The SS 433 Jets and their Ni Abundance

Herman L. Marshall,
Claude R. Canizares,
Norbert S. Schulz,
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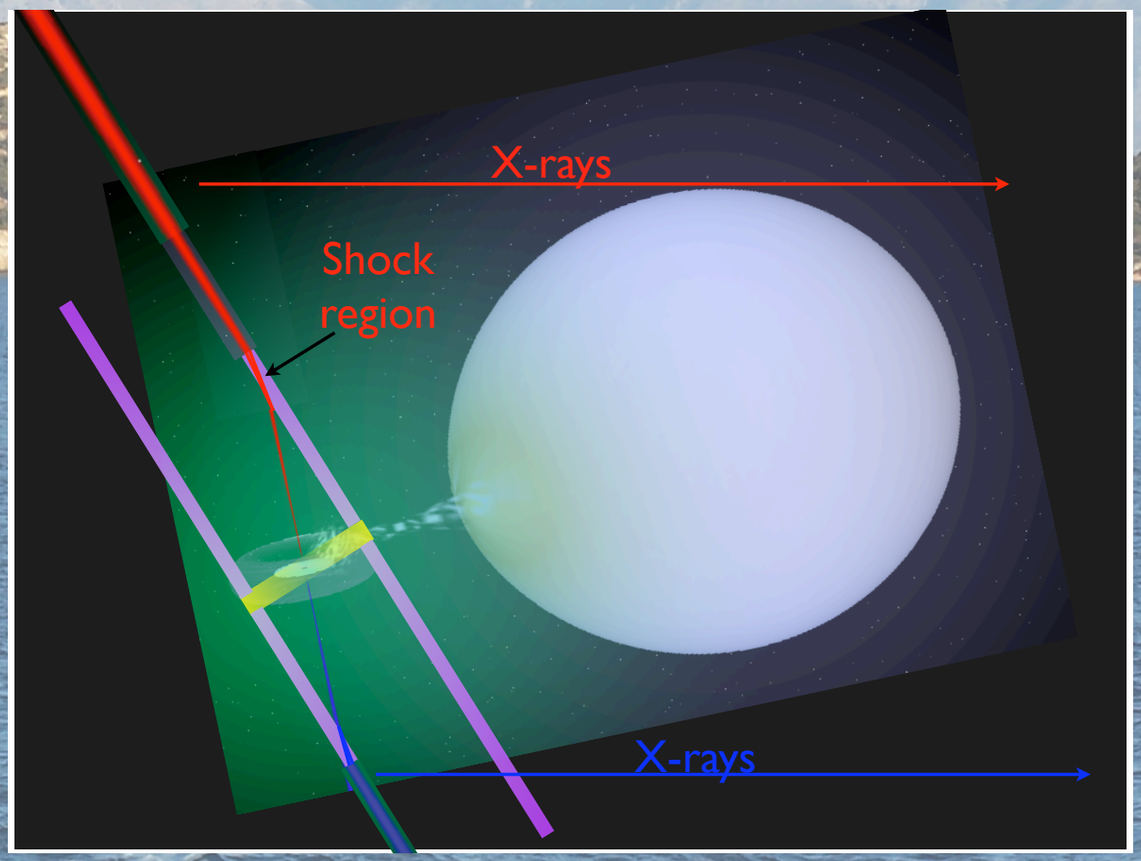
