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:

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

C = counts [photons], T = observation time [second], I = instrument channel, E = energy [keV]
R_{RMF} = redistribution matrix (probability of photon of given energy being counted in given instrument channel) [unitless]
R_{ARF} = ancillary response file containing effective area [cm^2], S = source spectrum [photons/(cm^2·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

Choosing the right model is not always easy, and doing so takes time

XSPEC Models

6.1 Alphabetical Summary of Models

Table 6.1: Summary of Models

Model	Description
absori	Ionized absorber.
acisabs	Extra absorption due to contamination on the ACIS filters.
agauss, zagauss	Gaussian line profile in wavelength space.
agnsed	AGN SED model.
agnslim	AGN super-Eddington accretion model.
ascac	ASCA PSF mixing model.
apec, vapec, vvapec	APEC thermal plasma model.
atable	Additive table model.
bapec, bvapec, bvvapec	Velocity broadened APEC thermal plasma model.
bbody, zbbody	Blackbody spectrum, with redshift variant
bbodyrad	Blackbody spectrum with norm proportional to surface area.
bexrav	E-folded broken power-law reflected from neutral matter
bexriv	E-folded broken power-law reflected from ionized matter
bknpower, zbknpower	Broken powerlaw.
bkn2pow	Three-segment broken powerlaw.
bmc	Comptonization by relativistically moving matter.
bremss, vbremss, zbremss	Thermal bremsstrahlung, with redshift variant.
brnei, bvrnei, bvvrnei	Velocity broadened non-equilibrium thermal plasma model.
btapec, bvtapec, bvvtapec	Broadened APEC emission spectrum with separate continuum and line temperatures.
bwcycl	Becker-Wolff self-consistent cyclotron line model
c6mekl, c6pmekl, c6vmekl, c6pvmkl	6th-order Chebyshev polynomial DEM using mekal and variants
cabs	Compton scattering (non-relativistic)
carbatm	Nonmagnetic carbon atmosphere of a neutron star
cemekl, cevmkl	Multi-temperature mekal.
cflow	Cooling flow model.
cflux	Calculate flux of other model components.
clmass, nfwmass, monomass	Cluster mass mixing models.
clumin	Calculate luminosityof 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 spectrum.
compTT	Comptonization spectrum after Titarchuk 1994.
constant	Energy-independent multiplicative factor.
cpflux	Convolution model to calculate photon flux.
cph, vcph	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.
disk	Disk model.
diskbb	Multiple blackbody disk model.
diskir	Irradiated inner and outer disk.
diskline	Line emission from relativistic accretion disk.
diskm	Disk model with gas pressure viscosity.
disko	Modified blackbody disk model.
diskpbb	Accretion disk with power-law T(r)
diskpn	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, compth	Paolo Coppi's hybrid hot plasma emission models.
equil, vequil	Equilibrium ionization collisional plasma model from Borkowski.
etable	Table model for exponential of -1 times the input.
expabs	Low-energy exponential rolloff.
expdec	Exponential decay
expfac	Exponential factor.
ezdiskbb	Multiple blackbody disk model with zero-torque inner boundary.
gabs	Gaussian absorption line.
gadem, vgadem	Plasma emission, multi-temperature with gaussian distribution of emission measure.
gauss, zgauss	Simple gaussian line profile.
gnei, vgnei	Generalized single ionization NEI plasma model.
grad	GR accretion disk around a black hole.
grbcomp	Comptonization model for GRB prompt emission.
grbjet	Two-phase Comptonization model of soft thermal seed photons for GRB prompt emission.
grbm	Gamma-ray burst model.
gsmooth	Gaussian smoothing with an energy dependent sigma.
hatm	Nonmagnetic hydrogen atmosphere of a neutron star.
heilin	Voigt absorption profiles for He I series.
highecut, zhighect	High energy cutoff.
hrefl	Simple reflection model good up to 15 keV.
ireflect	Reflection from ionized material.
ismabs	High resolution ISM absorption model.
ismdust	Extinction due to silicate and graphite grains.
jet	Leptonic relativistic jet model.
kdblur	Convolve with the Laor model shape.
kdblur2	Convolve with the Laor2 model shape.
kerrbb, zkerrbb	Multi-temperature blackbody model for thin accretion disk around a Kerr black hole.
kerrconv	Accretion disk line shape with BH spin as free parameter.
kerrd	Optically thick accretion disk around a Kerr black hole.
kerrdisk	Accretion disk line emission with BH spin as free parameter.
kyconv	Convolve with kyrline model shape.
kyrline	Line from accretion disk around a spinning black hole.
laor	Line from accretion disk around a black hole.
laor2	Line from accretion disk with broken power-law emissivity around a black hole.
logpar, zlogpar	Log-parabolic blazar model.
lorentz	Lorentzian line profile.
lsmooth	Lorentzian smoothing with an energy dependent sigma.
logconst	Constant in log units.
log10con	Constant in base 10 log units.
