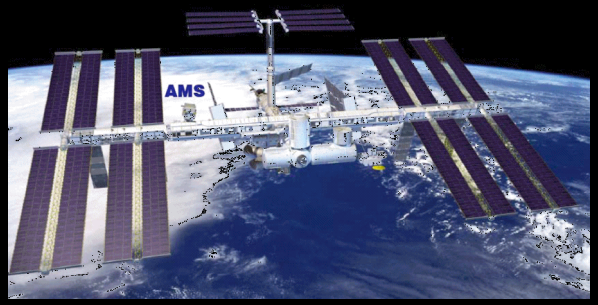
- Direct Detection

- Collider Search



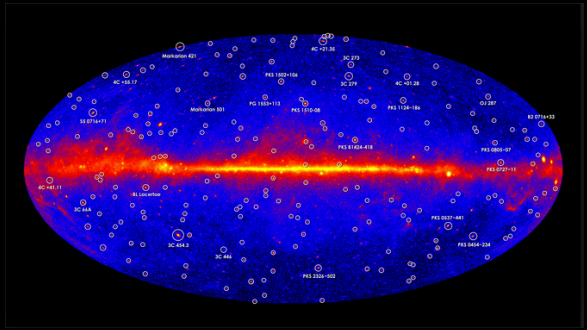


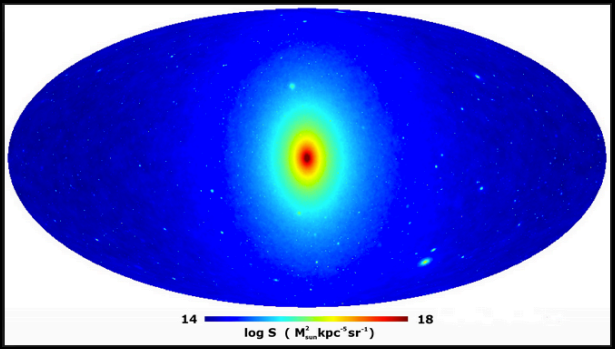
- Indirect Detection



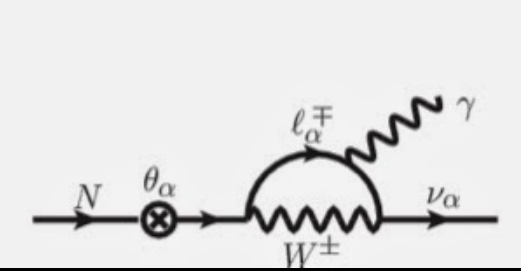
Indirect Detection

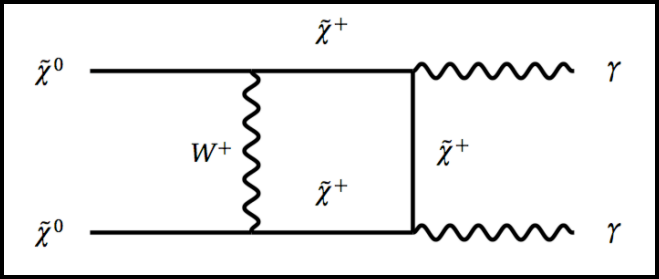
- The Good
  - Remote probe of DM
  - Branching fraction ⇔ DM couplings
- The Bad





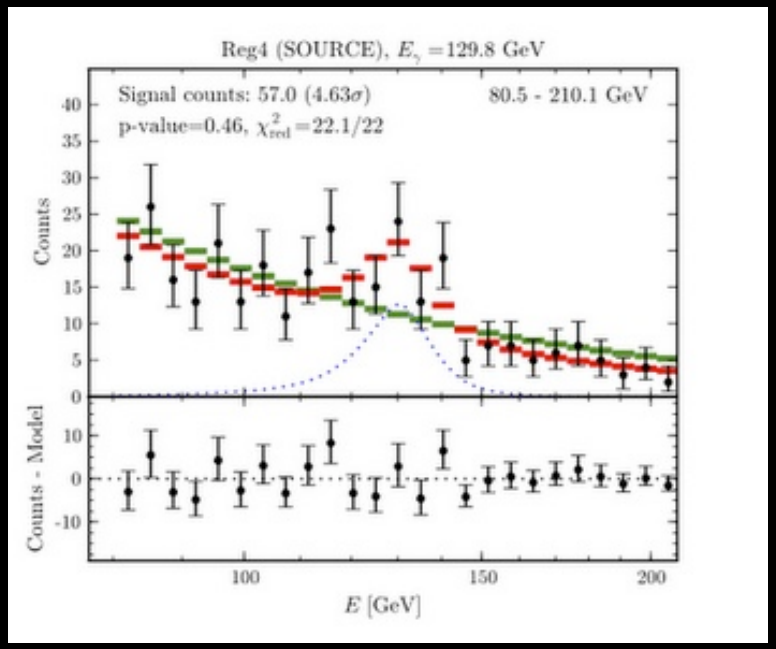
- Smoking gun signatures!