(MIT Kavli Institute)



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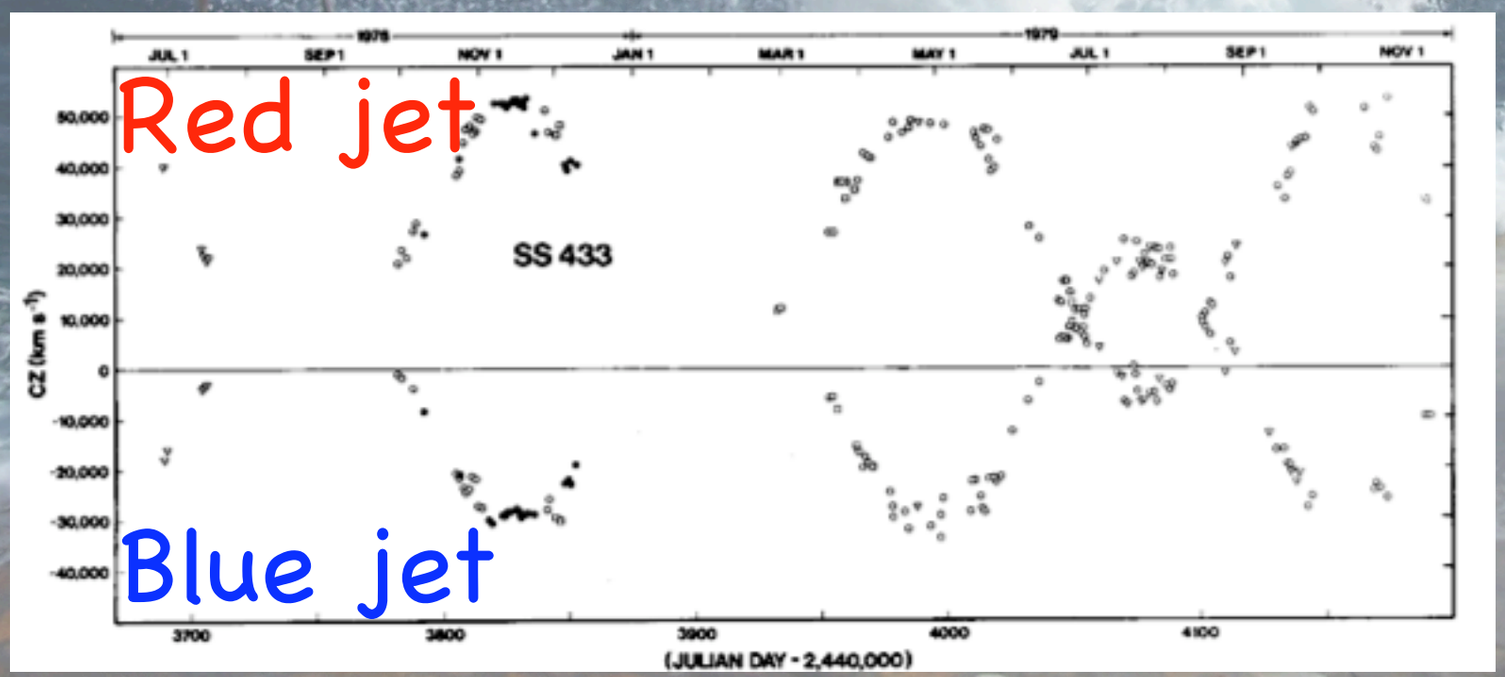
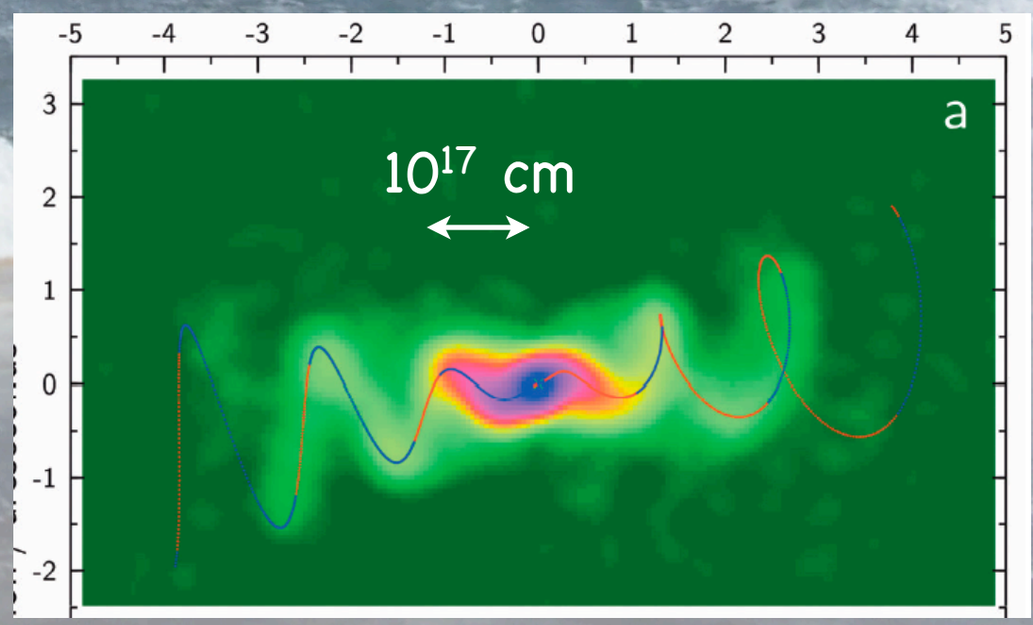
