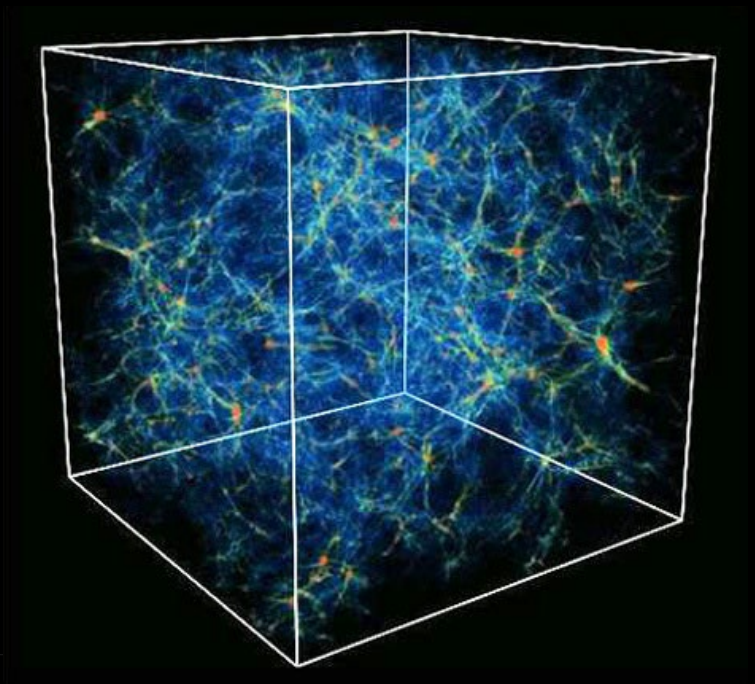
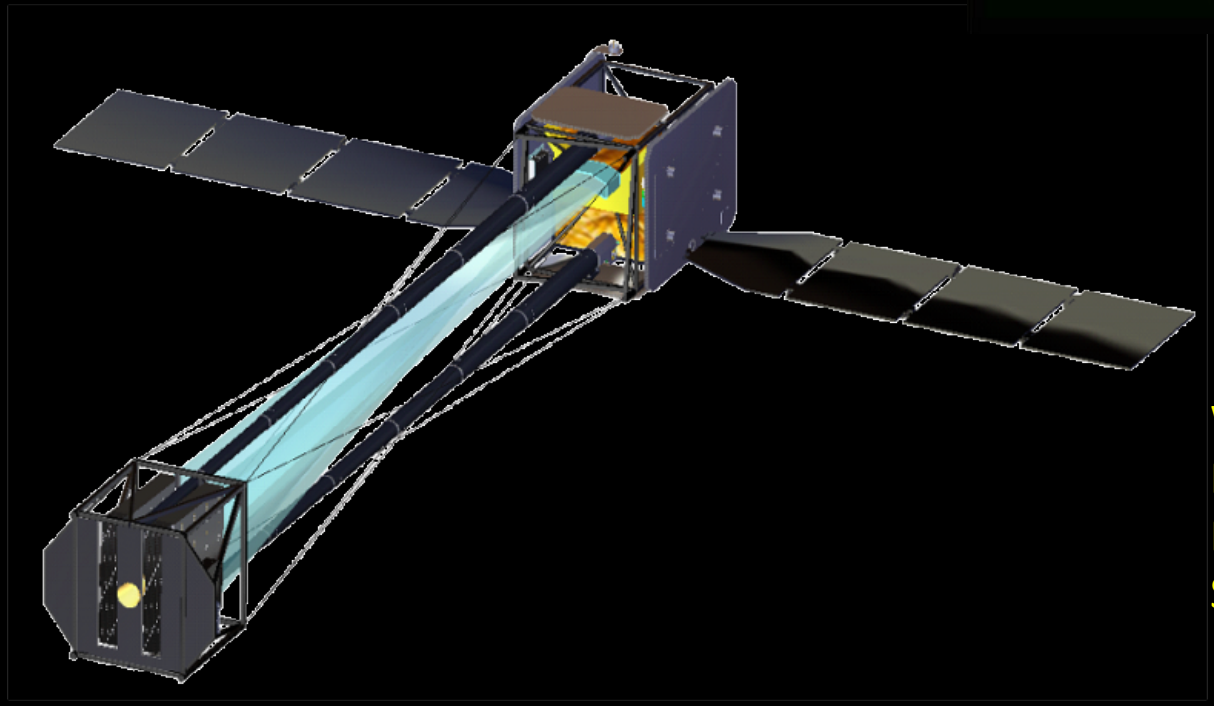
WHIMEX

Doing High Resolution X-ray Spectroscopy Right

Webster Cash, Chuck Lillie
and the WHIMEx Team





With Special Thanks to Northrop Grumman for Development and Proposal Support

The WHIMEx Team

Representative of the Community

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Designed for the WHIM Problem

- **The WHIM is the highest profile science that we can address in an Explorer**
- **The hugely exciting science of AGN's, stars etc comes free after WHIM problem is solved.**
- **IXO Requirement was R~3000, A~1000cm^2**
  (We fought for a decade to get IXO to raise R above 300)
- **IXO is gone, and there's nothing else on the high resolution horizon**