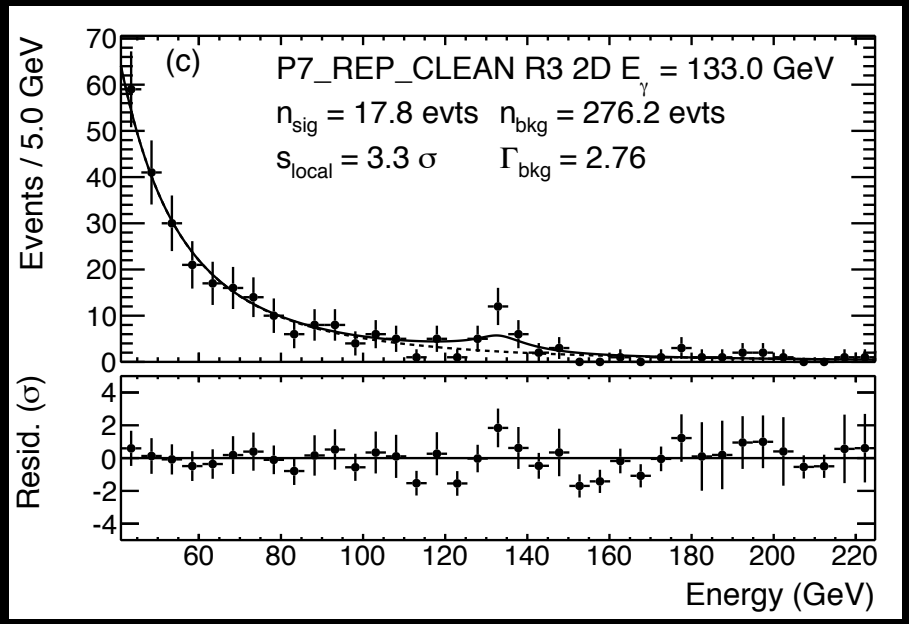




Indirect Detection

- The Ugly……
  - Small statistics
  - Difficult systematics
- (2012) 130 GeV line

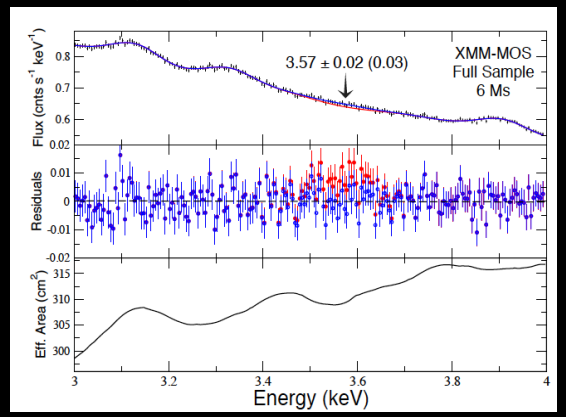




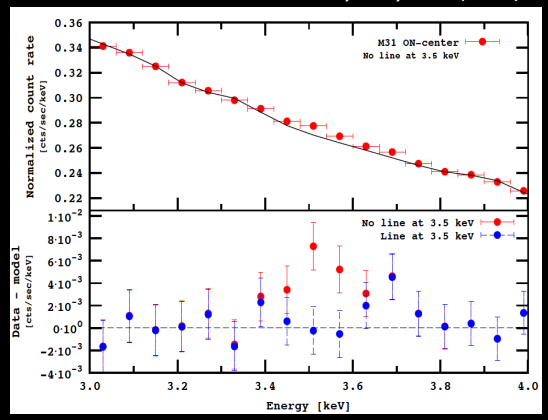
3.5 keV line

- Clusters
- Galaxies – M31
- Galactic Center

Bulbul et al (2014)



Boyarsky et al (2014)



- Origin Still Unclear

Studying the origin of the 3.5 keV line with CCD resolution observations of galaxy clusters and other astronomical objects appears to have reached its limit; the problem requires higher-resolution spectroscopy such as that expected from *Hitomi* (Astro-H).

