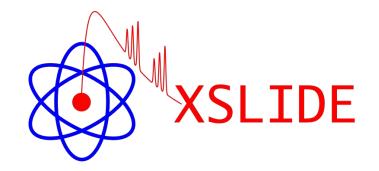
An Introduction to XSLIDE

X-Ray Spectral Line IDentifier and Explorer



NASA/GSFC XRISM SDC

Outline

- Scientific Methodology of Plotting X-Ray Spectra
- Overview of XSLIDE Software
- XSLIDE Walkthrough
- Software Development

Scientific Methodology of Plotting X-Ray Spectra

X-Ray Spectral Fitting

• An X-Ray spectrometer obtains photon counts, from which we seek to determine the source spectrum via the equation:

$$C(I) = T \int R_{\rm RMF}(I, E) R_{\rm ARF}(E) S(E) dE$$

C = counts [photons],T = observation time [second],I = instrument channel,E = energy [keV] $R_{\rm RMF} =$ redistribution matrix (probability of photon of given energy being counted in given instrument channel) [unitless] $R_{\rm RMF} =$ ancillary response file containing effective area [cm²],S = source spectrum [photons/(cm²·second·keV)]

- Problem: This equation cannot be analytically solved for S(E)
- Rigorous Solution: Forward fitting, by positing a model for *S*(*E*), minimizing the error by varying the model parameters, and revising the model as necessary

Problem With the Rigorous Solution

equil, vequil

etable

expabs

expdec

expfac

gabs

grad

grbcomp

gsmooth

highecut, zhighect

grbjet

grbm

hatm

heilin

hrefl

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ireflect

ismabs

kdblur

kdblur2

kerrconv

kerrdisk

kyconv

kyrline

laor

laor2

lorentz

lsmooth

logconst

log10con

lyman meka, vmeka

mtable

nlapec

nsagrav

nsatmos

nsmax

nsx

nteea

nsmaxg

nthcomp

olivineabs

partcov

pegpwrlw

pexmon

pexrav

pexriv

phabs,

optxagnf, optxagn

pcfabs, zpcfabs

zphabs, zvphabs

notch

nsa

nei, vnei

kerrd

kerrbb, zkerrbb

logpar, zlogpar

mekal, vmekal

mkcflow, vmcflow

npshock, vnpshock

ismdust

ezdiskbb

gadem, vgadem

gauss, zgauss gnei, vgnei

XSPEC Models

6.1 Alphabetical Summary of Models

	acisabs
	agauss, zag agnsed
	agnslim
	ascac
	apec, vape atable
	bapec, by
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not always	btapec,
	bvvtapec
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	cabs
an taken time	carbatm
so takes time	cemekl, ce
	cflux
	clmass,
	monomass
	compbb
	compLS
	compmag

