Evolutionary Optimization Approach towards Unraveling High-Resolution X-ray Imaging and Spectroscopic Studies of High-Energy Astrophysical Sources

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HRXS Conference

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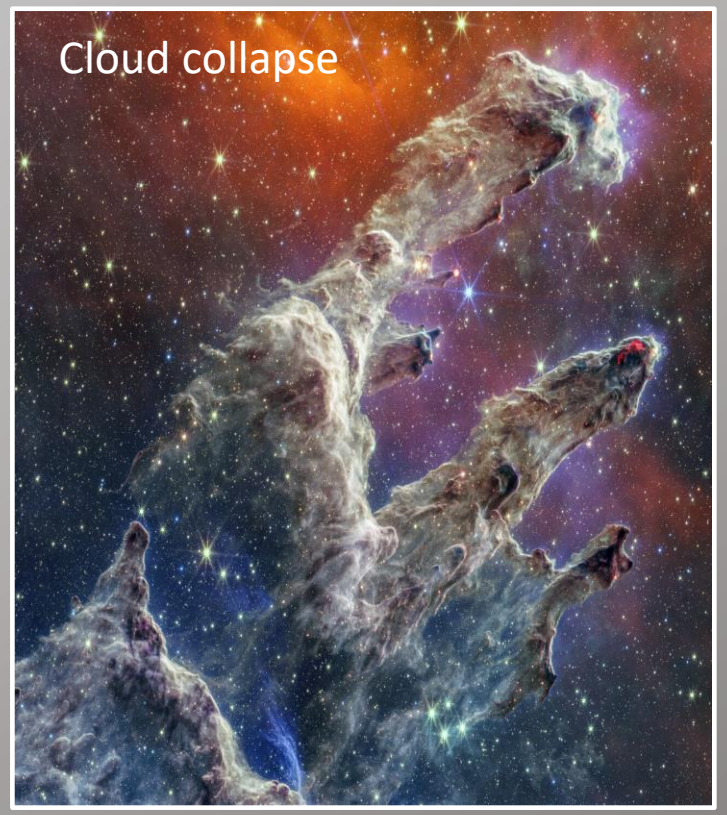
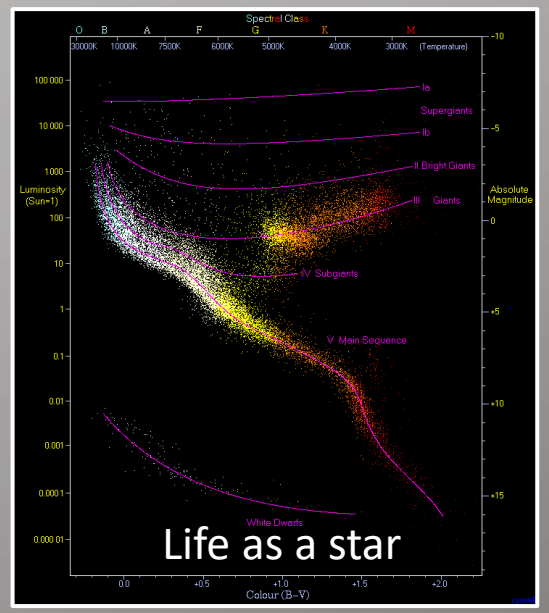
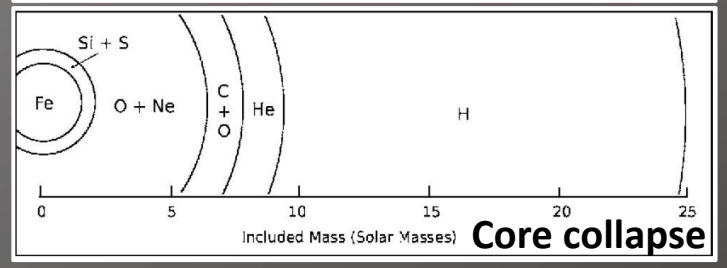
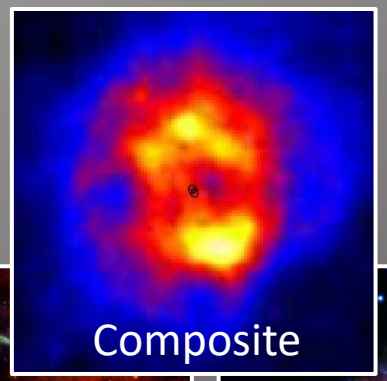
Supernovae