lyman	Voigt absorption profiles for H I or He II Lyman series.
meka, vmeka	Mewe-Gronenschild-Kaastra thermal plasma (1992).
mekal, vmekal	Mewe-Kaastra-Liedahl thermal plasma (1995).
mkcflow, vmcflow	Cooling flow model based on mekal.
mtable	Multiplicative table model.
nei, vnei	Simple nonequilibrium ionization plasma model.
nlapec	Continuum-only APEC emission spectrum.
notch	Notch line absorption.
npshock, vnpshock	Plane-parallel shock with ion and electron temperatures.
nsa	Neutron star with hydrogen atmosphere
nsagrav	Neutron star with hydrogen atmosphere for different g.
nsatmos	Neutron star H atmosphere with e-conduction and self-irradiation
nsmax	Neutron star magnetic atmosphere.
nsmaxg	Neutron star with a magnetic atmosphere.
nsx	Neutron star with a non-magnetic atmosphere.
nteea	Pair plasma model.
nthcomp	Thermally comptonized continuum.
olivineabs	Extinction due to olivine grains.
optxagnf, optxagn	Colour temperature corrected disc and energetically coupled Comptonisation model for AGN.
partcov	Convert absorption model into a partial covering absorption.
pcfabs, zpcfabs	Partial covering fraction absorption.
pegpwrlw	Powerlaw with pegged normalization.
pexmon	Neutral Compton reflection with self-consistent Fe and Ni lines.
pexrav	Exponentially cut-off power-law reflected from neutral matter.
pexriv	Exponentially cut-off power-law reflected from ionized matter.
phabs, vphabs, zphabs, zvphabs	Photo-electric absorption
pileup	CCD pile-up model for Chandra
plabs	Absorption model with power-law dependence on energy.
plcabs	Cut-off powerlaw observed through dense, cold matter.
polconst	Constant polarization.
pollin	Linearly dependent polarization.
polpow	Powerlaw dependent polarization.
posm	Positronium continuum.
powerlaw, zpowerlw	Simple photon power law.
projct	3-D to 2-D projection mixing model.
pshock, vpshock	Constant temperature, plane-parallel shock plasma model.
pwab	Power-law distribution of neutral absorbers.
qsosed	Simplified form of the AGN SED model.
raymond, vraymond	Raymond-Smith thermal plasma.
rdblur	Convolve with the diskline model shape.
recorn	Change correction norm for a spectrum (replaces old recornrm command).
redden	IR/optical/UV extinction from Cardelli et al. (1989)
redge	Recombination edge.
reflect	reflection from neutral matter
refsch	E-folded power-law reflected from an ionized relativistic disk.
relconv, relconvlp, relconvlpext	Convolve with the relline model shape.
relline, rellinelp, rellinelpext	Emission line from relativistic accretion disk around a BH.
rfxconv	angle-dependent reflection from an ionized disk
rgsxsrc	XMM RGS extended source
rnei, vrnei, vvrnei	Non-equilibrium recombining collisional plasma.
polrot	Rotate polarization.
sedov, vsedov	Sedov model with electron and ion temperatures.
sirf	Multi-blackbody self-irradiated funnel model.
simpl	Comptonization of a seed spectrum.
slimbh	Stationary slim accretion disk.
smaug	Model for an optically-thin, spherically-symmetric thermal plasma.
smedge	Smoothed absorption edge.
snapec	Galaxy cluster spectrum using SN yields.
spexpcut	Super-exponential cutoff absorption.
spline	Spline multiplicative factor.
srcut	Synchrotron radiation from cut-off electron distribution.
sresc	Synchrotron radiation from escape-limited electron distribution.
ssa	Strangeon star atmosphere model.
SSSice	Einstein Observatory SSS ice absorption.
step	Step function convolved with gaussian.
suzpsf	Suzaku PSF mixing model.
swind1	Absorption by partially ionized material with large velocity shear.
tapec, vtapec, vvtapec	APEC emission spectrum with separate continuum and line temperatures.
tbabs, ztbabs, tbgrain, tbvarabs	Absorption due to the ISM including molecules and grains.
thcomp	Thermally comptonized continuum convolution model.
uvred	UV reddening.
varabs, zvarabs	Photoelectric absorption with variable abundances.
vashift	Velocity shifts an additive model.
vmshift	Velocity shifts a multiplicative model.
voigt	A simple Voigt line profile.
wabs, zwabs	Photoelectric absorption (Morrison & McCammon).
wdem, vwdem, vvwdem	Plasma emission, multi-temperature with power-law distribution of emission measure.
wndabs, zwndabs	Photoelectric absorption with low energy window.
xion	The reflected spectrum from a photo-ionized accretion disk.
xilconv	angle-dependent reflection from an ionized disk
xmmpsf	XMM PSF model
xscat	dust scattering
zashift	Redshift an additive model.
zbabs	EUV ISM attenuation.
zdust	Extinction by dust grains (Pei, 1992).
zigm	UV/Optical attenuation by the intergalactic medium.
zmshift	Redshift a multiplicative model.
zredden	Redshifted IR/optical/UV extinction from Cardelli et al. (1989)
zsmdust	Extinction by dust grains in starburst galaxies.
zvfeabs	Redshifted absorption with variable iron abundance.
zxipab	Power-law distribution of ionized absorbers.
zxipcf	Partial covering absorption by partially ionized material.