	Table 6.1: Summary of Models
fodel	Description
bsori	Ionized absorber.
cisabs	Extra absorption due to contamination on the ACIS filters.
igauss, zagauss	Gaussian line profile in wavelength space.
gnsed	AGN SED model.
gnslim	AGN super-Eddington accretion model.
iscac	ASCA PSF mixing model.
apec, vapec, vvapec	APEC thermal plasma model.
table	Additive table model.
papec, bvapec, bv-	Velocity broadened APEC thermal plasma model.
apec	
body, zbbody	Blackbody spectrum, with redshift variant
obodyrad	Blackbody spectrum with norm proportional to surface area.
Dexrav	E-folded broken power-law reflected from neutral matter
pexriv	E-folded broken power-law reflected from ionized matter
oknpower, zbknpower okn2pow	Broken powerlaw. Three-segment broken powerlaw.
omc	Comptonization by relativistically moving matter.
oremss, vbremss,	Thermal bremsstrahlung, with redshift variant.
bremss	
ornei, bvrnei, bvvrnei	Velocity broadened non-equilibrium thermal plasma model.
otapec, bytapec,	Broadened APEC emission spectrum with separate continuum and
ovvtapec	line temperatures.
bwevel	Becker-Wolff self-consistent cyclotron line model
c6mekl, c6pmekl,	6th-order Chebyshev polynomial DEM using mekal and variants
comekl, c6pvmkl	oth-order Chebysnev polyholinai DEM using mekai and variants
cabs	Compton scattering (non-relativistic)
carbatm	Nonmagnetic carbon atmosphere of a neutron star
cemekl, cevmkl	Multi-temperature mekal.
flow	Cooling flow model.
flux	Calculate flux of other model components.
clmass, nfwmass,	Cluster mass mixing models.
monomass	
clumin	Calculate luminosity of other model components.
compbb	Comptonized blackbody spectrum after Nishimura et al. 1986.
compLS	Comptonization spectrum after Lamb and Sanford 1979.
compmag	Thermal and bulk Comptonization for cylindrical accretion onto
	the polar cap of a magnetized neutron star.
compPS	Comptonization spectrum after Poutanen and Svenson 1986.
compST	Comptonization spectrum after Sunyaev and Titarchuk 1980.
comptb	Thermal and bulk Comptonization of a seed blackbody-like spec-
(D)(D)	trum.
COMPTT	Comptonization spectrum after Titarchuk 1994.
constant cpflux	Energy-independent multiplicative factor. Convolution model to calculate photon flux.
epnux eph, veph	Cooling + heating model for cool core clusters.
cplinear	Non-physical model for low count background spectra
cutoffpl, zcutoffpl	Powerlaw with high energy exponential rolloff.
cyclabs	Cyclotron absorption line.
lisk	Disk model.
liskbb	Multiple blackbody disk model.
liskir	Irradiated inner and outer disk.
liskline	Line emission from relativistic accretion disk.
liskm	Disk model with gas pressure viscosity.
lisko	Modified blackbody disk model.
liskpbb	Accretion disk with power-law T(r)
liskpn	Accretion disk around a black hole.
dust	Dust scattering out of the beam.
edge, zedge	Absorption edge.
eplogpar	Log-parabolic blazar model with vFv normalization.
eqpair, eqtherm,	Paolo Coppi's hybrid hot plasma emission models.
compth	

	Equilibrium ionization collisional plasma model from Borkowski. Table model for exponential of -1 times the input. Low-energy exponential rolloff.
	Exponential decay
	Exponential factor. Multiple blackbody disk model with zero-torque inner boundary. Gaussian absorption line.
em	Plasma emission, multi-temperature with gaussian distribution of emission measure.
8	Simple gaussian line profile.
	Generalized single ionization NEI plasma model. GR accretion disk around a black hole.
	Comptonization model for GRB prompt emission.
	Two-phase Comptonization model of soft thermal seed photons for GRB prompt emission.
	Gamma-ray burst model.
	Gaussian smoothing with an energy dependent sigma.
	Nonmagnetic hydrogen atmosphere of a neutron star. Voigt absorption profiles for He I series.
ighect	High energy cutoff.
	Simple reflection model good up to 15 keV. Reflection from ionized material.
	High resolution ISM absorption model.
	Extinction due to silicate and graphite grains. Leptonic relativistic jet model.
	Convolve with the Laor model shape.
	Convolve with the Laor2 model shape.
rbb	Multi-temperature blackbody model for thin accretion disk around a Kerr black hole.
	Accretion disk line shape with BH spin as free parameter. Optically thick accretion disk around a Kerr black hole.
	Accretion disk line emission with BH spin as free parameter.
	Convolve with kyrline model shape. Line from accretion disk around a spinning black hole.
	Line from accretion disk around a black hole.
	Line from accretion disk with broken power-law emissivity around a black hole.
ar	Log-parabolic blazar model.
	Lorentzian line profile.
	Lorentzian smoothing with an energy dependent sigma. Constant in log units.
	Constant in base 10 log units.
	Voigt absorption profiles for H I or He II Lyman series. Mewe-Gronenschild-Kaastra thermal plasma (1992).
al	Mewe-Kaastra-Liedahl thermal plasma (1992).
cflow	Cooling flow model based on mekal.
	Multiplicative table model. Simple nonequilibrium ionization plasma model.
	Continuum-only APEC emission spectrum.
oshock	Notch line absorption. Plane-parallel shock with ion and electron temperatures.
	Neutron star with hydrogen atmosphere
	Neutron star with hydrogen atmosphere for different g.
	Neutron star H atmosphere with e-conduction and self-irradiation Neutron star magnetic atmosphere.
	Neutron star with a magnetic atmosphere.
	Neutron star with a non-magnetic atmosphere. Pair plasma model.
	Thermally comptonized continuum.
	Extinction due to olivine grains.
otxagn	Colour temperature corrected disc and energetically coupled Comptonisation model for AGN.
10.54	Convert absorption model into a partial covering absorption.
abs	Partial covering fraction absorption. Powerlaw with pegged normalization.
	Neutral Compton reflection with self-consistent Fe and Ni lines.
	Exponentially cut-off power-law reflected from neutral matter.
vphabs,	Exponentially cut-off power-law reflected from ionized matter. Photo-electric absorption
nabs	