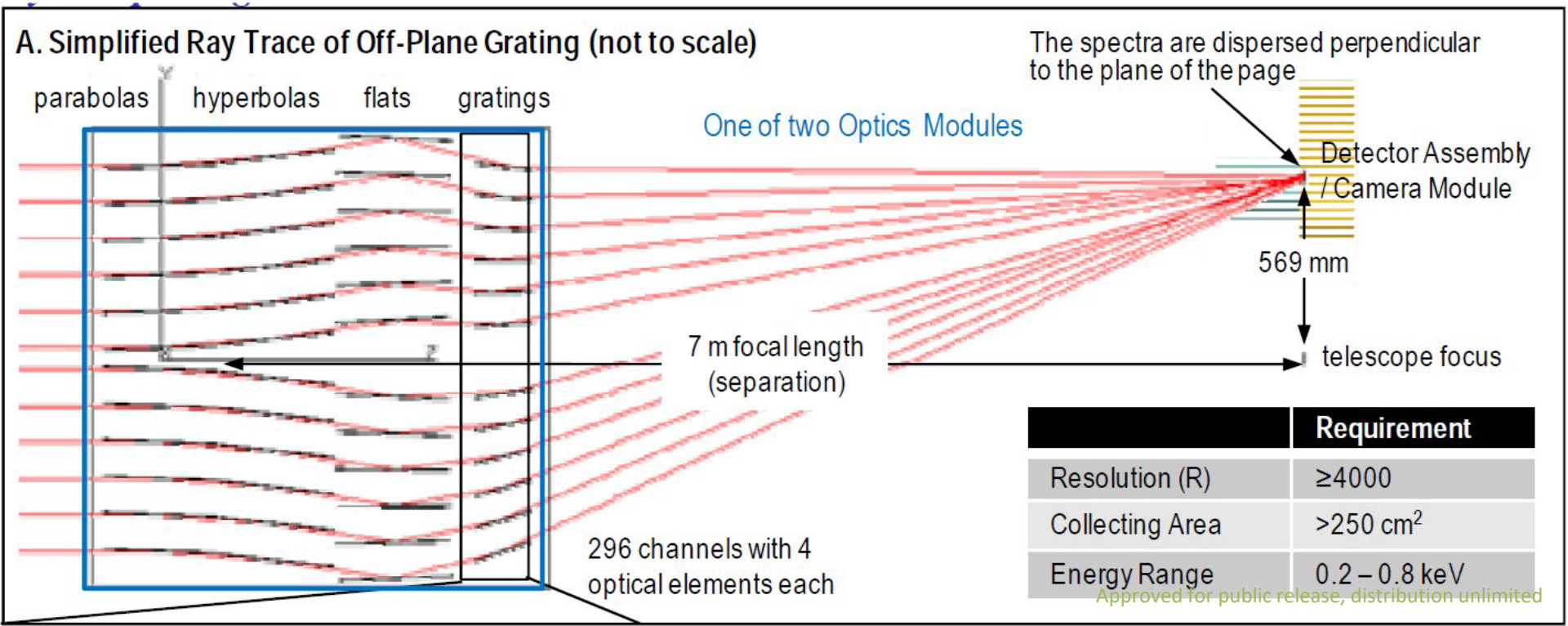
Origin of Concept

- **IXO Technology Studies and Older Suborbital Work**
- **Science from Decadal**
- **Will Zhang's slumped glass Wolter optics (NUSTAR/IXO)**
- **MIT Flat Mirrors and Metrology**
- **Web Cash and Randy McEntaffer's Off-plane Gratings**
- **CCD Arrays - Open U, Osaka U, MIT, GSFC**

Reoptimized for an Explorer

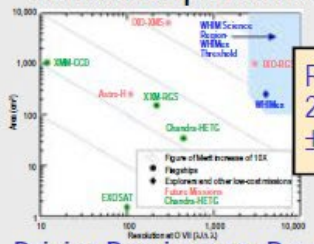
Reduced Complexity

- **A Single Wolter Mandrel**
- **A Single Grating Master**
- **15” Quality**
- **7m Focal Length with Deployable Bench**



	Requirement
Resolution (R)	≥4000
Collecting Area	>250 cm^2
Energy Range	0.2 – 0.8 keV

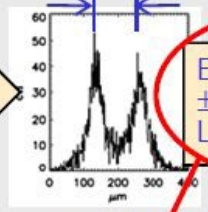
Science Requirements



Driving Requirement: R = 4000

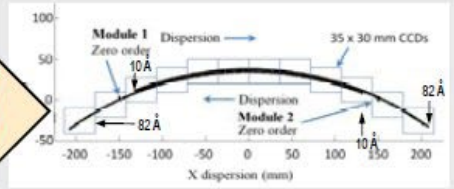
Resolution Equates to 2 arcsec FWHM, or 70 µm +/- ±1.18 σ Line Separation

Telescope Architecture/Derived LOS Requirements



89 µm 3σ min peak-to-peak separation

Equates to ±2.63 arcsec 3σ Line Separation



LOS requirements derived from telescope design and LOS architecture

Spectral Resolving Power Budget	Arcsec (+/- 3σ)	µm (+/- 3σ)	FWHM (arcsec)	Arcsec (+/- 3σ)	µm (+/- 3σ)	FWHM (arcsec)
	Requirement[1]			Capability		
Centroiding	**0.15**	**5**	**0.06**	**0.13**	**4**	**0.10**
Centroiding Error	0.15			0.13	4	0.10
Subapertured beam	**2.40**	**81**	**0.94**	**2.16**	**73**	**1.70**
Single Channel P/H[2]	2.00			1.78	61	1.40
Channel to Channel Alignment[3]	0.95			0.90	31	0.71
Groove fan error[4]	0.90			0.83	28	0.65
Drift (200 sec)	**0.55**	**19**	**0.22**	**0.21**	**7**	**0.16**
Zero order position error[5]	0.40			0.18	6	0.14
Bore sight camera error[6]	0.20			0.10	3	0.08
Reconstruction error[7]	0.05			0.03	1	0.02
Jitter (100 msec)	**0.75**	**25**	**0.29**	**0.22**	**8**	**0.18**
Bus rigid body motion	0.15			0.10	3	0.08
Bus to OMA flex body motion	0.70			0.20	7	0.17
Unallocated Margin	**0.50**	**17**	**0.20**			
Total	**2.63**	**89**	**2.00**	**2.19**	**74.21**	**1.72**