XSLIDE's solution

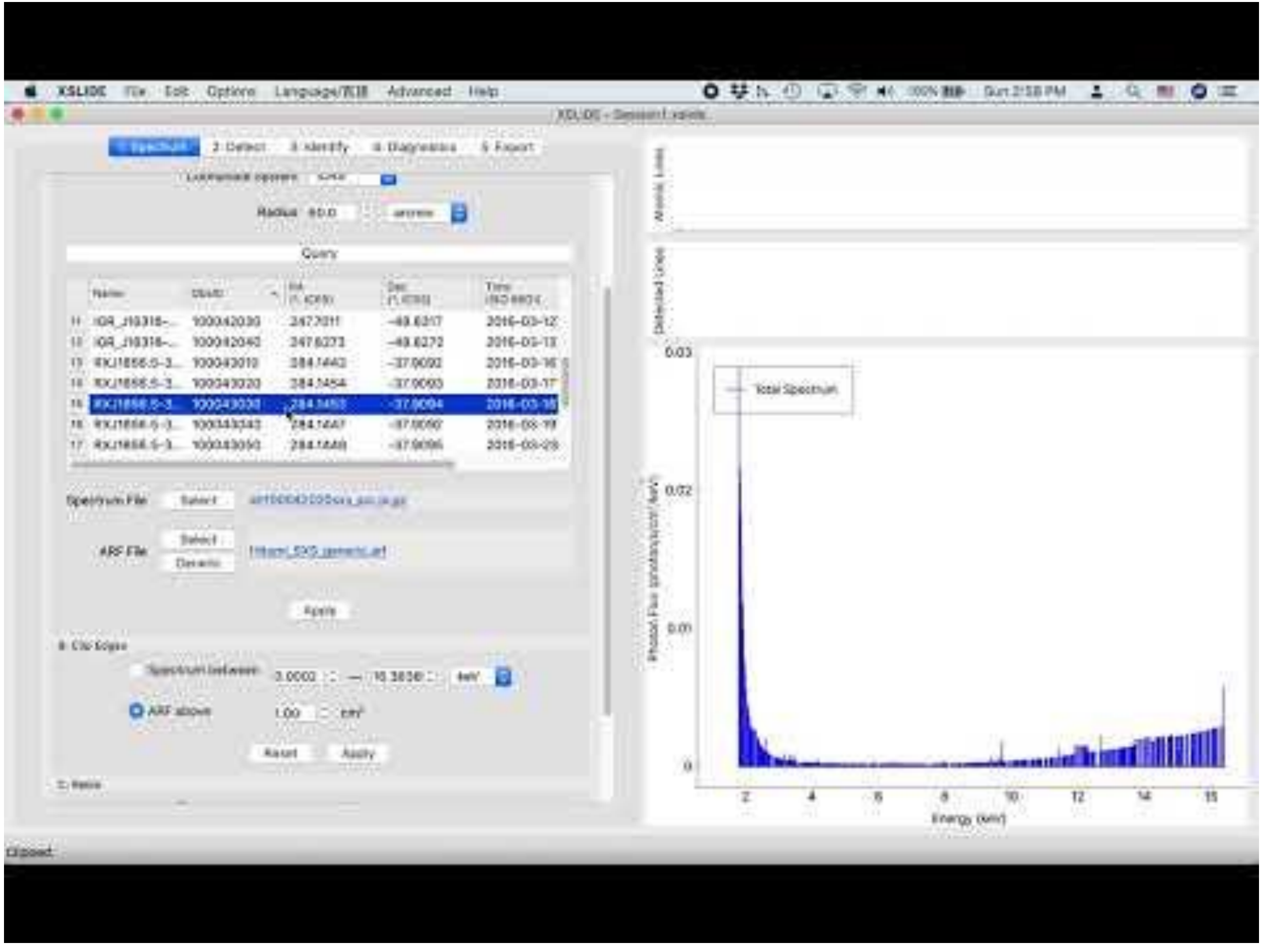
$$C(I) = T \int R_{\mathrm{RMF}}(I, E) R_{\mathrm{ARF}}(E) S(E) dE$$

C = counts [photons], T = observation time [second], I = instrument channel, E = energy [keV]
R_{RMF} = redistribution matrix (probability of photon of given energy being counted in given instrument channel) [unitless]
R_{ARF} = ancillary response file containing effective area [cm^2], S = source spectrum [photons/(cm^2·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:

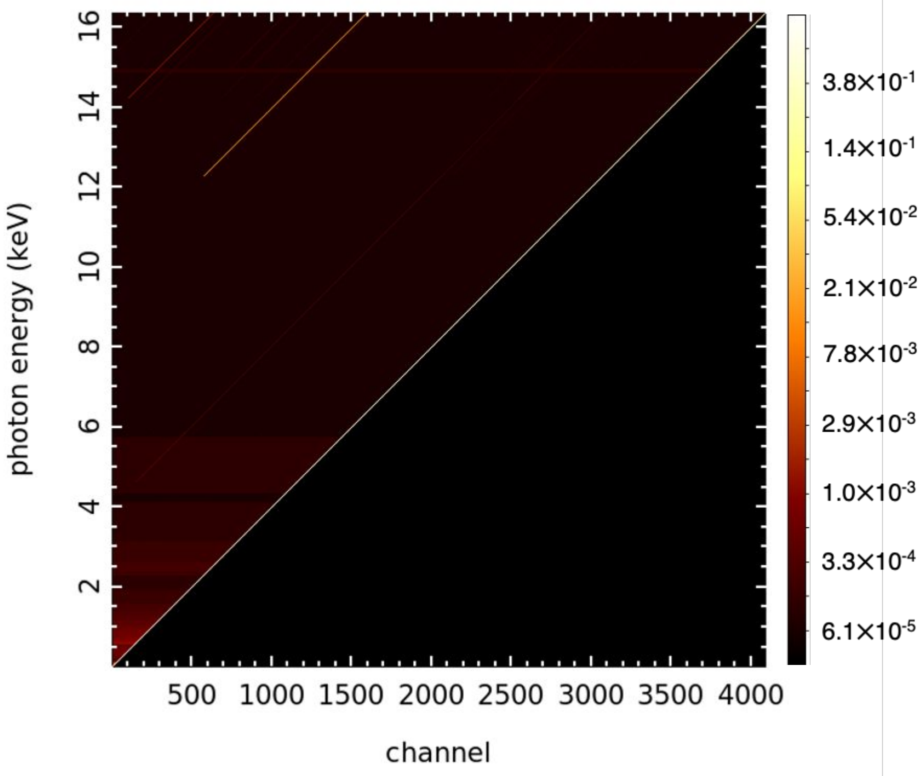
$$S(E) = \frac{C(I)}{R_{\mathrm{ARF}}(E) T \Delta E}$$