planbs Absorption model with power-law dependence on energy. poleconst Constant polarization. polonin Linearly dependent polarization. polony Powerlaw dependent polarization. powerlaw. Simple photon power law. projet 3D to 2-D projection mixing model. pshock, vpshock Simple photon power law. projet 3D to 2-D projection mixing model. raymond, versymood Raymood-Smith theman plasma. raymond, versymood Raymood-Smith theman plasma. robust Convolve with the diskline model shape. recorn Convolve with the reline model shape. reflect reflection from carterial matter reflect reflection from carterial matter reflection reflection from an ionized relativistic disk. reflection Recombination edge. reflection Recombination edge. reflection Robided power-law reflection from an ionized relativistic disk. reflection Recombination recombining collisional plasma. reflection Recombination recombining collisional plasma. reflection Recombination from car	pileup	CCD pile-up model for Chandra
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XSLIDE's solution

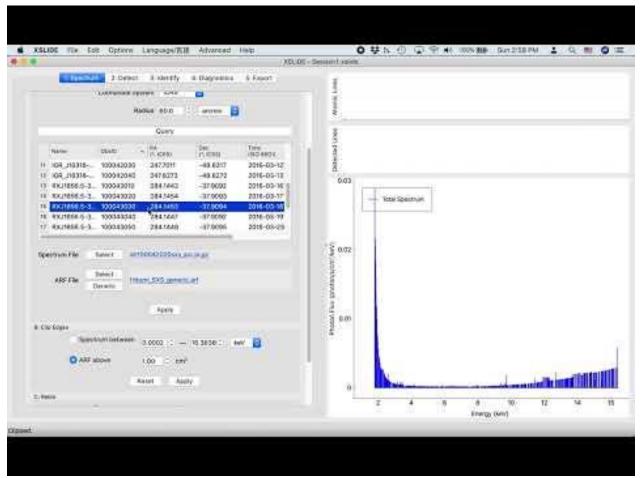
 $C(I) = T \int R_{\rm RMF}(I, E) R_{\rm ARF}(E) S(E) dE$

C = counts [photons],T = observation time [second],I = instrument channel,E = energy [keV] $R_{\text{RMF}} = \text{redistribution matrix (probability of photon of given energy being counted in given instrument channel) [unitless]<math>R_{\text{ARF}} = \text{ancillary response file containing effective area [cm²]},$ S = source spectrum [photons/(cm²·second·keV)]

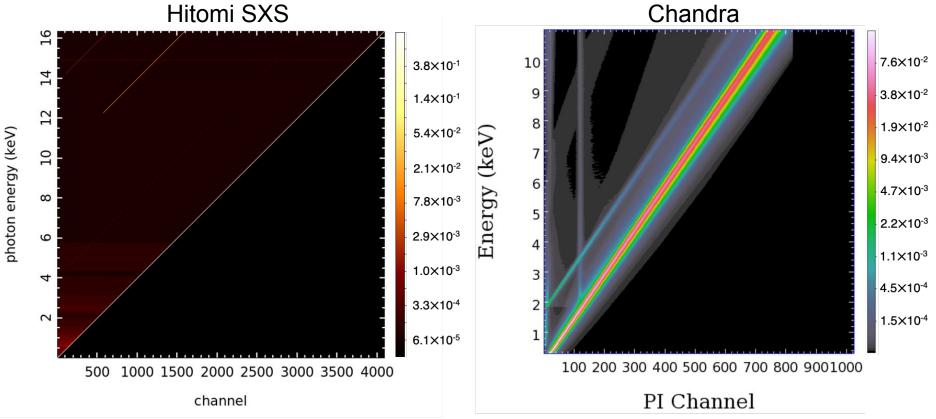
- Assume RMF is a diagonal matrix providing an ideal one-to-one mapping between incident photon energy and detector channel
- Assume ARF is slowly varying such that it is approximately constant between neighboring instrument channels
- Allows for *S*(*E*) to be solved directly as:

$$S(E) = \frac{C(I)}{R_{\rm ARF}(E)T\Delta E}$$

Benefit of XSLIDE's Solution

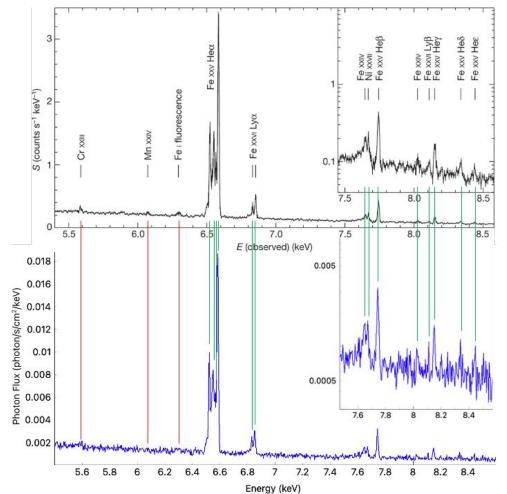


Diagonal RMF Assumption



https://cxc.harvard.edu/cdo/xray_primer.pdf

Validity of XSLIDE's Solution

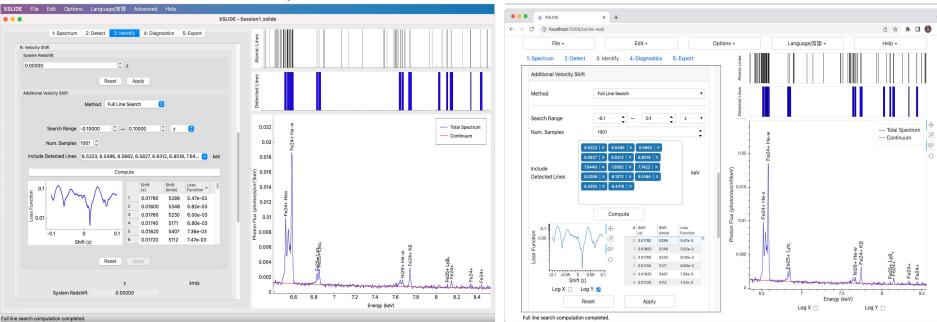


The Hitomi collaboration, *Nature*, 2016

Overview of XSLIDE Software

How to Access XSLIDE

• Both desktop and web versions are available, with very similar user interfaces

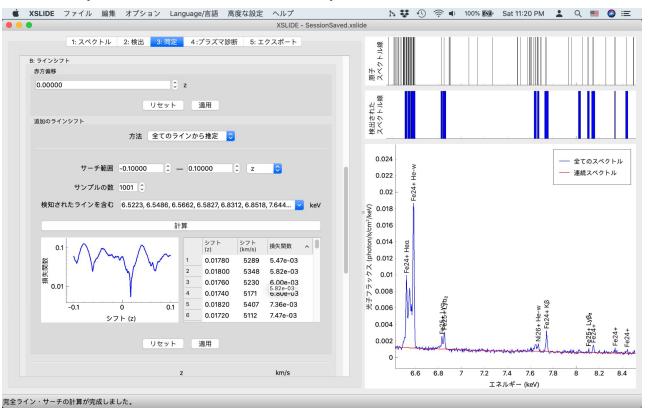


Desktop

Web

Language Localisation

• Available in Japanese on both desktop and web



Thanks to Chris Baluta and Megumi Shidatsu for their work on these translations!