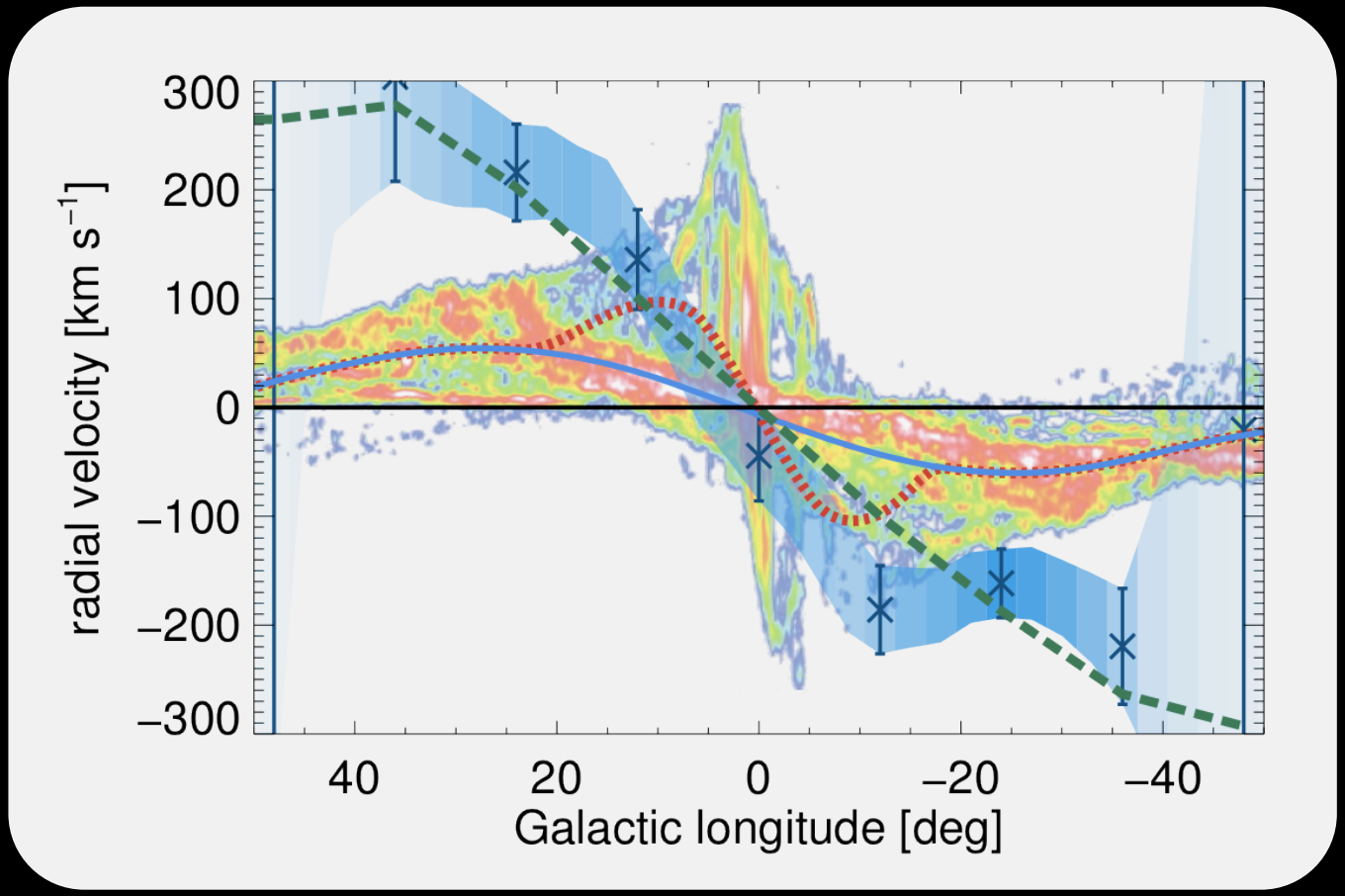
- Astro-h
  - 10^{-3} energy resolution

Need more than smoking guns!