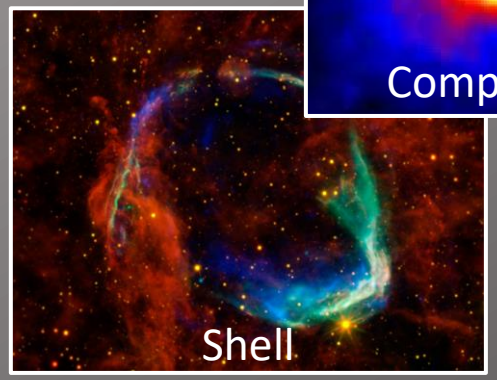
… and their Remnants











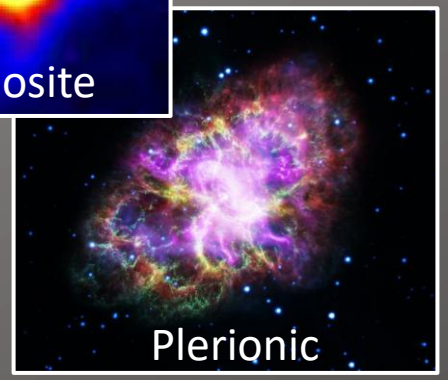
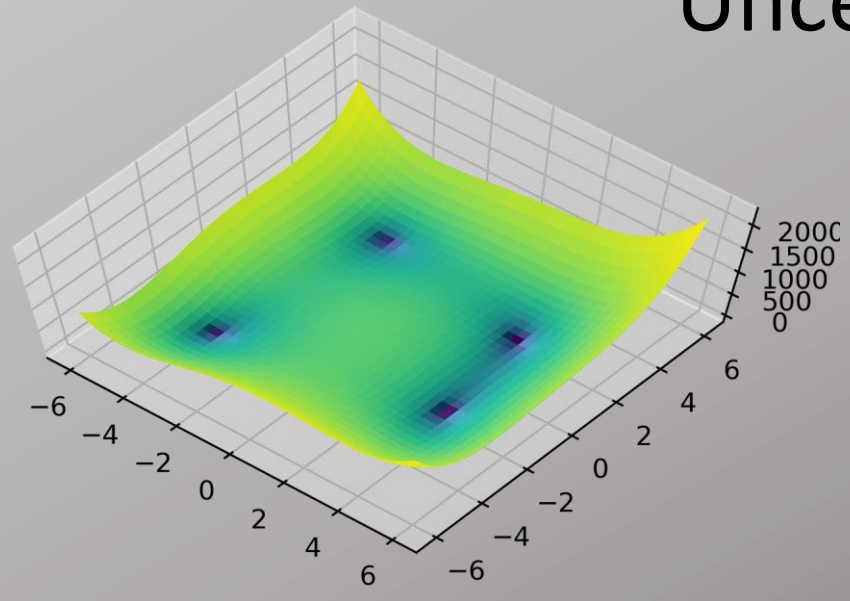


Image credits
NASA/CXC
NASA/ESA/CSA/STScI
Seward F.D. & Charles P.A. (2010)

Uncertainty & Degeneracy



Systematic Uncertainty

Model Approximations

Spectral Database

Fitting Technique

Spatial/Spectral Resolution

Random Uncertainty (Noise)