[1] Based on R=4000

[2] 1.4 FWHM achieved for single P/H pair, see image to the right

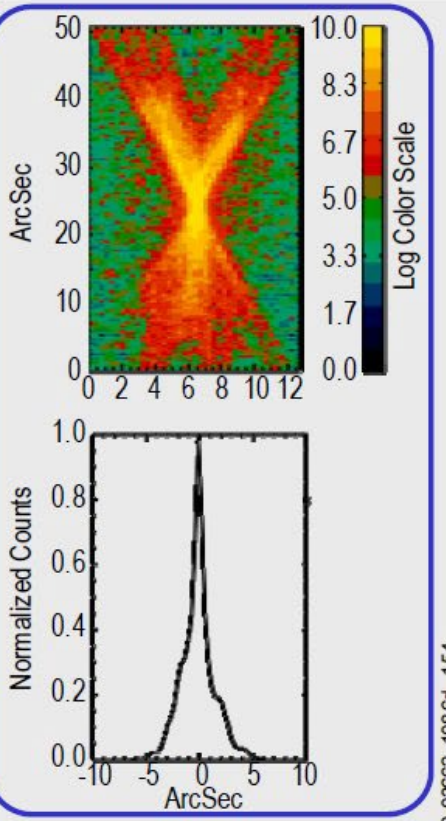
[3] Hartmann tests during P/H stacking can currently limit this error to 0.9" 3σ

[4] JY routinely makes groove densities with errors better than 1 part in 10000 (3σ)

[5] Ability to centroid line spread function from raytrace simulations

[6] Post Kalman filtered; specification to Terma at 0.5 arcsec 3σ single read

[7] Least squares fit error in pointing reconstruction



Single P/H Pair Measured Performance

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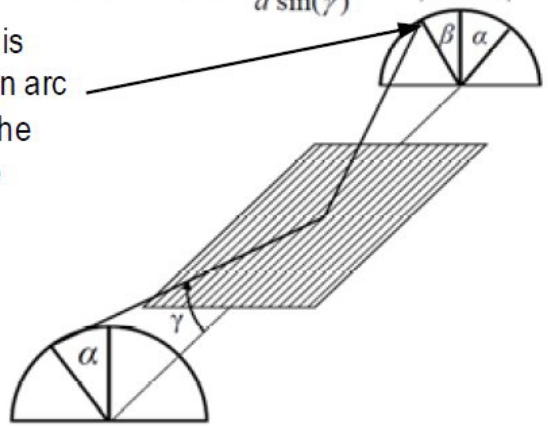
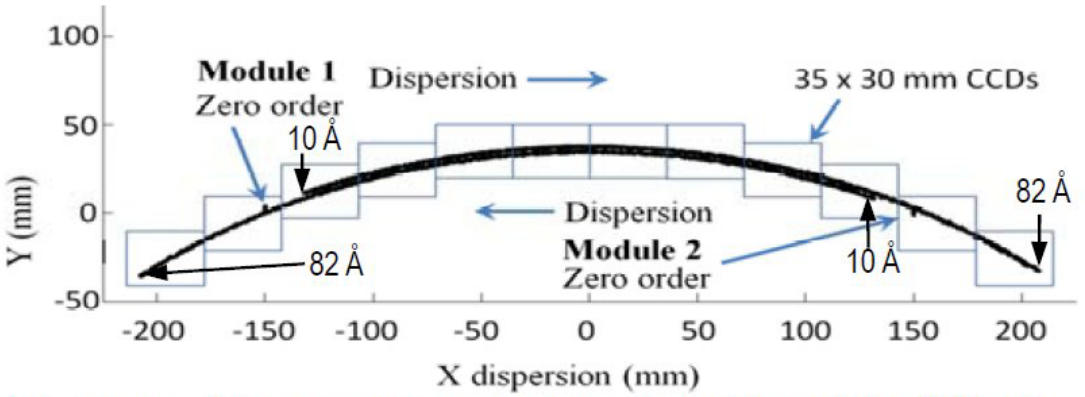
B. Off-Plane Grating Theory

$$\sin(\alpha)+\sin(\beta)=\frac{n\lambda}{d\sin(\gamma)}$$

The spectrum is dispersed in an arc "off plane" to the incident angle

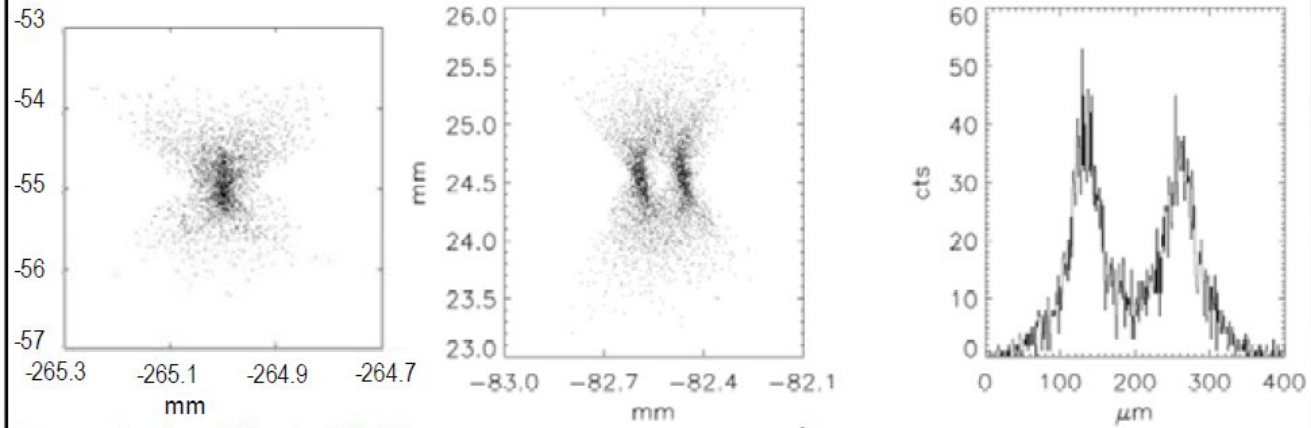


C. WHIMex Arcs – Two Modules, mirrored dispersion



With coverage of the zero order, the focal plane naturally covers the 200 – 800 eV range; higher energies are covered at reduced sensitivity