Velocity Spectroscopy

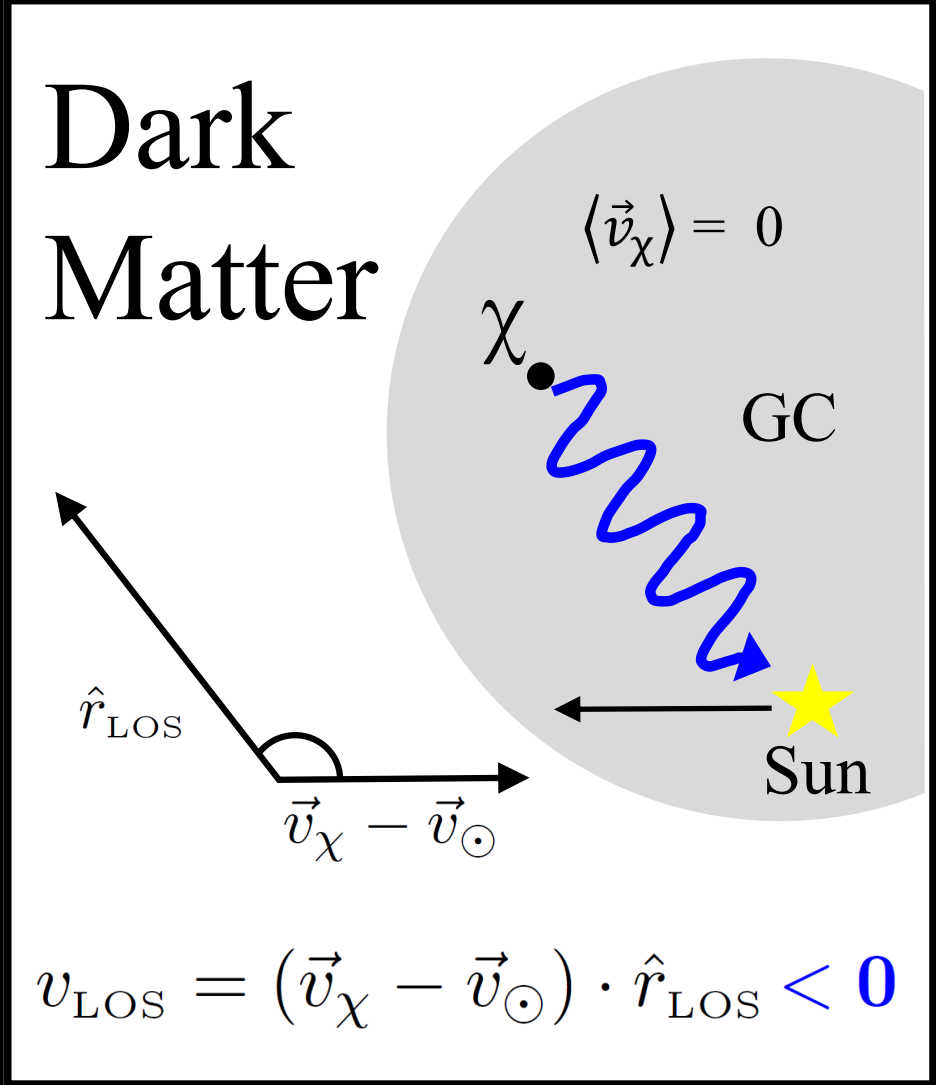
- 10^{-3} resolution <=> Typical MW velocity (~100km/s)
  - Velocity effects become important!