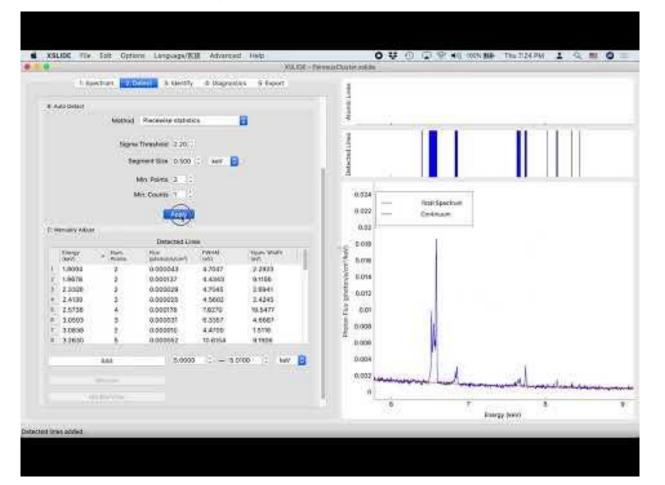
Design

- XSLIDE is designed to be simple and easy to use
- The user is guided through ordered steps and substeps:
 - 1. Load and Modify Spectrum
 - 2. Detect Lines
 - 3. Identify Lines
 - 4. Perform Diagnostics
 - 5. Export Results

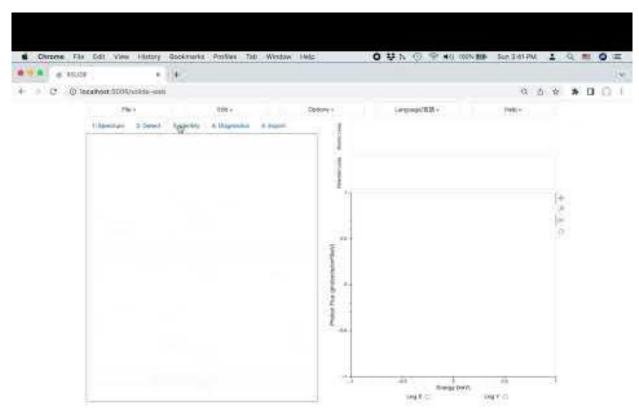
• XSL	IDE - Session1.	kslide									
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XSLIDE Walkthrough

Exploring Hitomi's Perseus Data

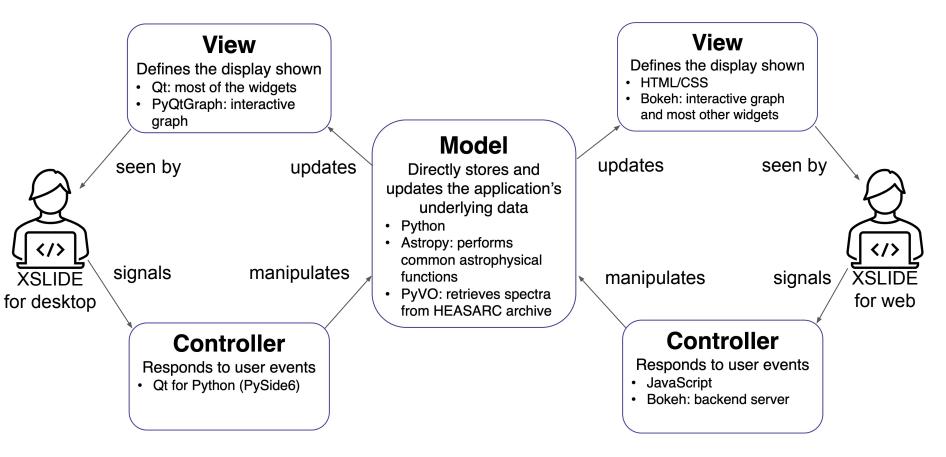


Brief Demonstration of Web Version



Software Development

Model-View-Control Software Architecture



Testing

- Unit testing for Python-based Model
- Functional testing for GUIs
 - Squish for desktop
 - $\circ \quad \ \ \text{Selenium for web}$

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Summary

- XSLIDE is a simple and user-friendly application that allows for the interactive plotting of spectra from XRISM's Resolve instrument without forward-fitting.
- XSLIDE performs many common tasks involved in X-ray spectrum analysis:
 - Rebinning
 - Continuum fitting
 - Automatically detecting lines
 - Assigning detected lines to known atomic transitions
 - Spectral diagnostics
- XSLIDE will help XRISM's scientific investigators to rapidly examine many spectra to find those that contain spectral lines of particular interest.
- XSLIDE will also allow astronomers from outside the field of X-ray spectroscopy to easily interact with XRISM data.

Thank You!

Questions?

For follow-up questions, or to request access to the beta version of XSLIDE, please contact xrism-sdc-help@lists.nasa.gov