D. Resolution Pairs (Module 1, first order) Each Separated by 0.035Å

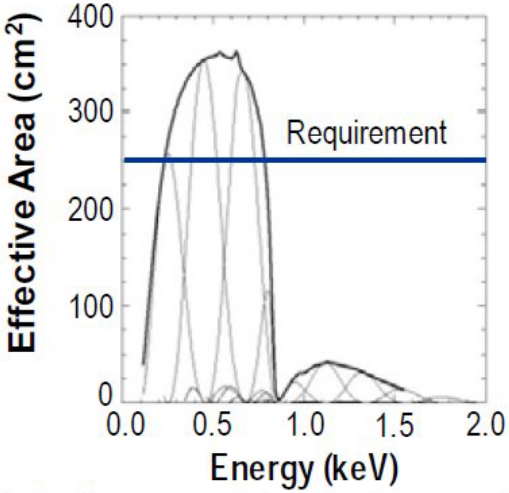


Zero order (undiffracted light)

65 & 65.035Å ~190 eV R~4000

1st order diffraction spots are separated by >2 resolution elements.
Higher orders = higher resolution 32Å, n=2, R~8000, 16Å, n=4, R~16000, etc

E. Estimated Collecting Area



Collecting area achieved using sum of multiple diffraction orders

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Payload

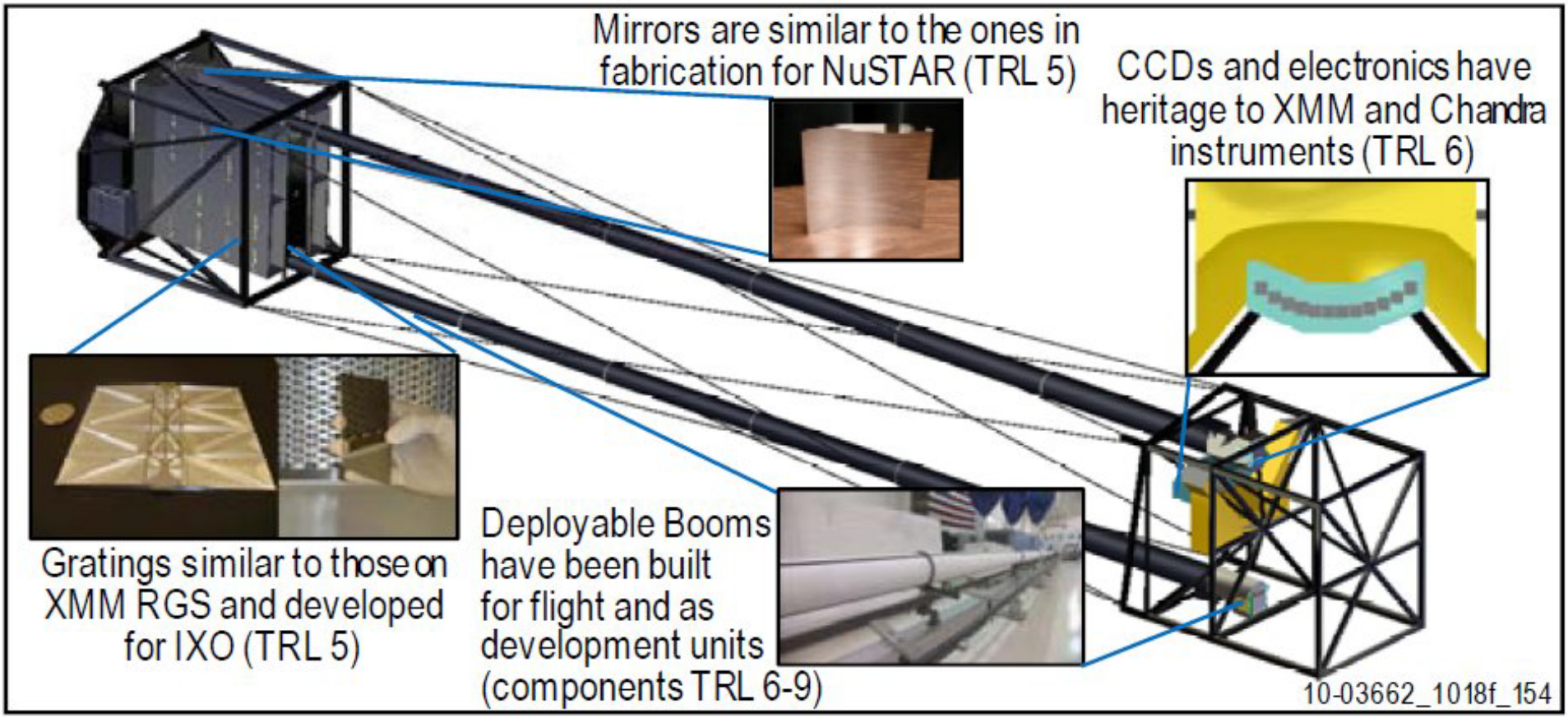
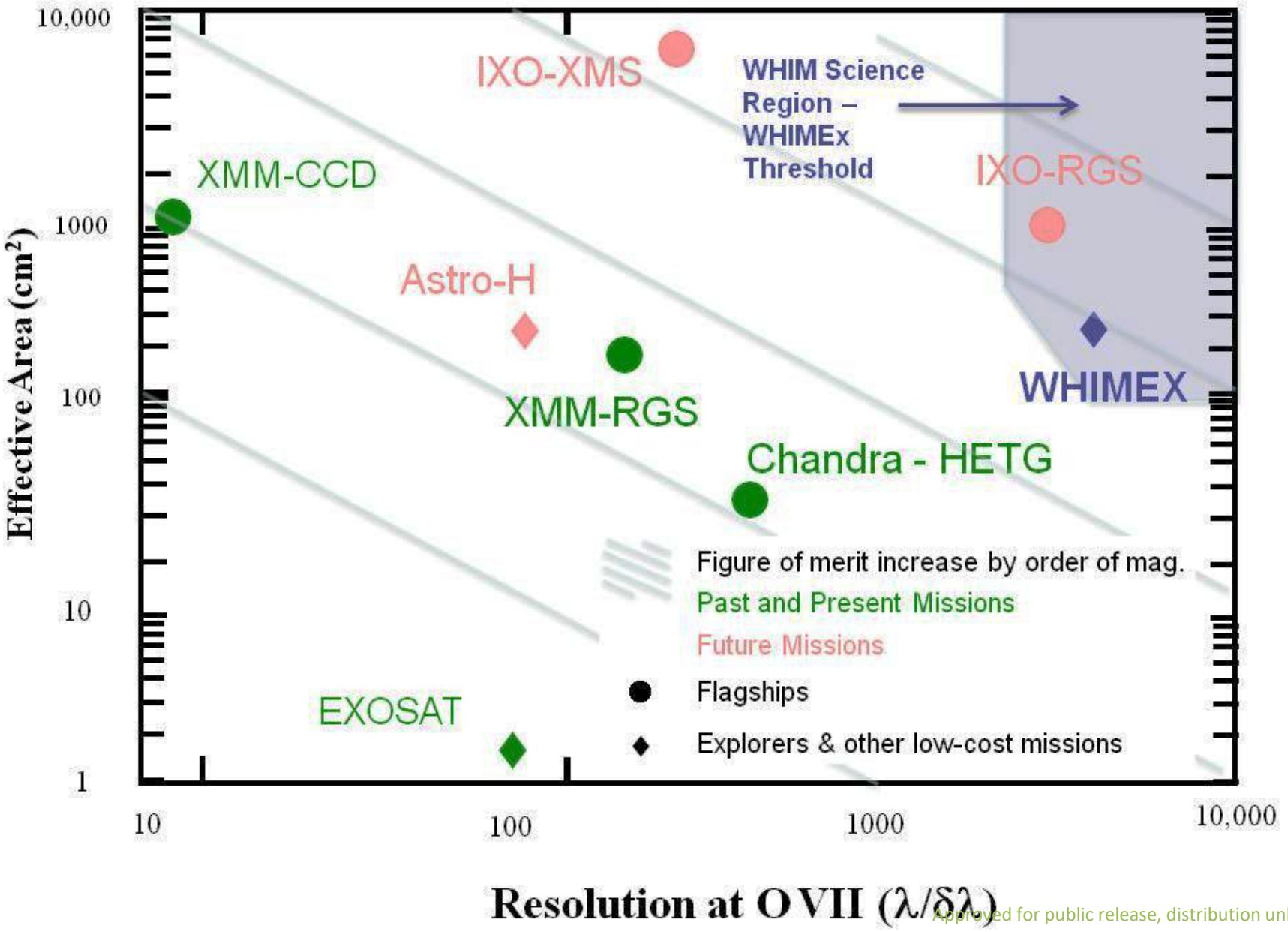
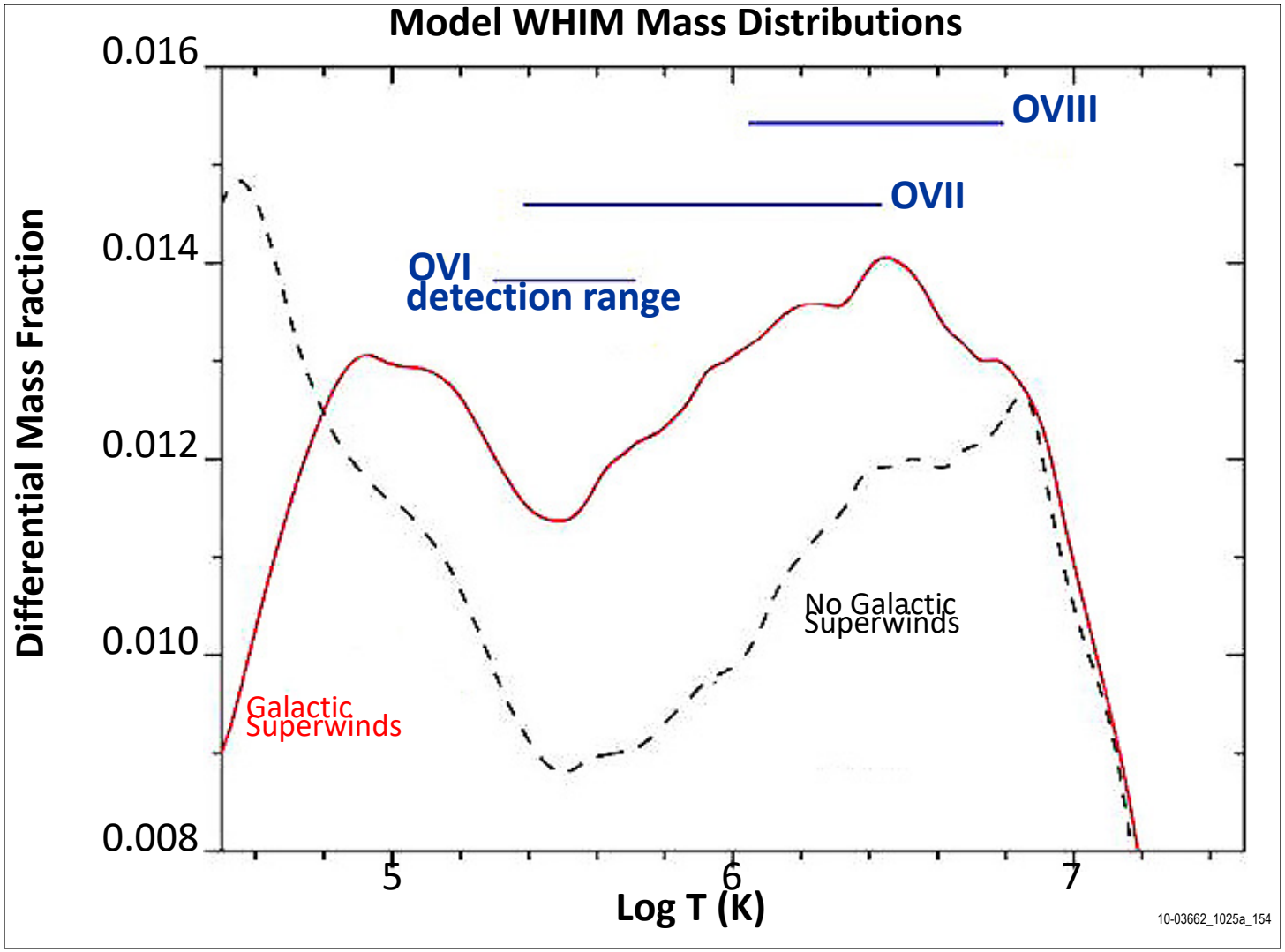