- CO, AL26



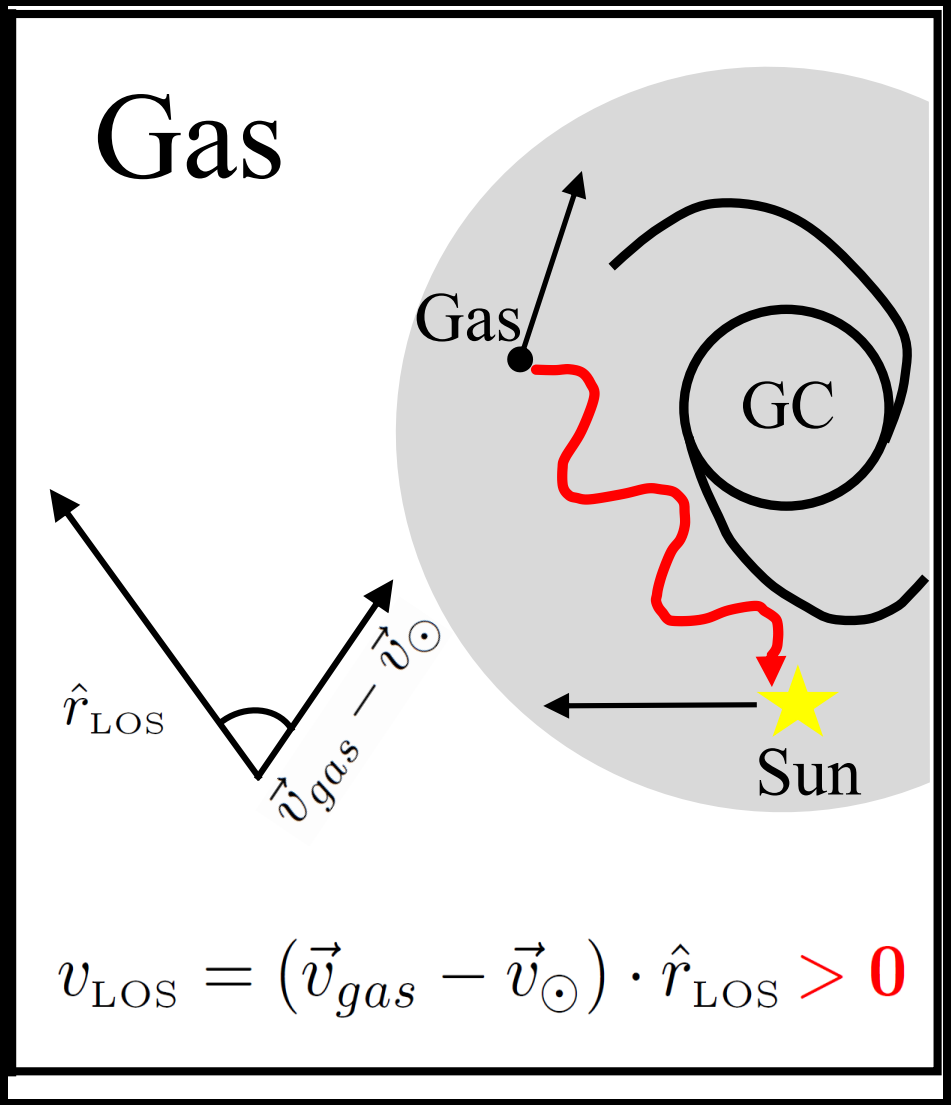
Milky Way DM

- Velocity of the Sun
  - (+)220km/s, +longitude
- Mean dark matter velocity ~ 0
- DM line
  - Blue shifted for +longitude

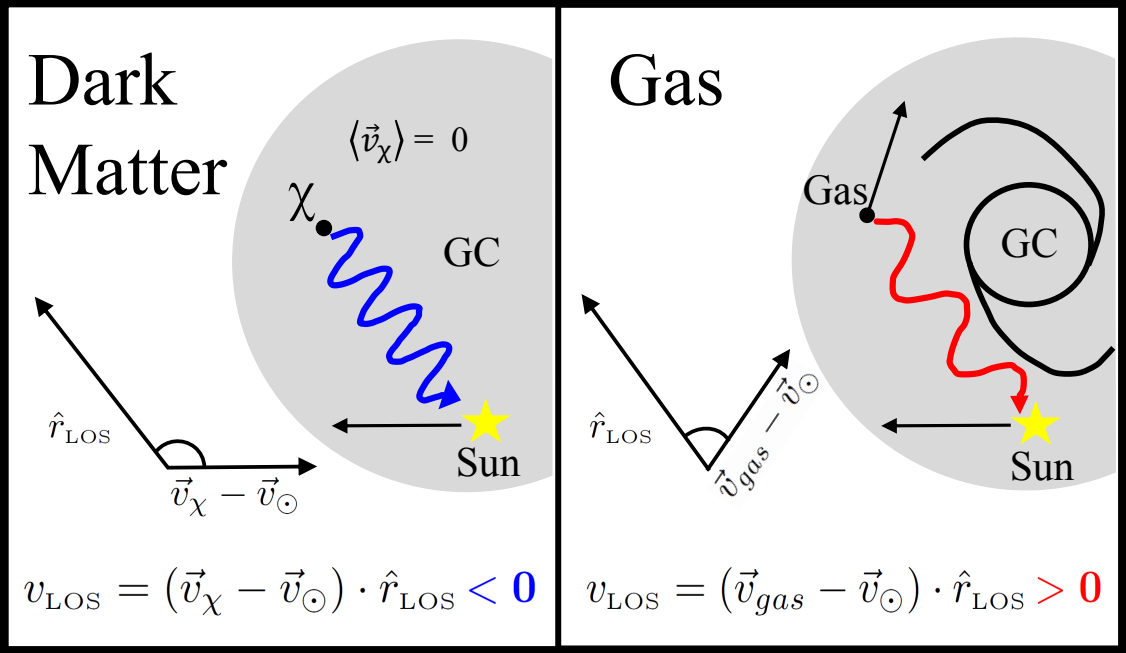


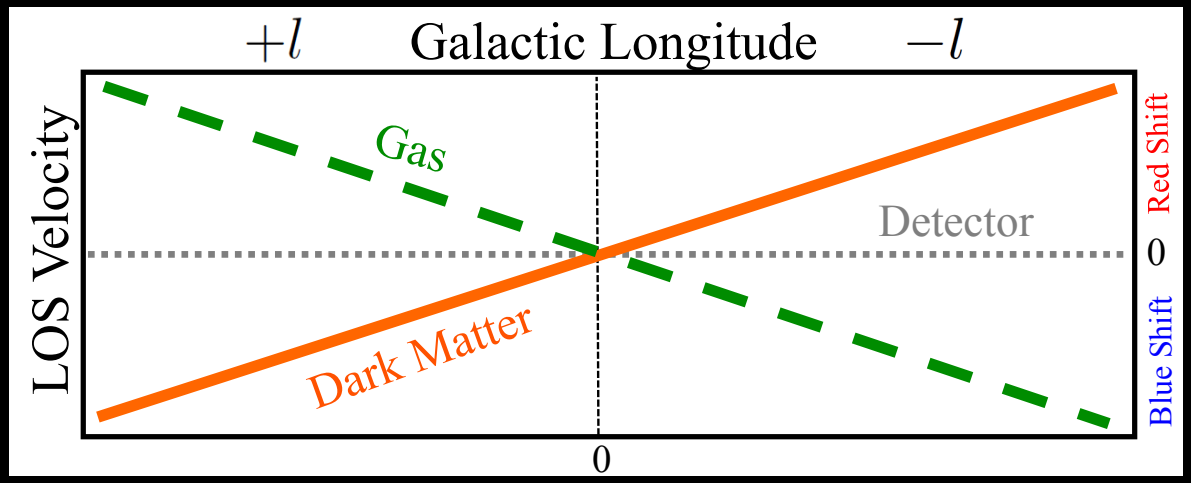
Milky Way Gas (Background)