SS 433 Background

- Periodically Doppler shifting Hα HeI and H β
- Only jet known to contain baryons
- Model: oppositely directed jets at 0.26 c
  - Precession period: 162 days
  - Orbital period: 13.08 days
- Radio: verifies model and sets orientation

$$\frac{\lambda}{\lambda_0} = 1 + z = \gamma(1 \pm \beta \cos\alpha)$$



Margon et al. 1980



Blundell & Bowler 2005

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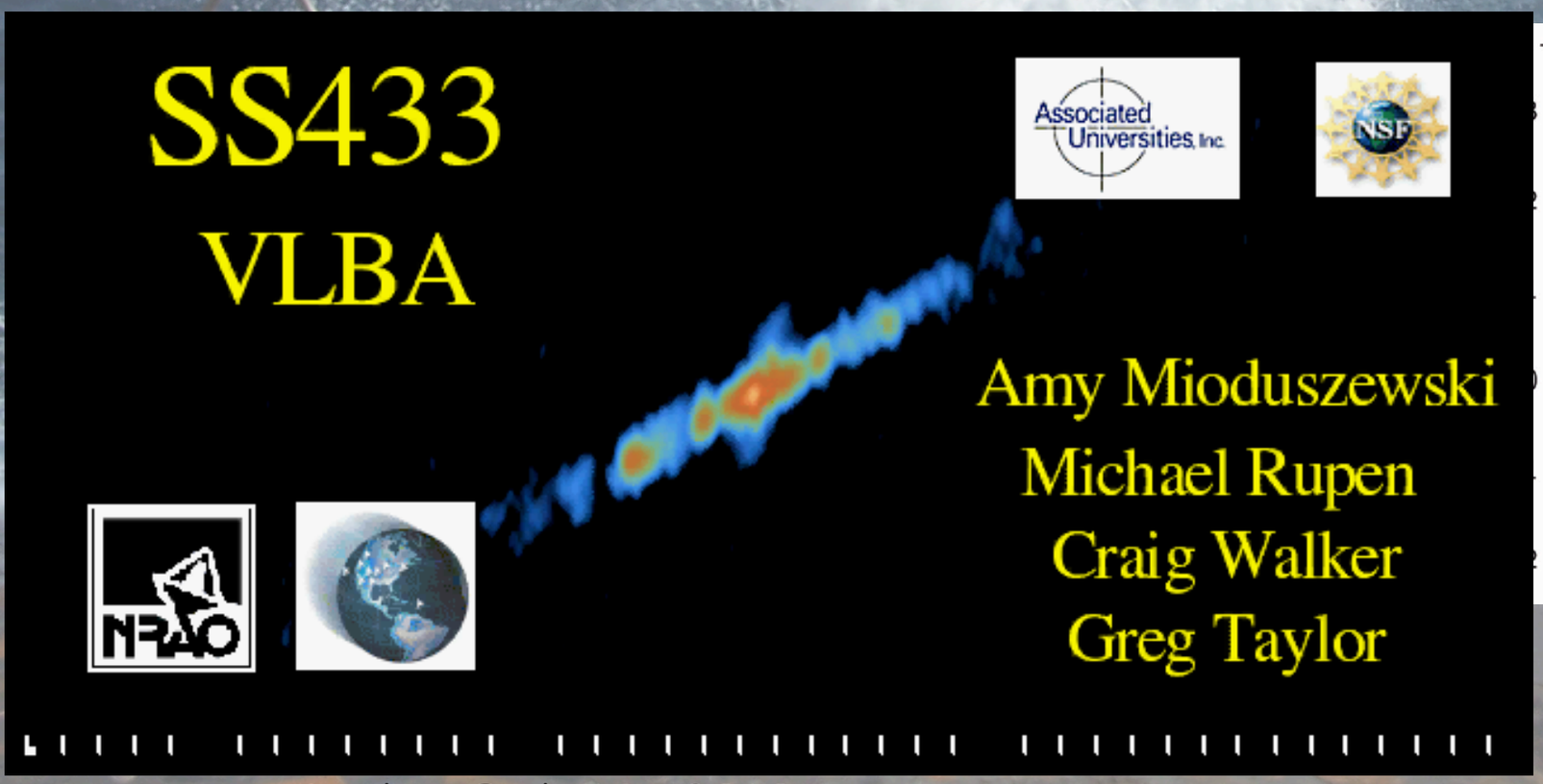

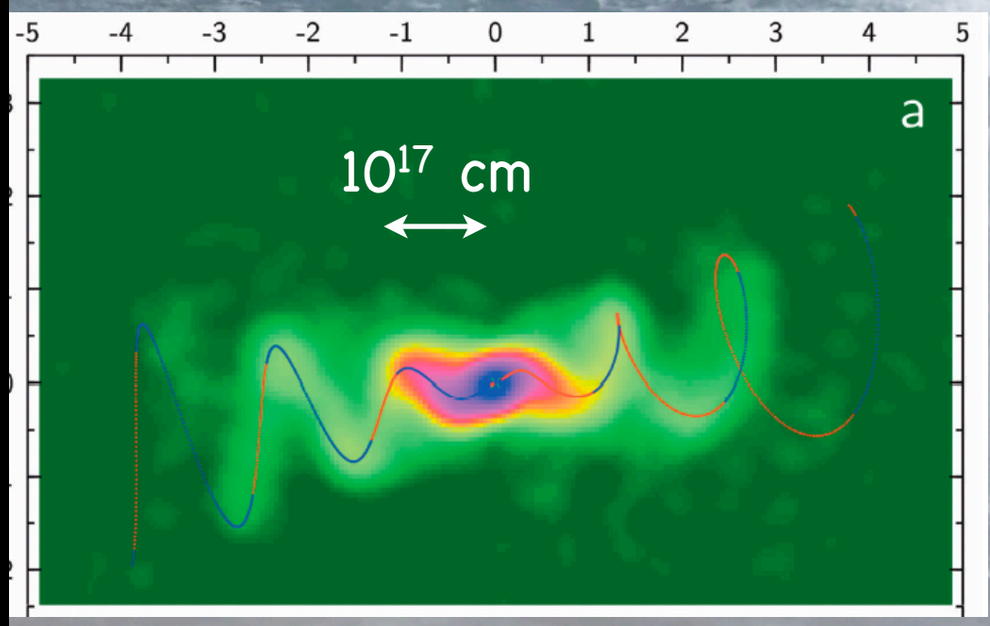