Benefit of XSLIDE’s Solution

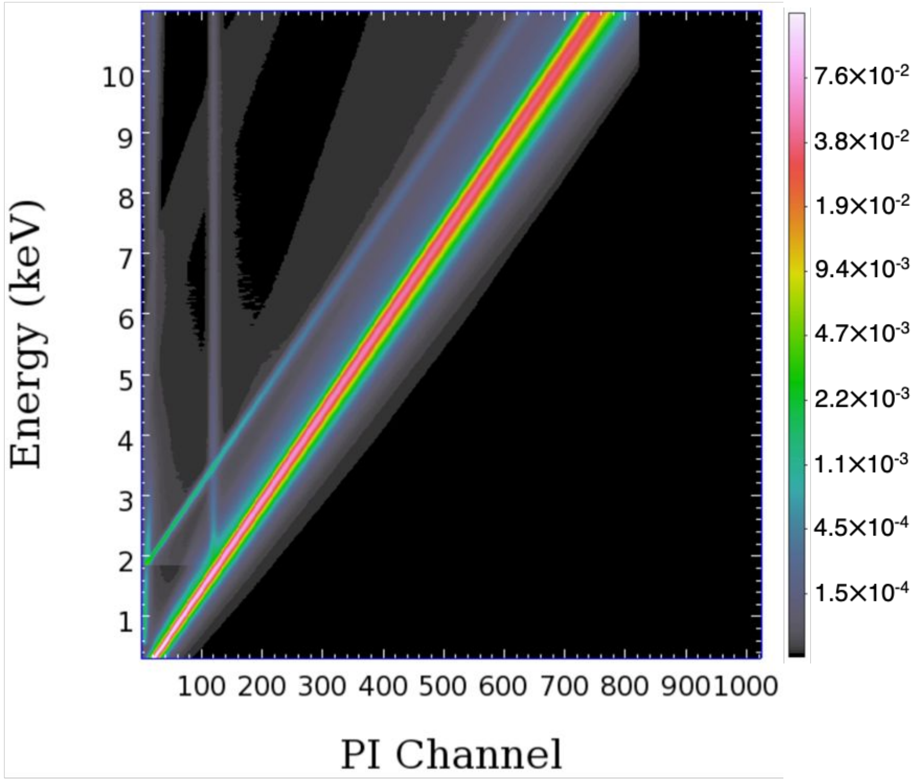


Diagonal RMF Assumption

Hitomi SXS

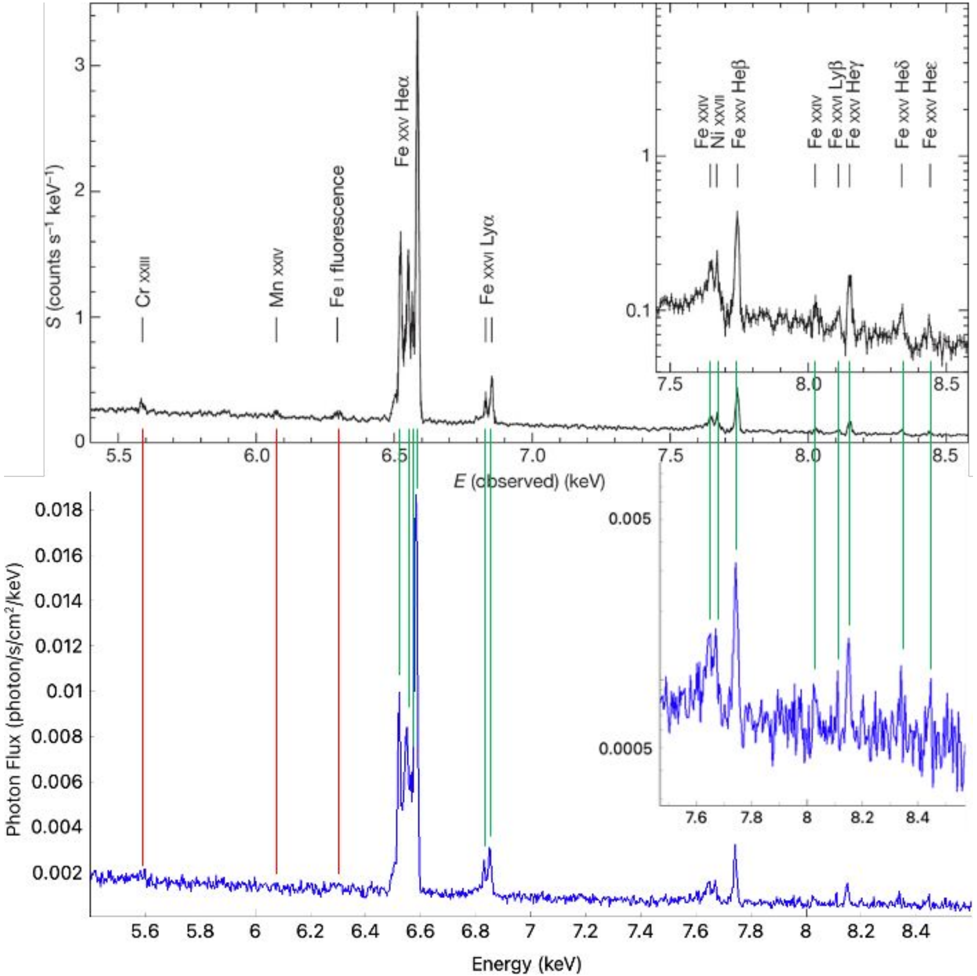


Chandra



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

Validity of XSLIDE's Solution



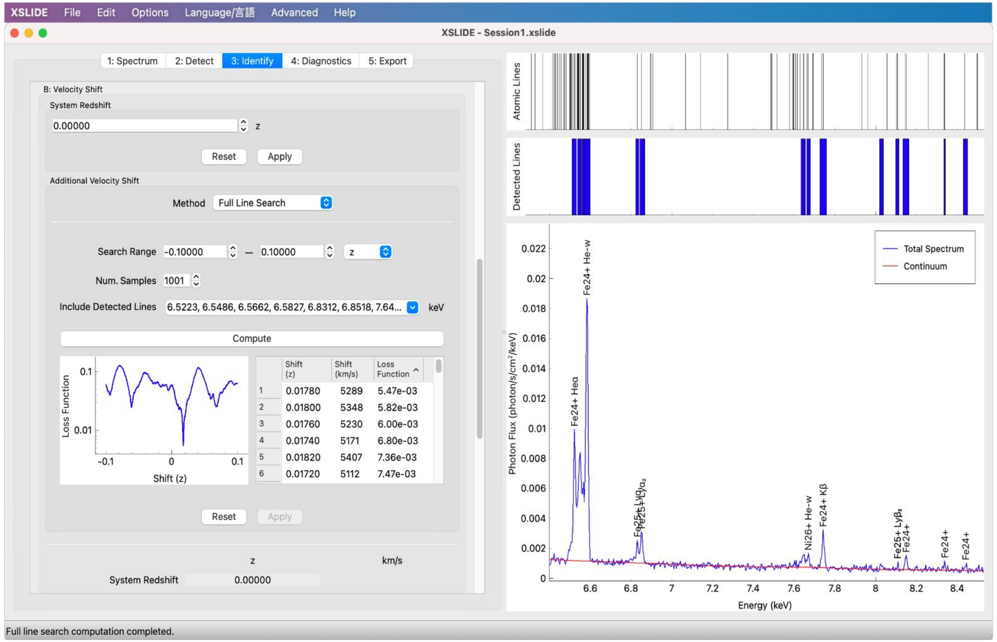
The Hitomi collaboration, *Nature*, 2016