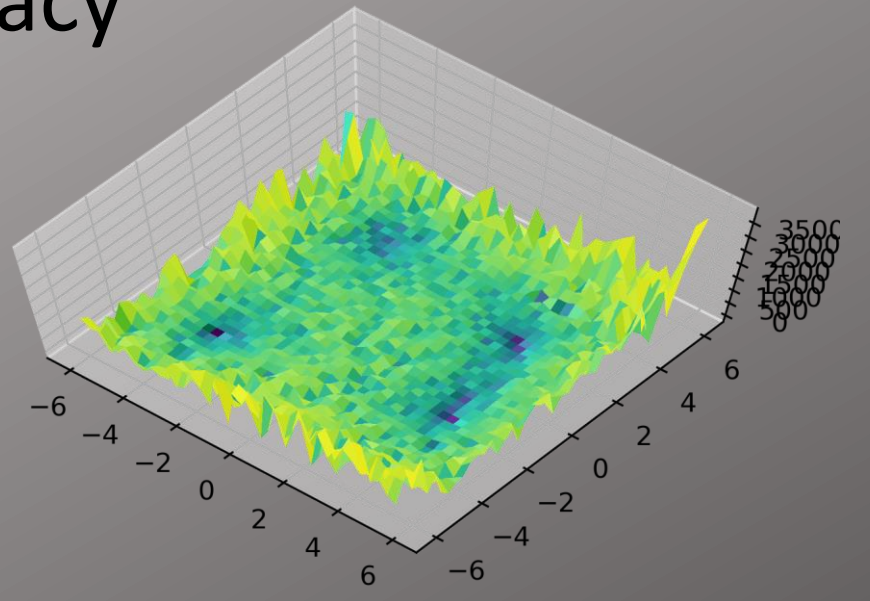
Detector Background

Soft Proton Flares

Readout noise

Charge-pileup

Cosmic Rays



Flattening/Broadening

Narrowing/Jagged features

Insensitivity to fit

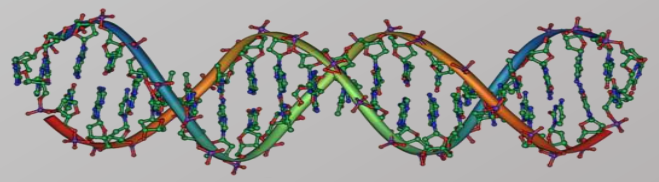
Objective (fitness) function

Chi-squared: $\chi^2 = \sum_i \frac{[N_{i,S} - M_i(x_i, p_B, p_S)]^2}{\sigma_i^2}$

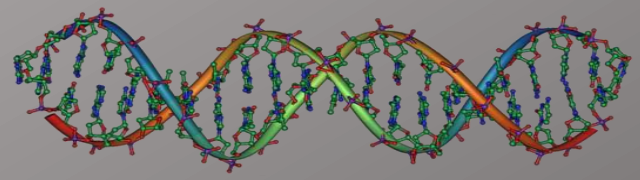
C-stat: $C = 2\sum_i [M_i - N_i + N_i log\,(N_i/M_i)]$