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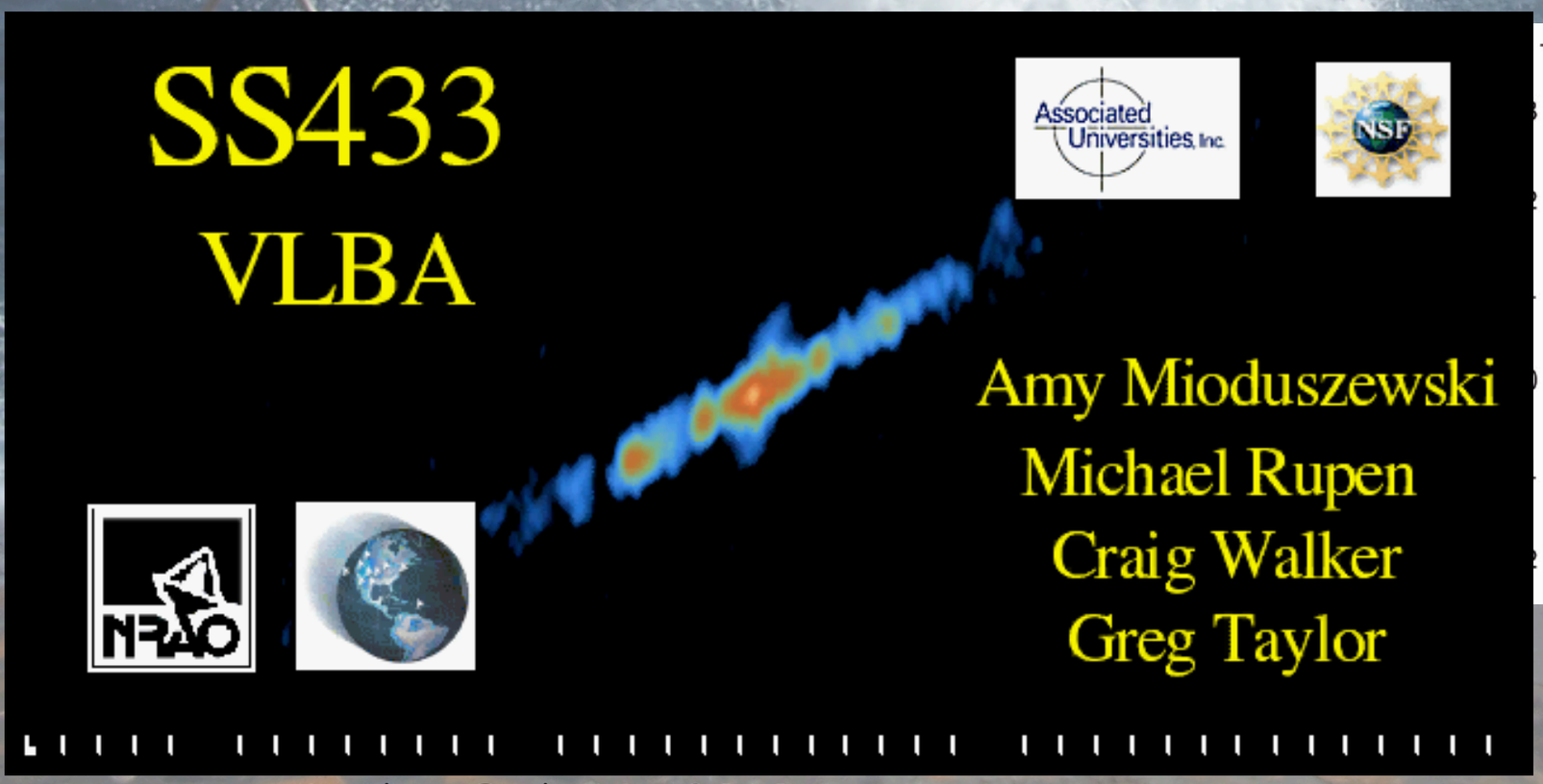

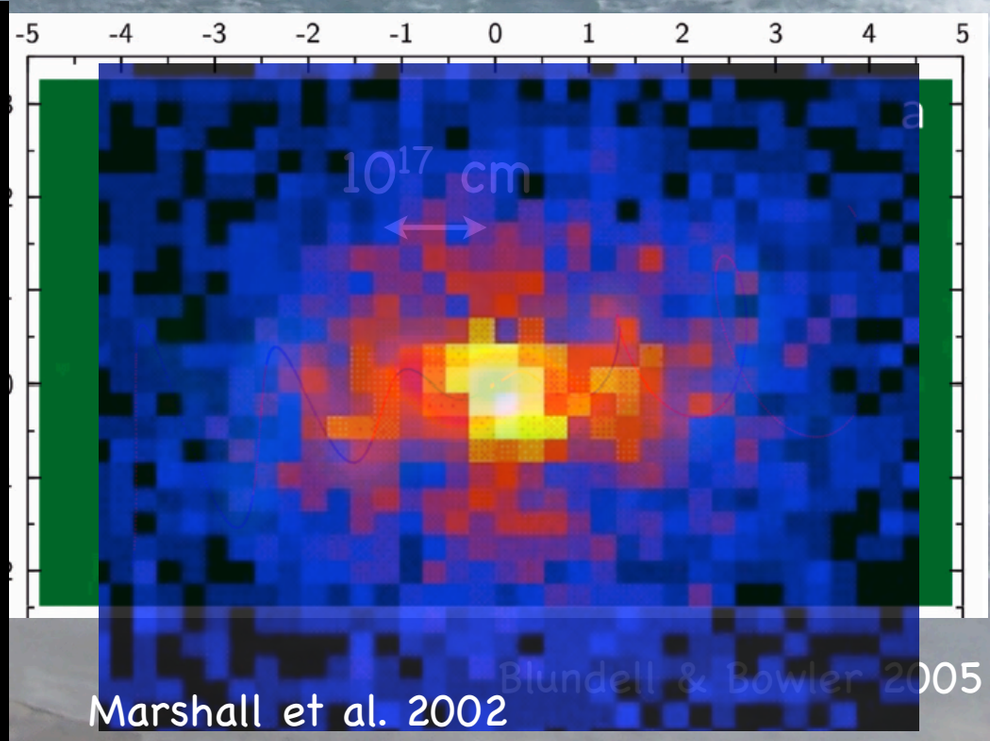