Overview of XSLIDE Software

How to Access XSLIDE

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

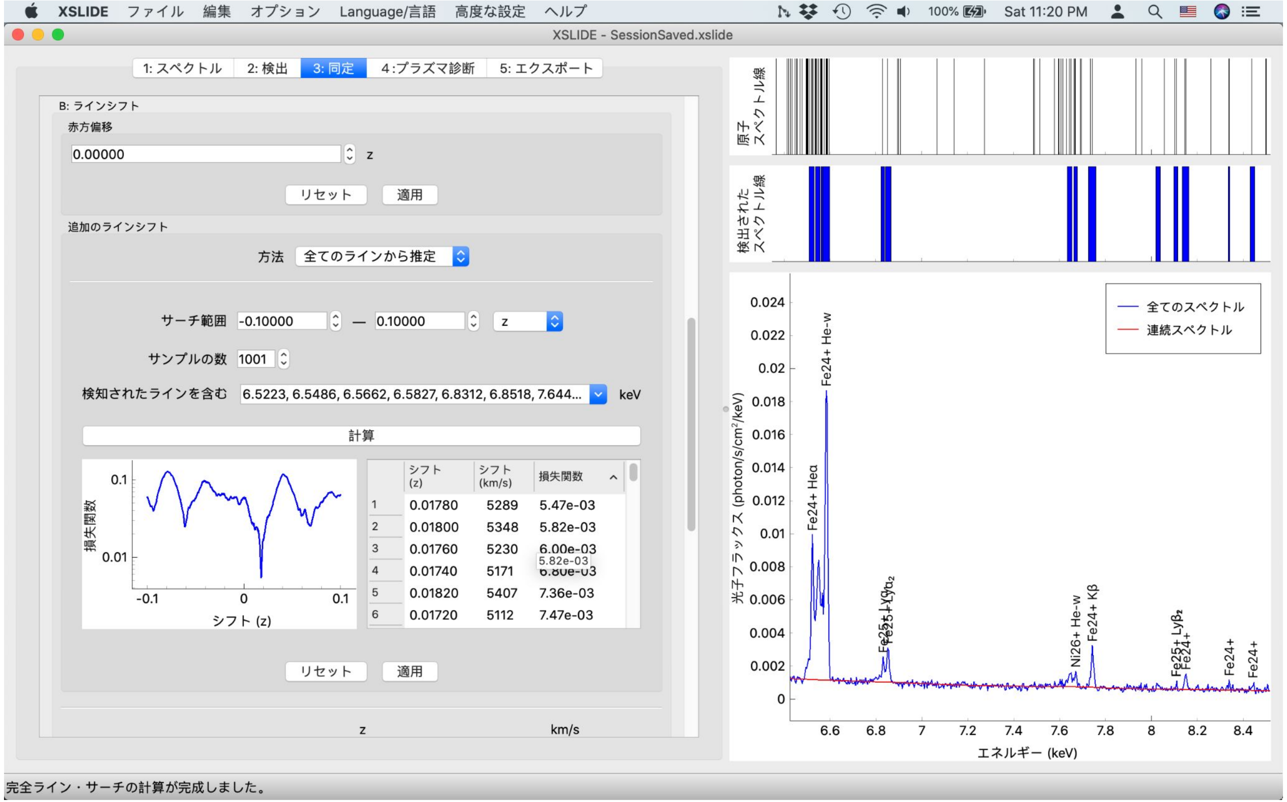
Desktop



Web

Language Localisation

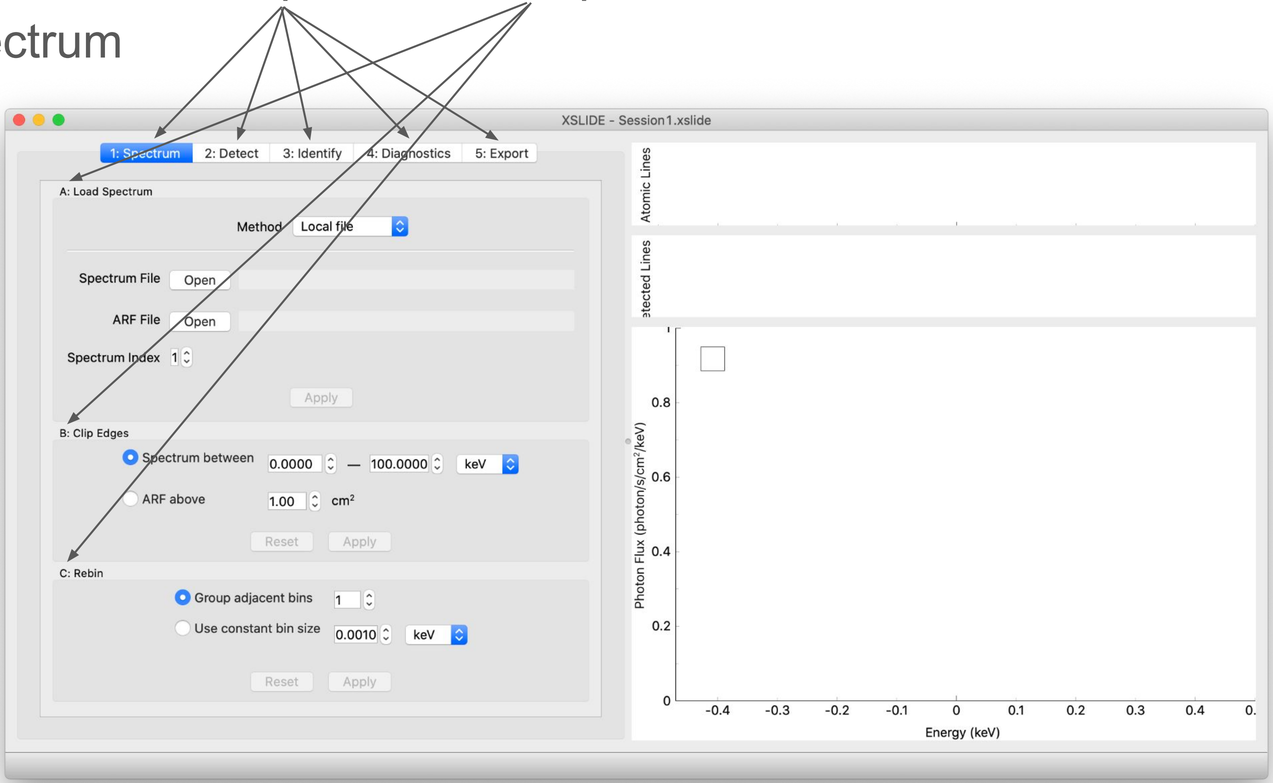
- Available in Japanese on both desktop and web