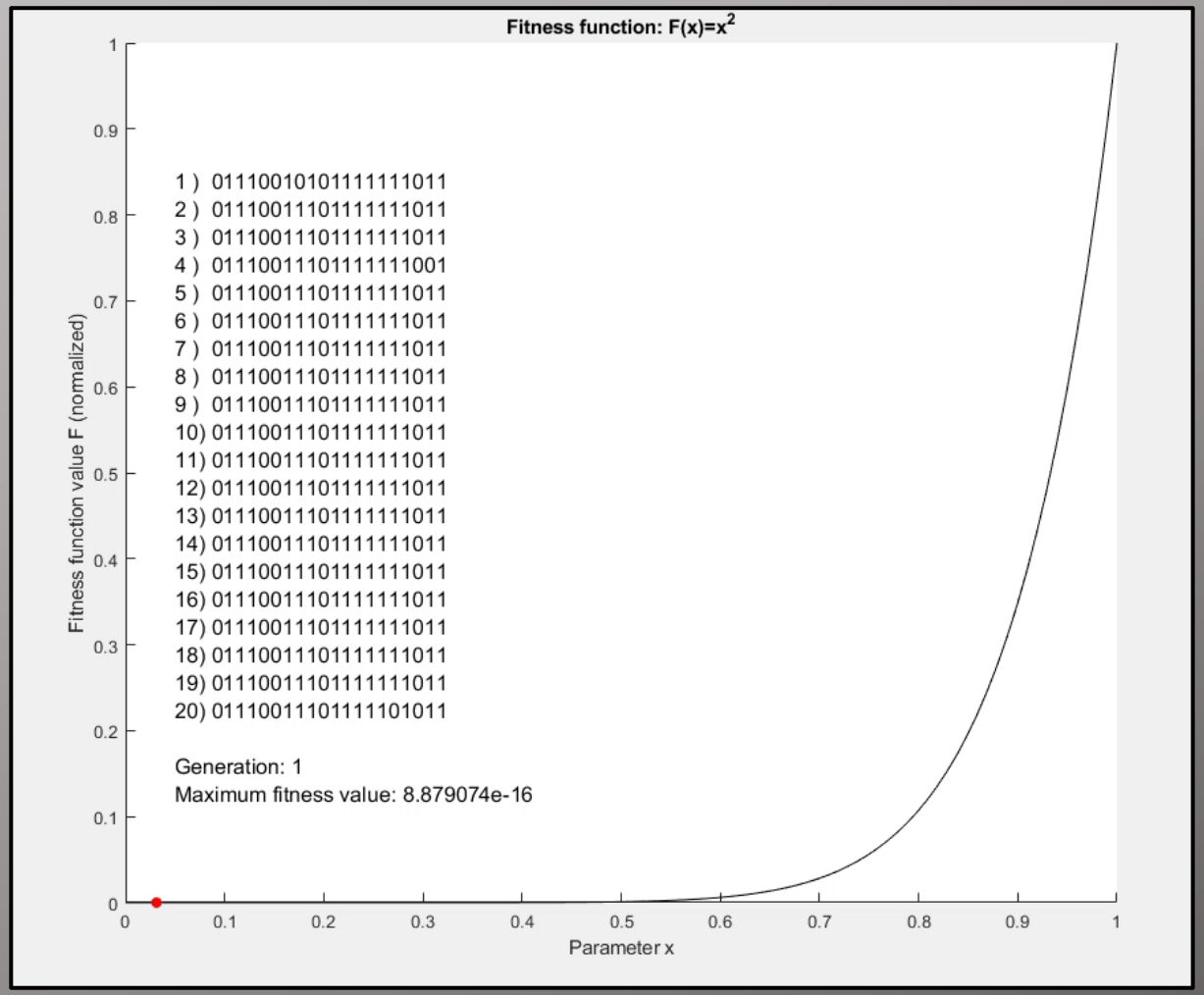
See Kaastra (2017)

Anton Vengo



Evolutionary Algorithms





Based on the principles of **natural selection.**

Gradient-free:

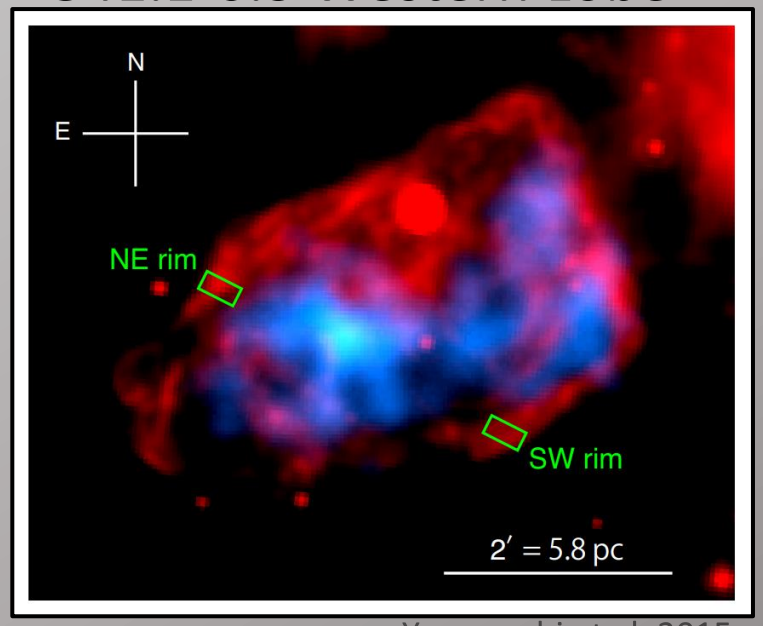
- Weak dependence on initial conditions
- Less tendency to get stuck in local minima
- Discontinuous/non-differentiable functions