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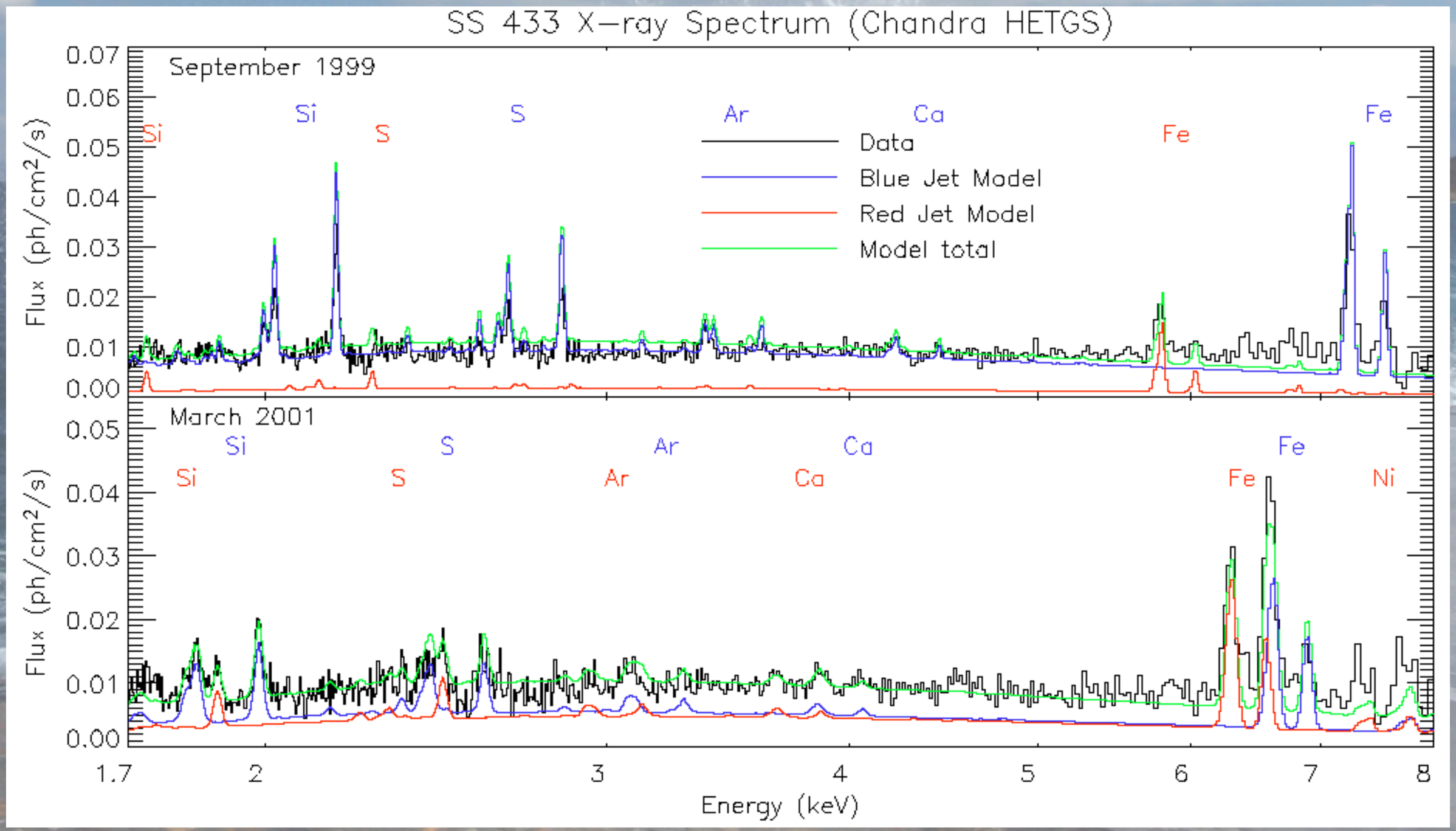
Two HETGS Spectra



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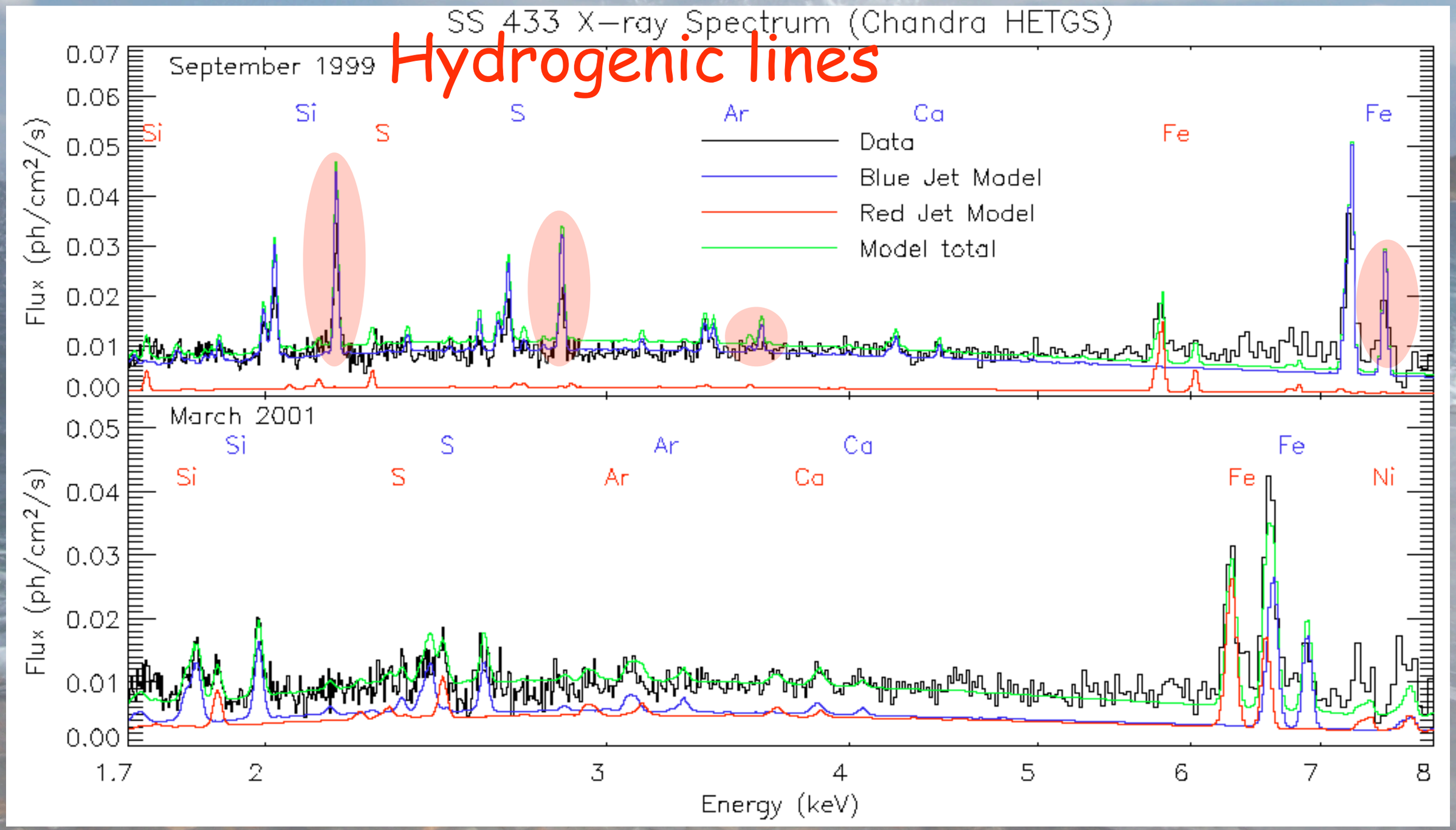