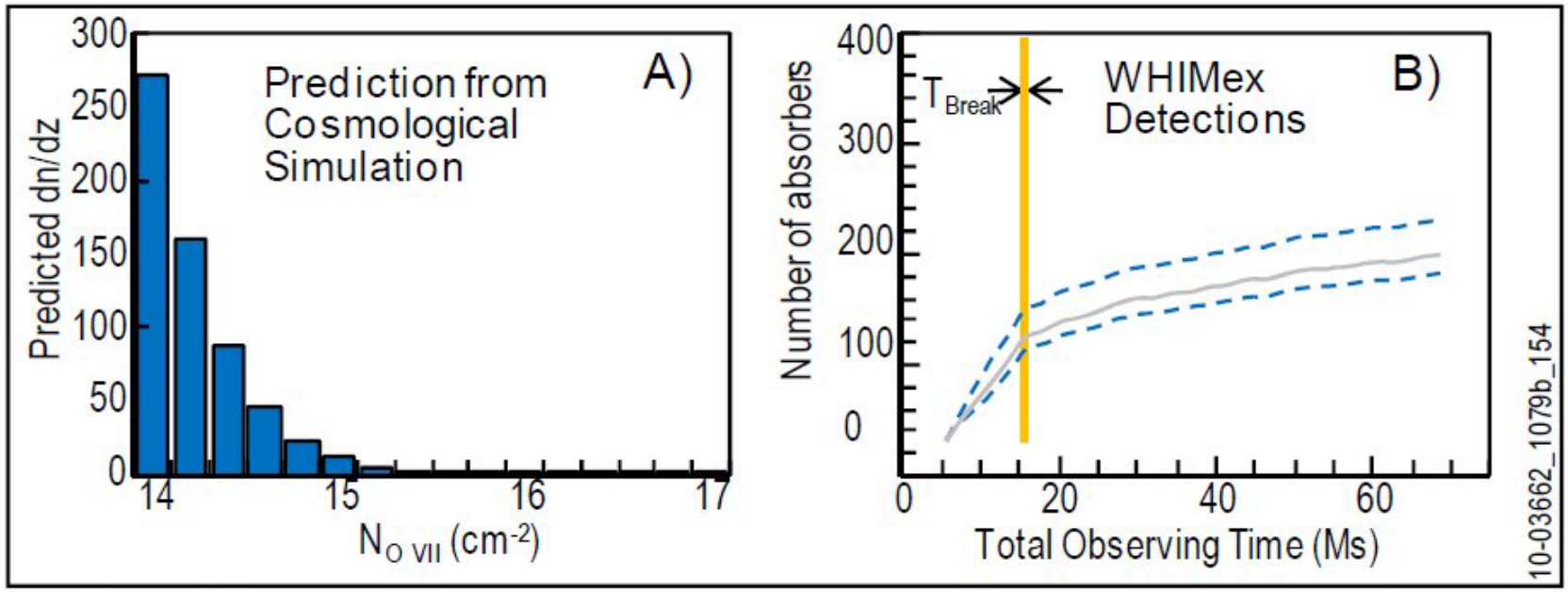
Figure of Merit



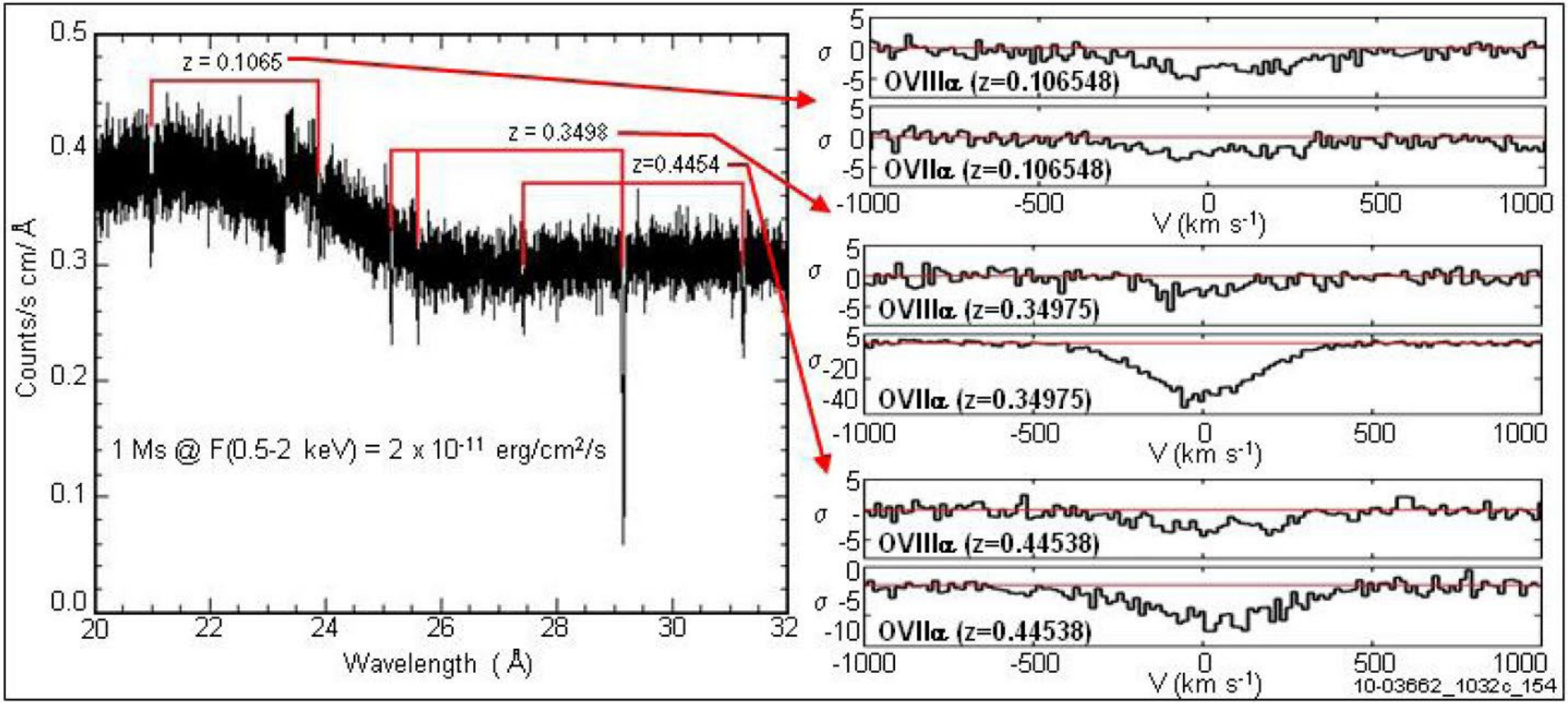
OVII and OVIII Diagnostic of WHIM

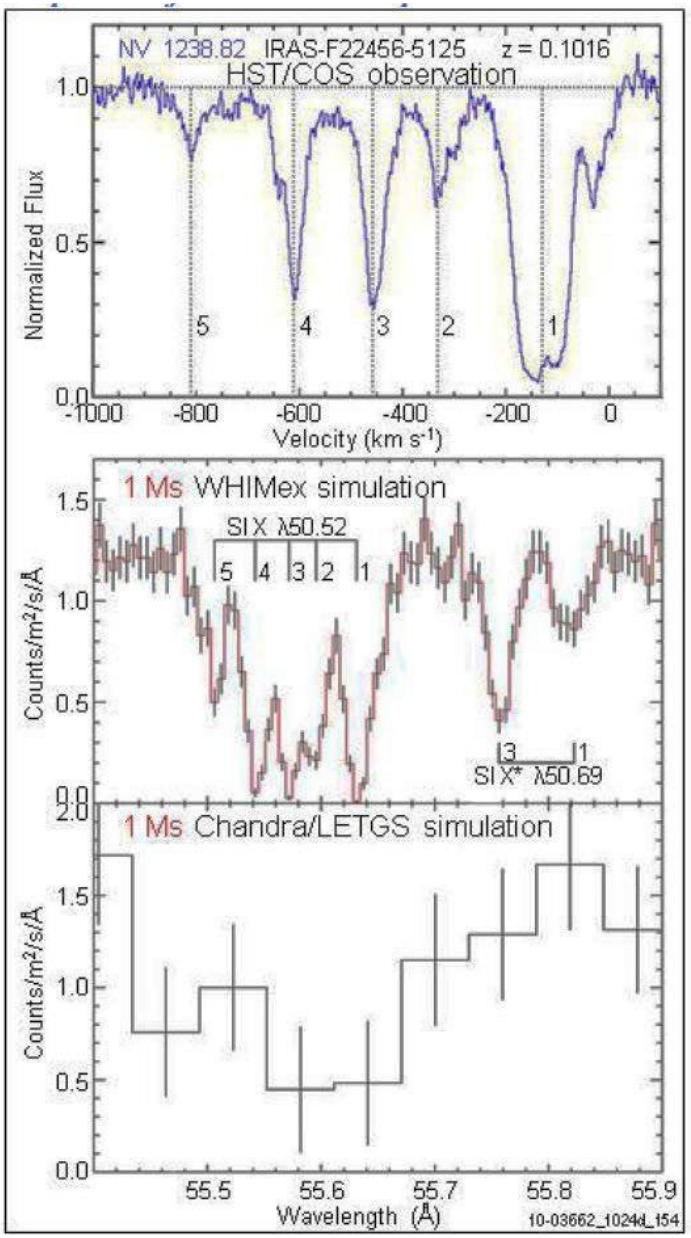


Filament Column Densities



Simulated WHIMEx Spectrum





WHIMEx

AGN Simulations

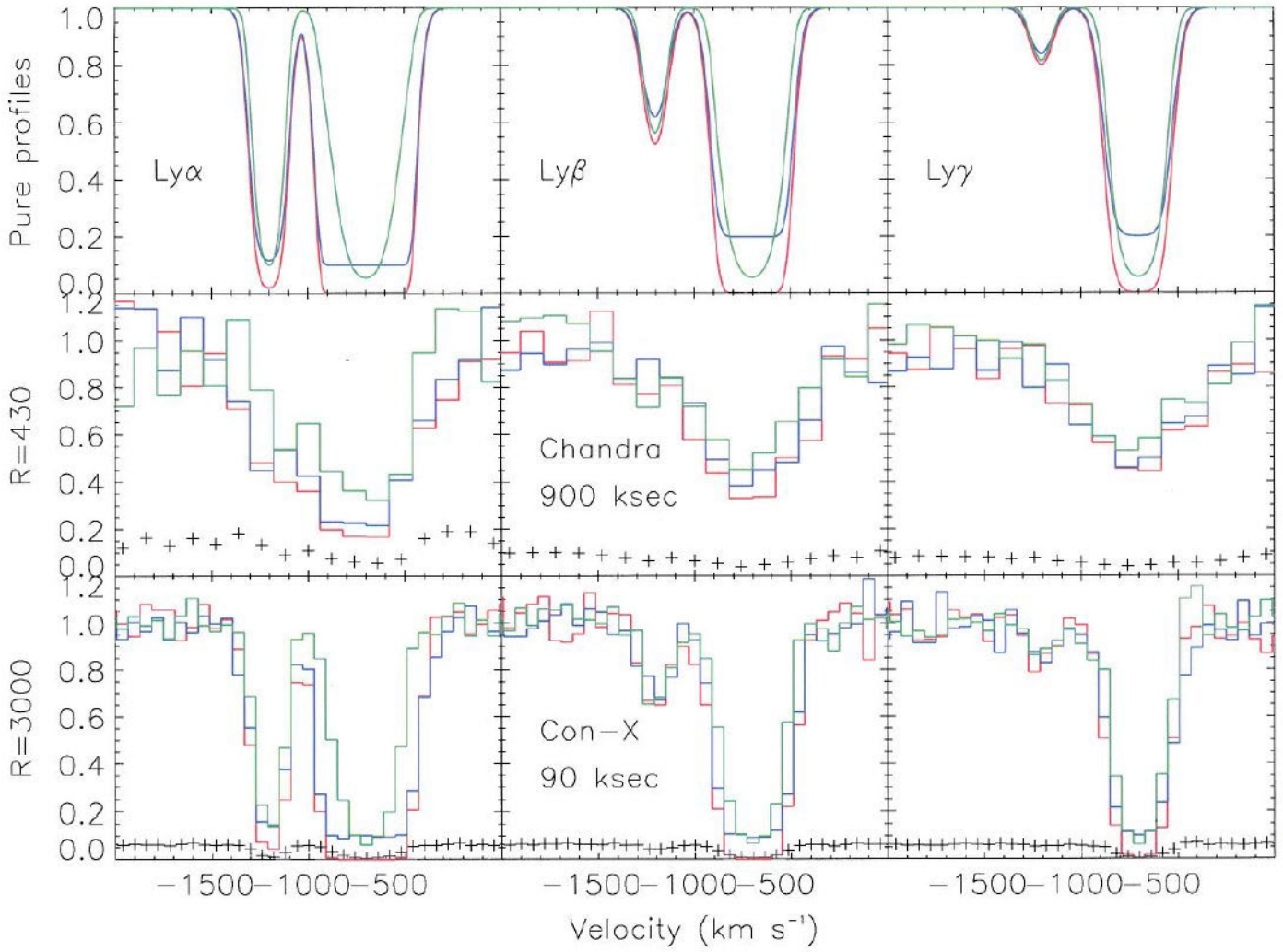
COS

WHIMex

Chandra

High Resolution is Essential to Measuring the Basic Parameters