- Gas and the Sun co-rotate in a disk
  - $V^2 \sim GM/r$
- Astrophysical line
  - Red shifted in + longitude!



Dark Matter Velocity Spectroscopy





Dark Matter Velocity Spectroscopy

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- Need to model both line shifts and line widths

Intensity = $\frac{\rho_\odot R_\odot}{4\pi m_s \tau_s} \mathcal{J}(\psi) \frac{dN}{dE}$

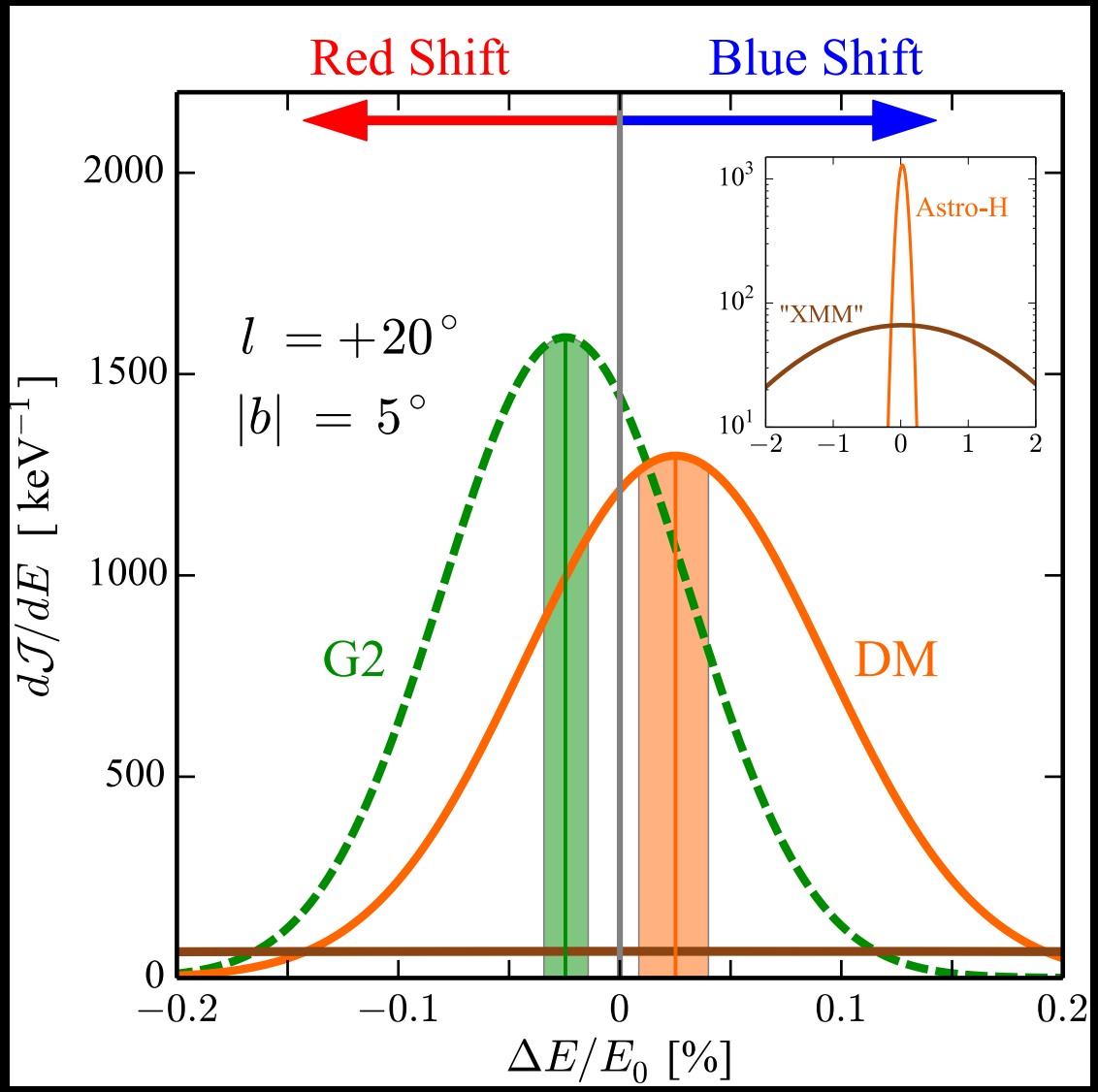
$$\frac{d\mathcal{J}}{dE} = \frac{1}{R_\odot \rho_\odot} \int ds\, \rho_\chi(r[s,\psi]) \frac{d\widetilde{N}(E - \delta E_{\rm MW}, r[s,\psi])}{dE}$$