Multi-agent:

- Evaluation of large numbers of patterns simultaneously
- Capable of outputting families of degenerate solutions

Case Study: G41.1-0.3 (3C 397)

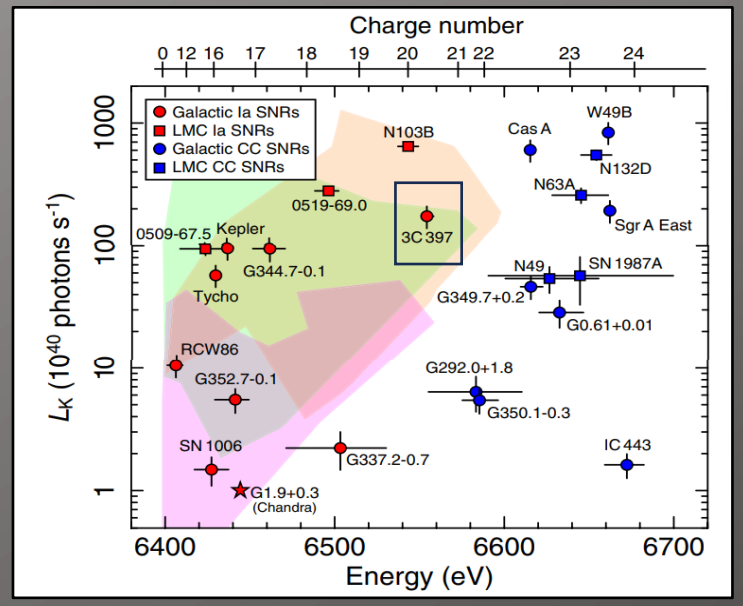
G41.1-0.3 Western Lobe



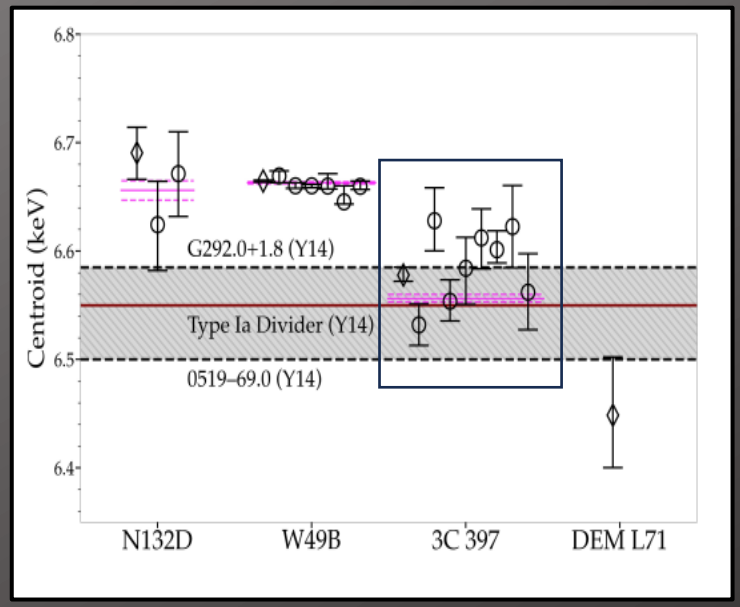
Yamaguchi et al. 2015

- Centroids **dependent on position** within the PWN.
- More sensitive diagnostics need to be explored.

- Type Ia SNRs **tend** to be significantly less ionized than CC remnants.
- Different species and ions can populate the same line intensities → **degeneracy**