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

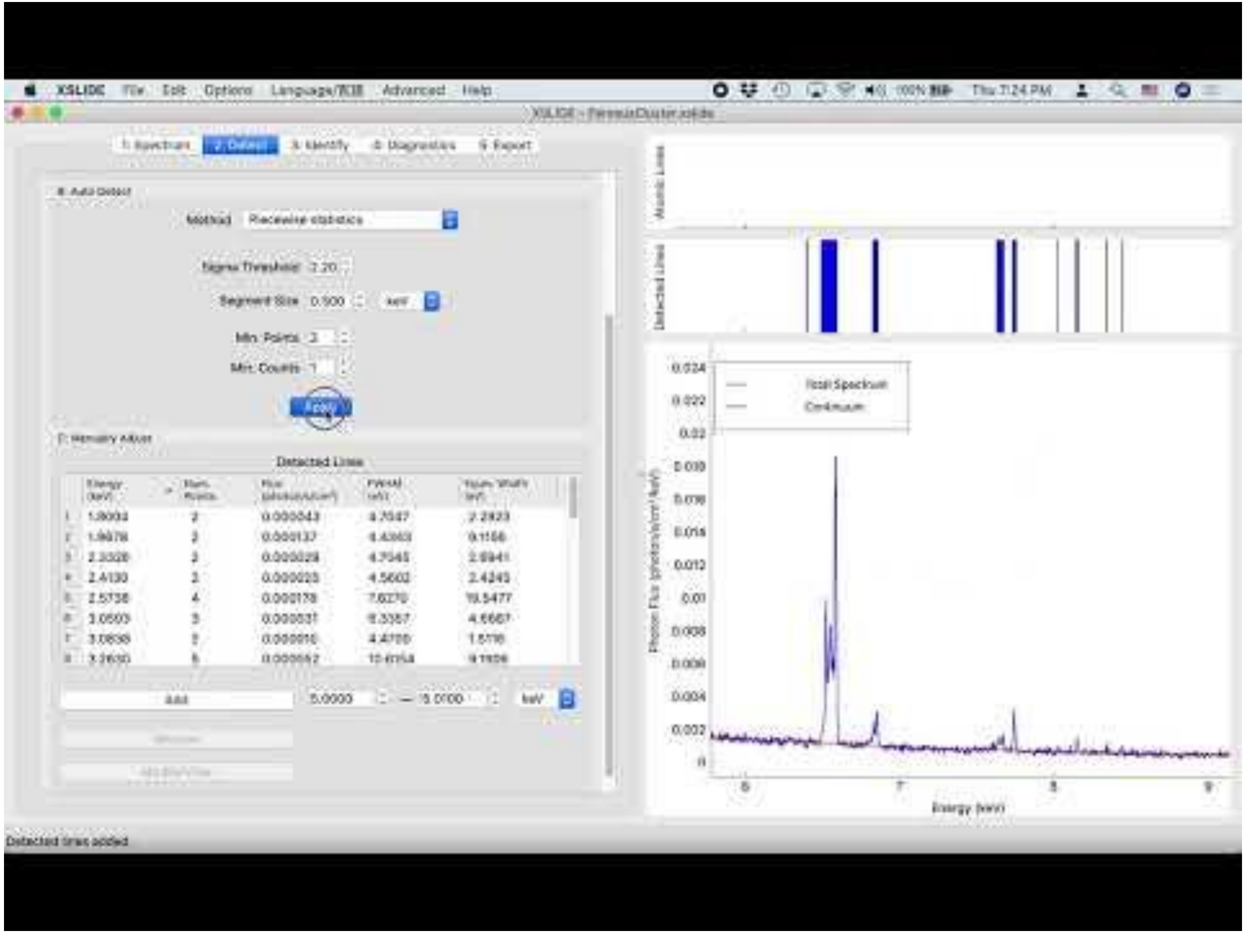
Design

- 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

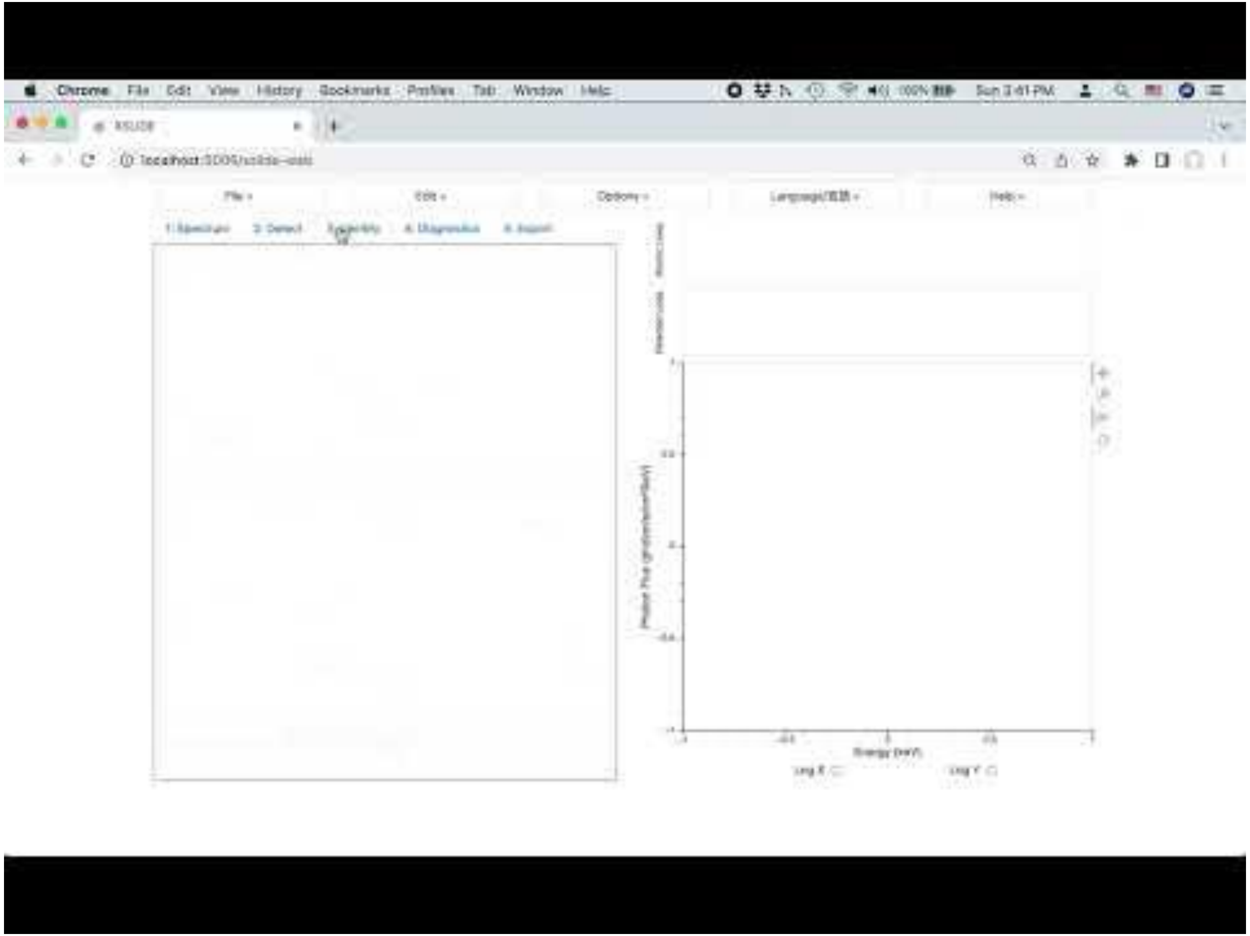


XSLIDE Walkthrough

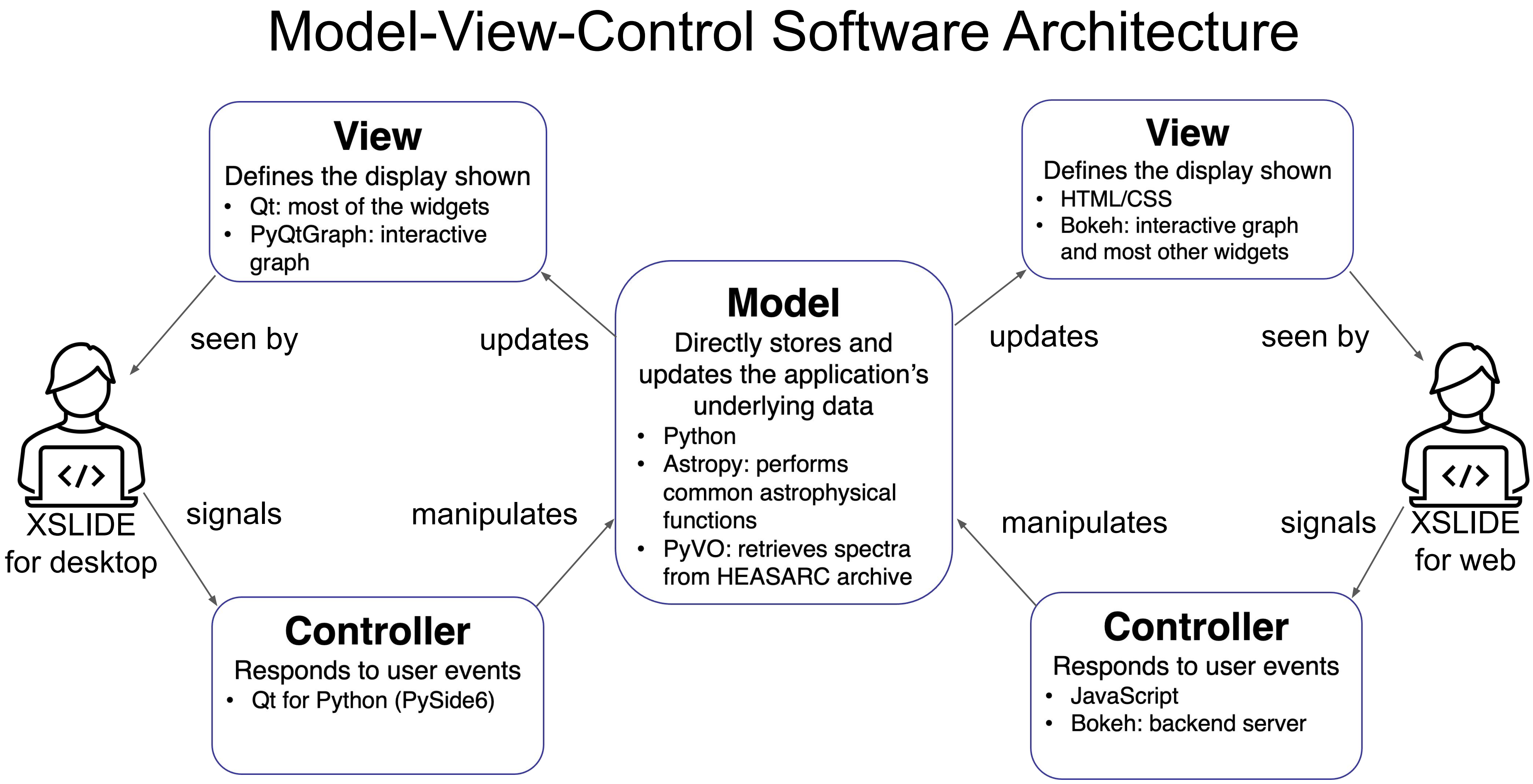
Exploring Hitomi's Perseus Data



Brief Demonstration of Web Version

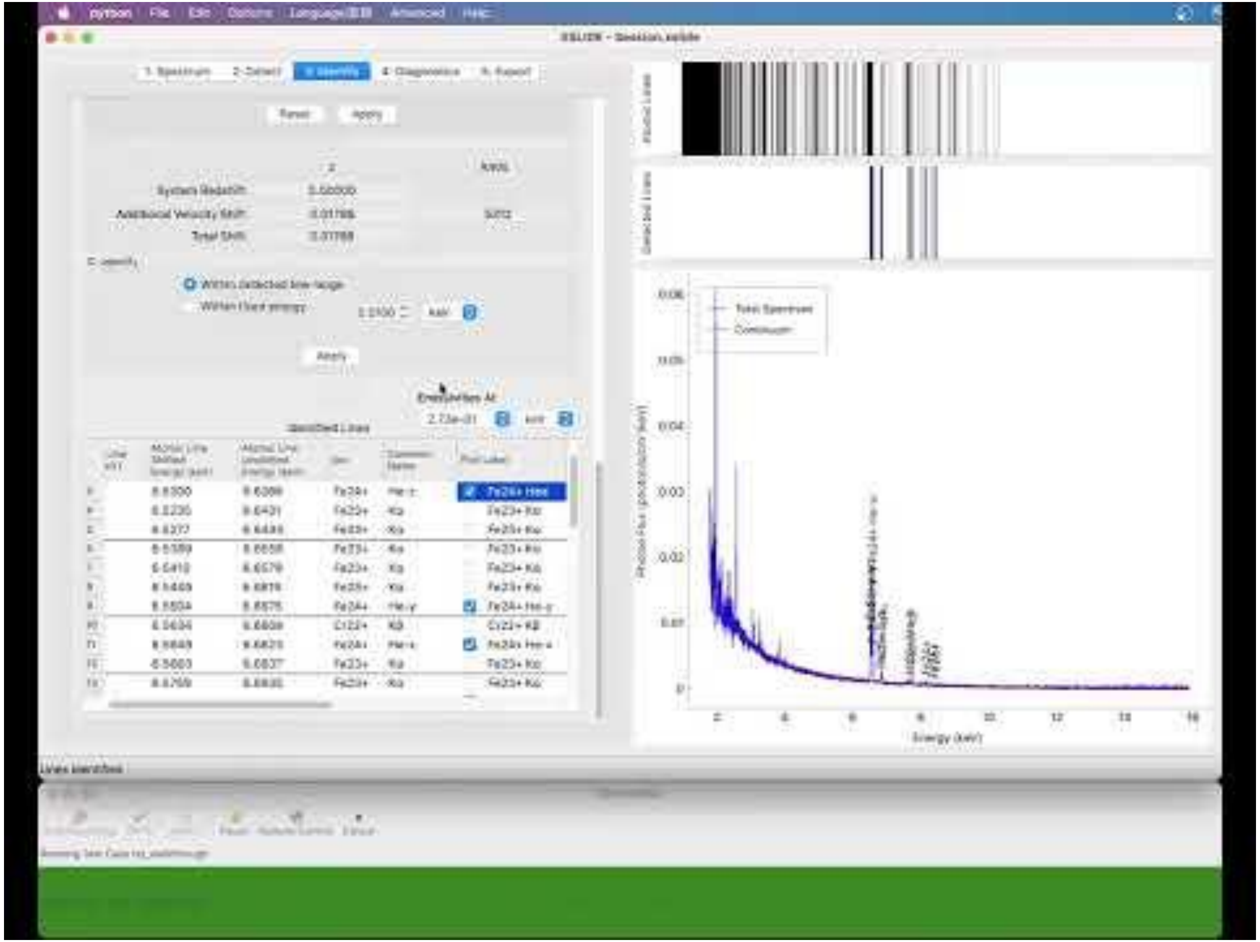


Software Development


Model-View-Control Software Architecture
View
Defines the display shown
• Qt: most of the widgets
• PyQtGraph: interactive graph
View
Defines the display shown
• HTML/CSS
• Bokeh: interactive graph and most other widgets
Model
Directly stores and updates the application's underlying data
• Python
• Astropy: performs common astrophysical functions
• PyVO: retrieves spectra from HEASARC archive
seen by
updates
updates
seen by
</>
XSLIDE for desktop
</>
XSLIDE for web
signals
manipulates
manipulates
signals
Controller
Responds to user events
• Qt for Python (PySide6)
Controller
Responds to user events
• JavaScript
• Bokeh: backend server

Testing

- Unit testing for Python-based Model
- Functional testing for GUIs
  - Squish for desktop
  - Selenium for web



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