Line shift

Line dispersion

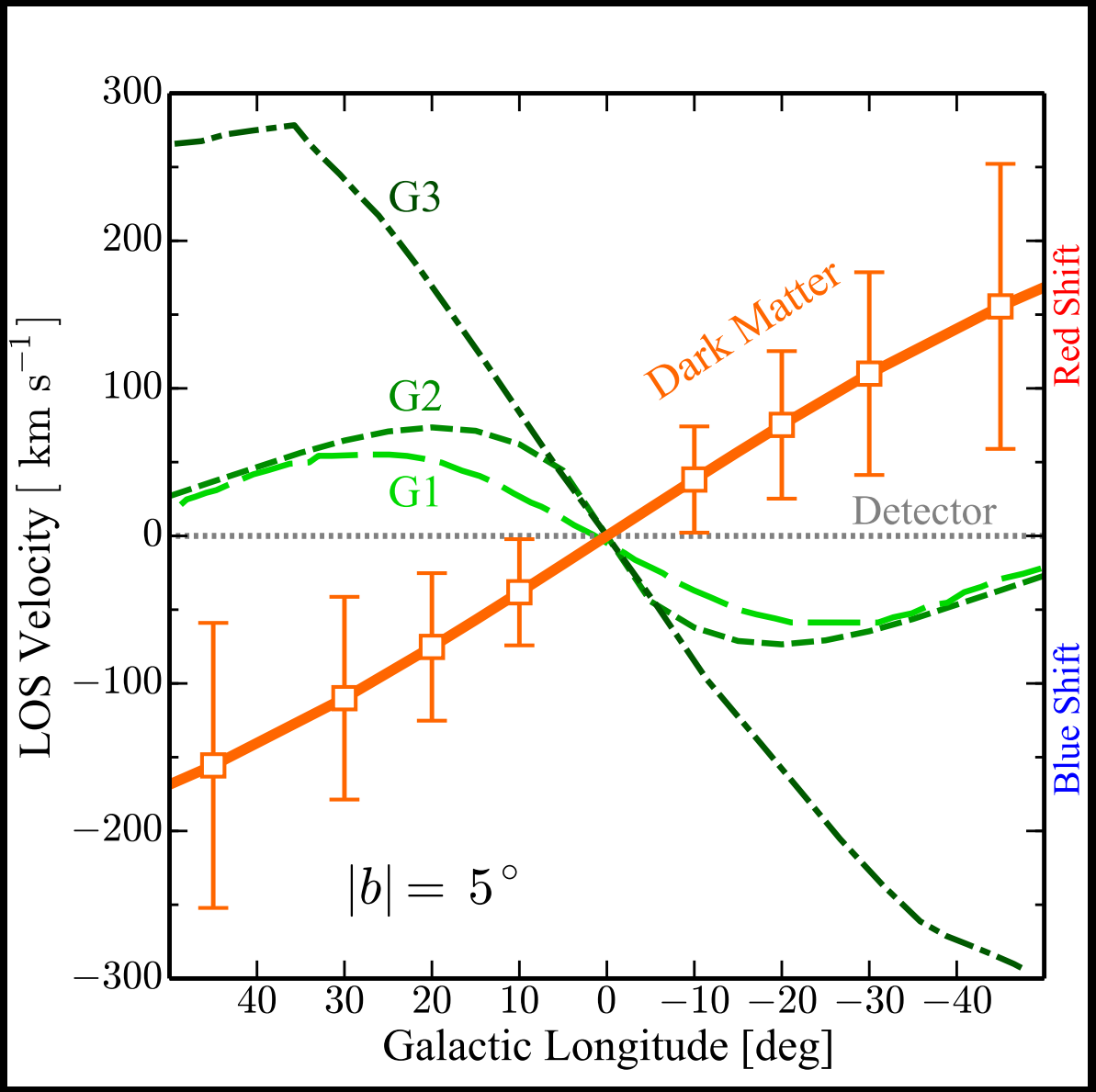
Spectrum

- 2Ms Astro-H observation
  - > 5 sigma detection
- Taken into account both intrinsic and detector line dispersion.