Yamaguchi et al. 2014



Siegel et al. 2021

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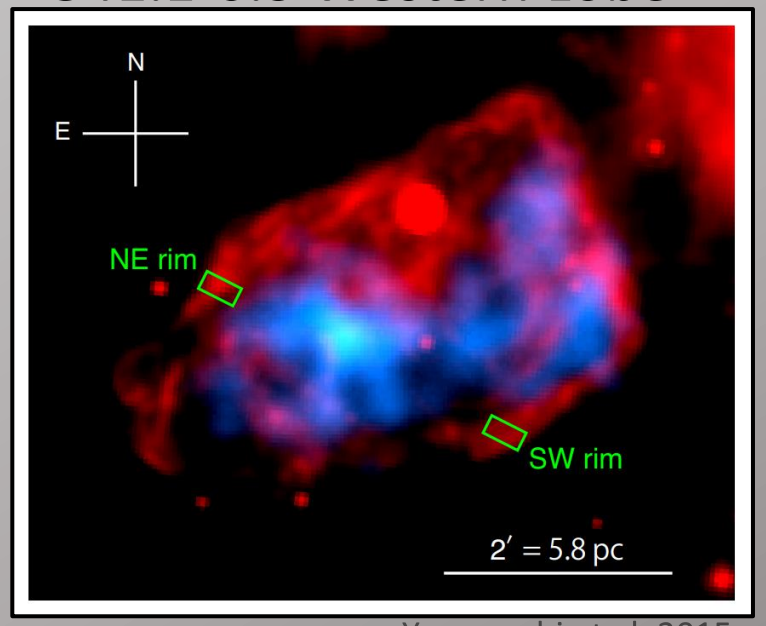

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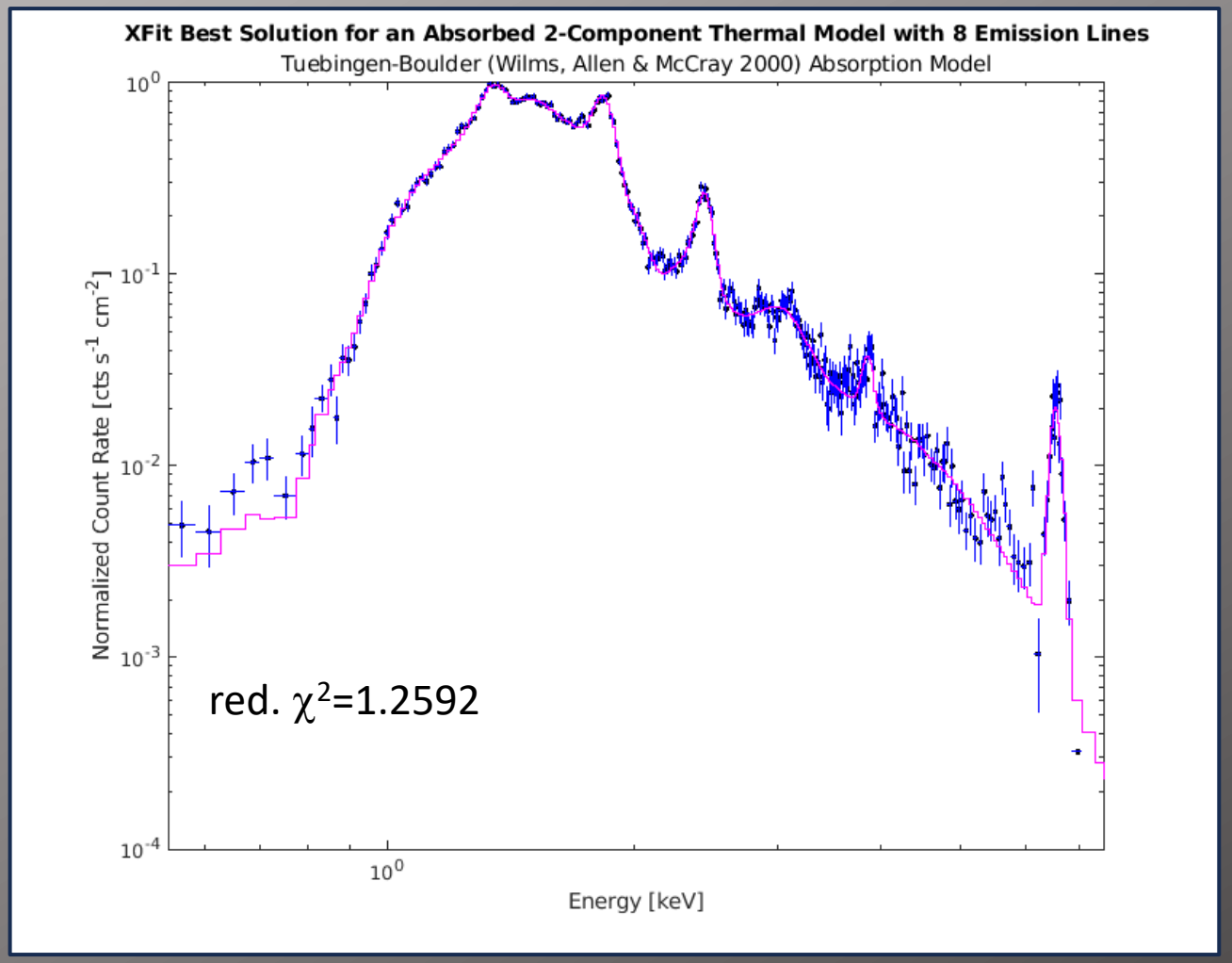