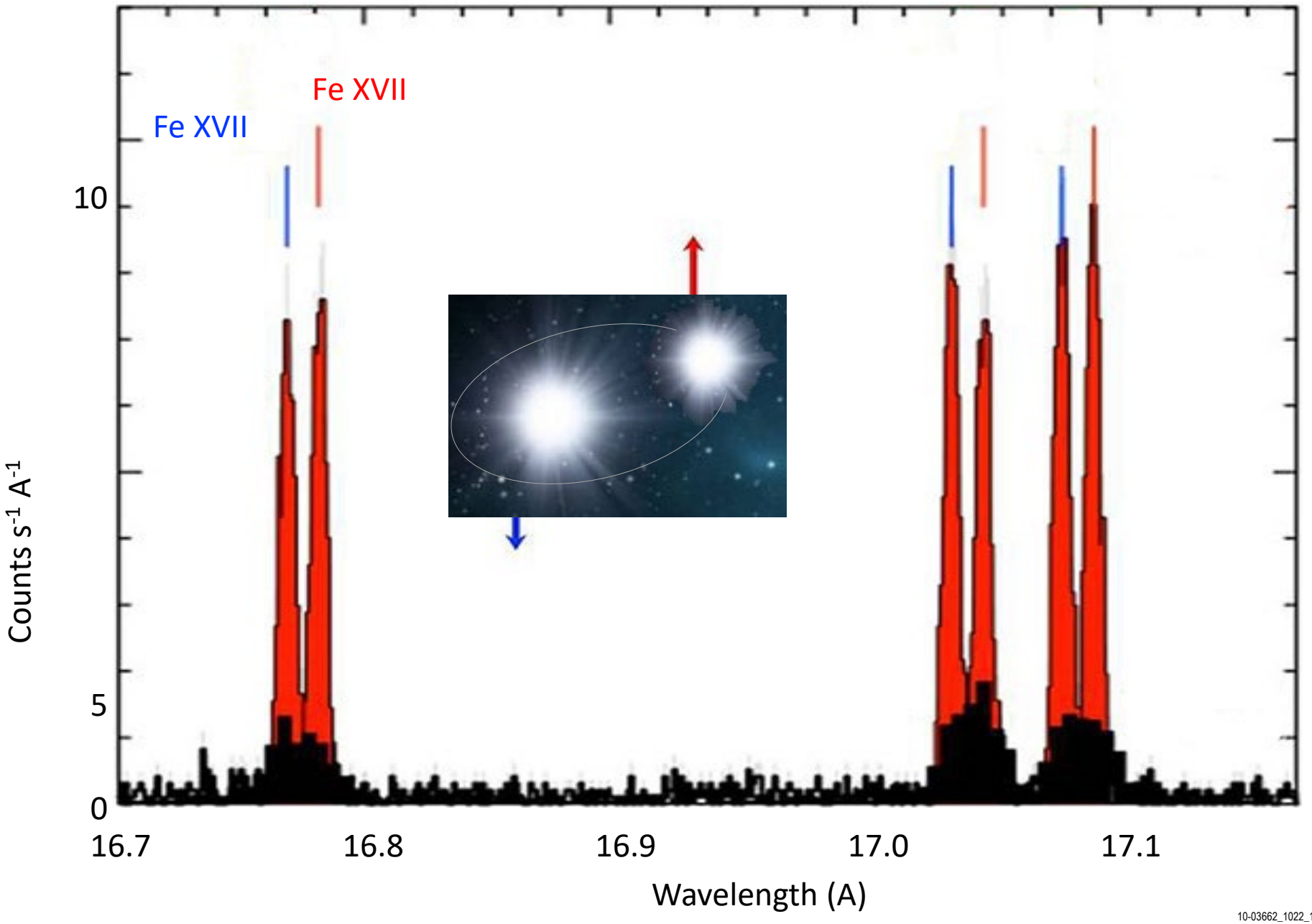
(Slide courtesy of Schindhelm and Arav)



Shape of line is crucial to separating continuum from saturated line.

Without E/δE > 3000, can miss energy outflow by factor of 100!

AR Lac binary; (ϕ=0.25, Δ v = 230 km/s)



Conclusions

- WHIMEx is Astronomy for and by the community
  It is the IXO XGS channel repackaged
- Can be implemented at the low end of the cost scale under consideration.
- Important Core Science and Exploration
  that Cannot be Addressed Other Ways
- Wide Open Guest Observing
- Can Be Built Now, But Needs Prototype Demonstration
- Also Needs a Community Statement of Why It is Relevant
  to the Decadal. There is much mischief between competing disciplines