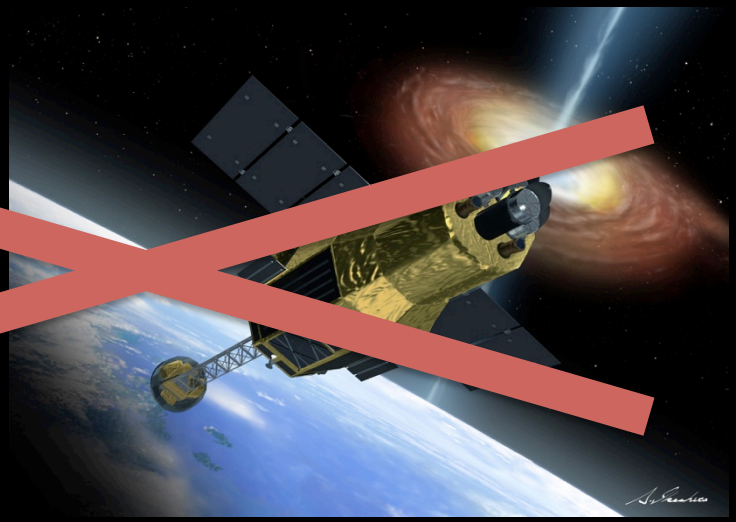
DM – Astro Separation (MW)

- Clean separation
  - DM
  - Astro
  - Detector effect
- Minimal theoretical uncertainty

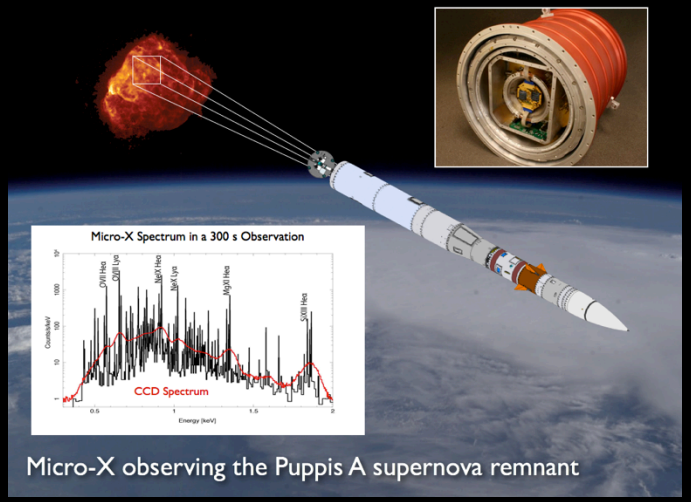


Solutions to the 3.5 keV line?

- SXS - Astro-H
  - Satellite
  - Narrow FOV
  - 10^{-3} resolution !



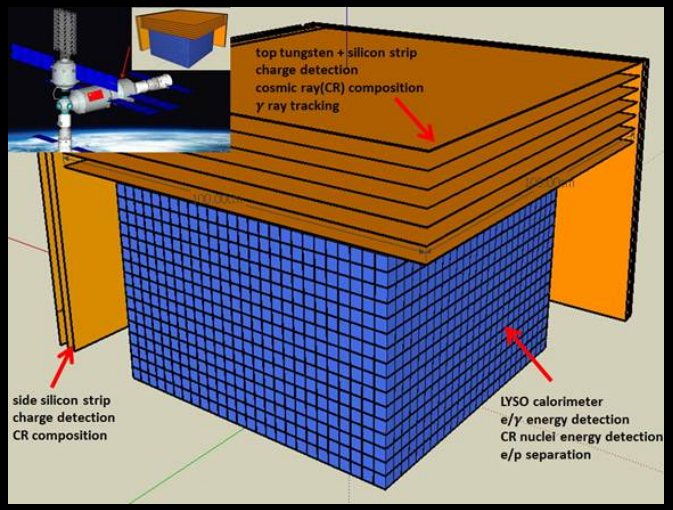
- Micro-X
  - Rocket
  - Wide FOV
  - 10^{-3} resolution !
  - Multiple flights?!



Future mission with ~10^{-3} resolution

- Athena (keV range)
  - E-resolution 2x better than SXS on Astro-H
  - ~5x photon collecting area
  - 2028?

- HERD (GeV-TeV)
  - Photons and electrons
  - 2020?



DM Velocity Spectroscopy

- Extra handle for testing line-like signal
  - The "smoking gun" sometimes is not enough

- If DM decay/annihilation produces a line.
- Allow us to do Dark Astronomy
  - Currently no velocity information on DM!

Thanks!