Parameter	Value
nH	6.2980
Bremss(1) 1 kT	0.15892
Bremss(1) Norm	505.13
Bremss(2) kT	2.0499
Bremss(2) Norm	0.00271
Gauss(1) E0	0.52783
Gauss(1) sigma	0.15241
Gauss(1) Norm	647.64
Gauss(2) E0	1.3348
Gauss(2) sigma	0.00138
Gauss(2) Norm	0.00945
Gauss(3) E0	1.8269
Gauss(3) sigma	0.02761
Gauss(3) Norm	0.00095
Gauss(4) E0	2.2890
Gauss(4) sigma	0.19262
Gauss(4) Norm	0.00041
Gauss(5) E0	2.4309
Gauss(5) sigma	0.00388
Gauss(5) Norm	0.00018
Gauss(6) E0	2.9587
Gauss(6) sigma	0.20612
Gauss(6) Norm	0.00011
Gauss(7) E0	3.8497
Gauss(7) sigma	0.00399
Gauss(7) Norm	9.55e-06
Gauss(8) E0	6.5465
Gauss(8) sigma	0.06932
Gauss(8)	4.28e-05

Qubist
Global Optimization Toolbox
design.innovate.optimize
nQube Technical Computing

See: Rogers, A., Safi-Harb, S., and Fiege, J. (2015) for more information on **XFit**

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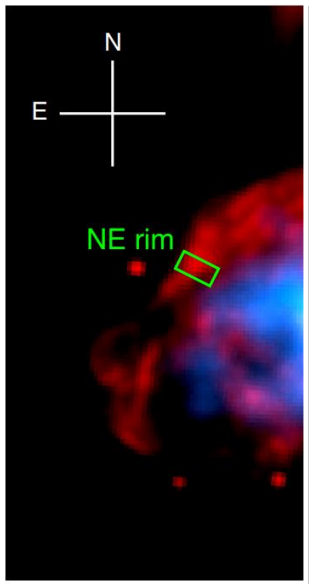
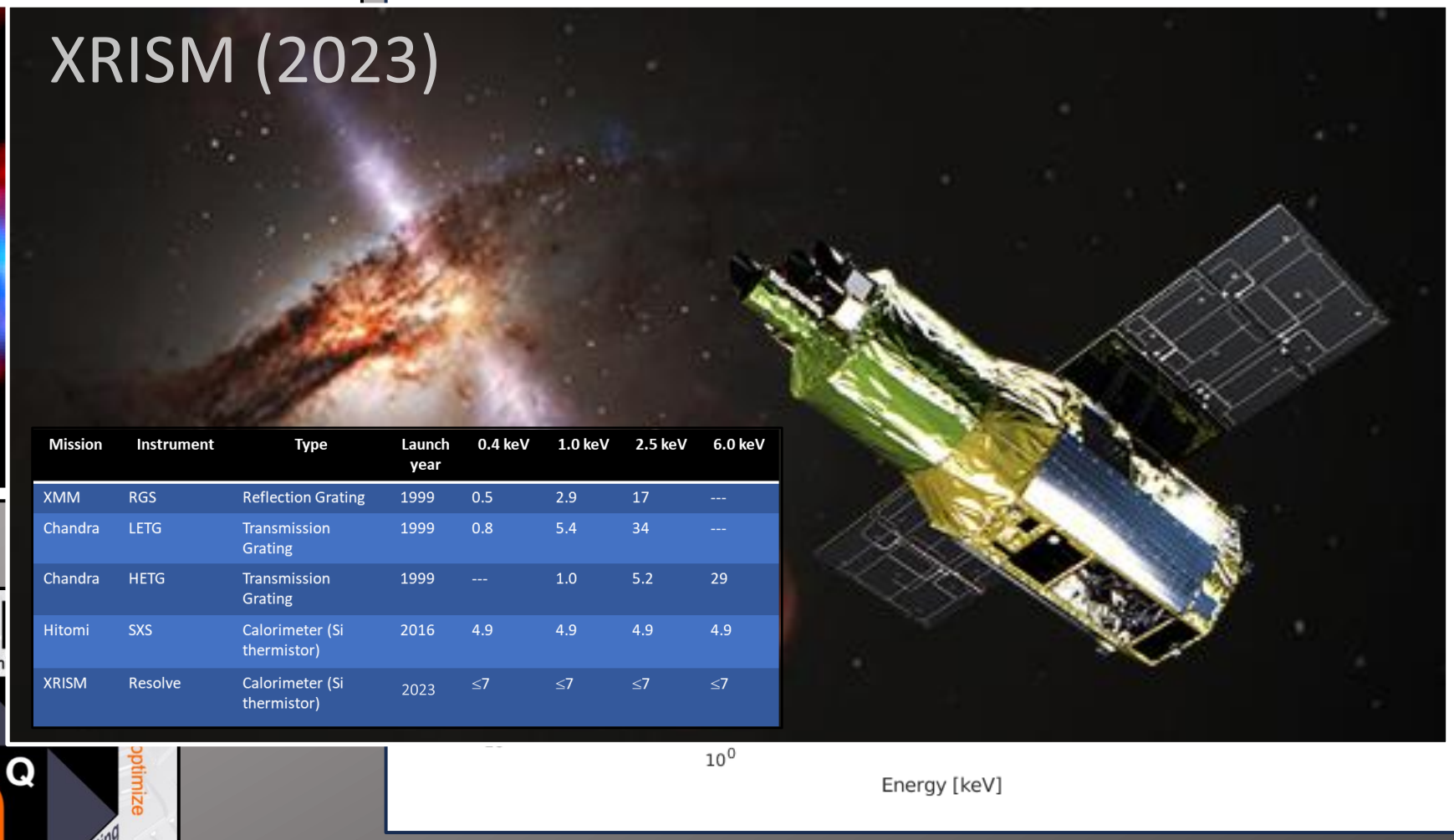
G41.1-0.3 Western Lobe





Mission	Instrument	Type	Launch year	0.4 keV	1.0 keV	2.5 keV	6.0 keV
XMM	RGS	Reflection Grating	1999	0.5	2.9	17	---
Chandra	LETG	Transmission Grating	1999	0.8	5.4	34	---
Chandra	HETG	Transmission Grating	1999	---	1.0	5.2	29
Hitomi	SXS	Calorimeter (Si thermistor)	2016	4.9	4.9	4.9	4.9
XRISM	Resolve	Calorimeter (Si thermistor)	2023	≤7	≤7	≤7	≤7

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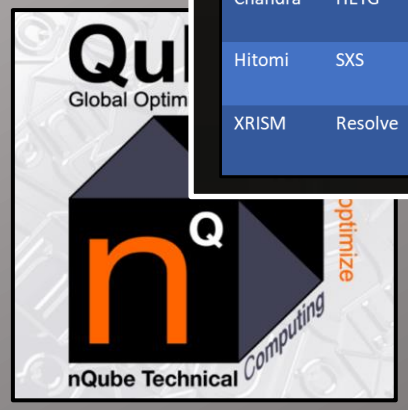

See: Rogers, A., Safi-Harb, S., and Fiege, J. (2015) for more information on **XFit**

References

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Thank you!