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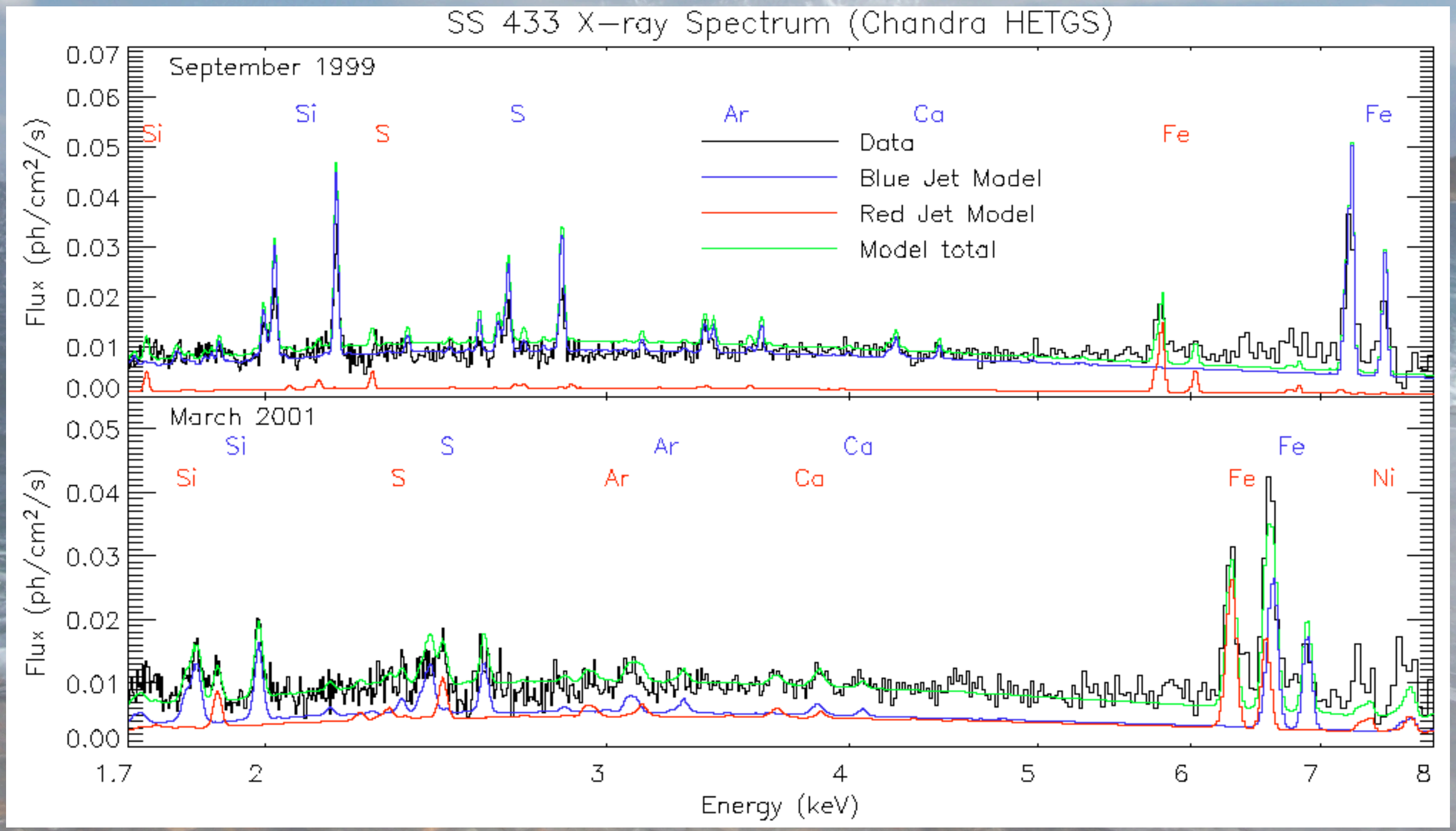

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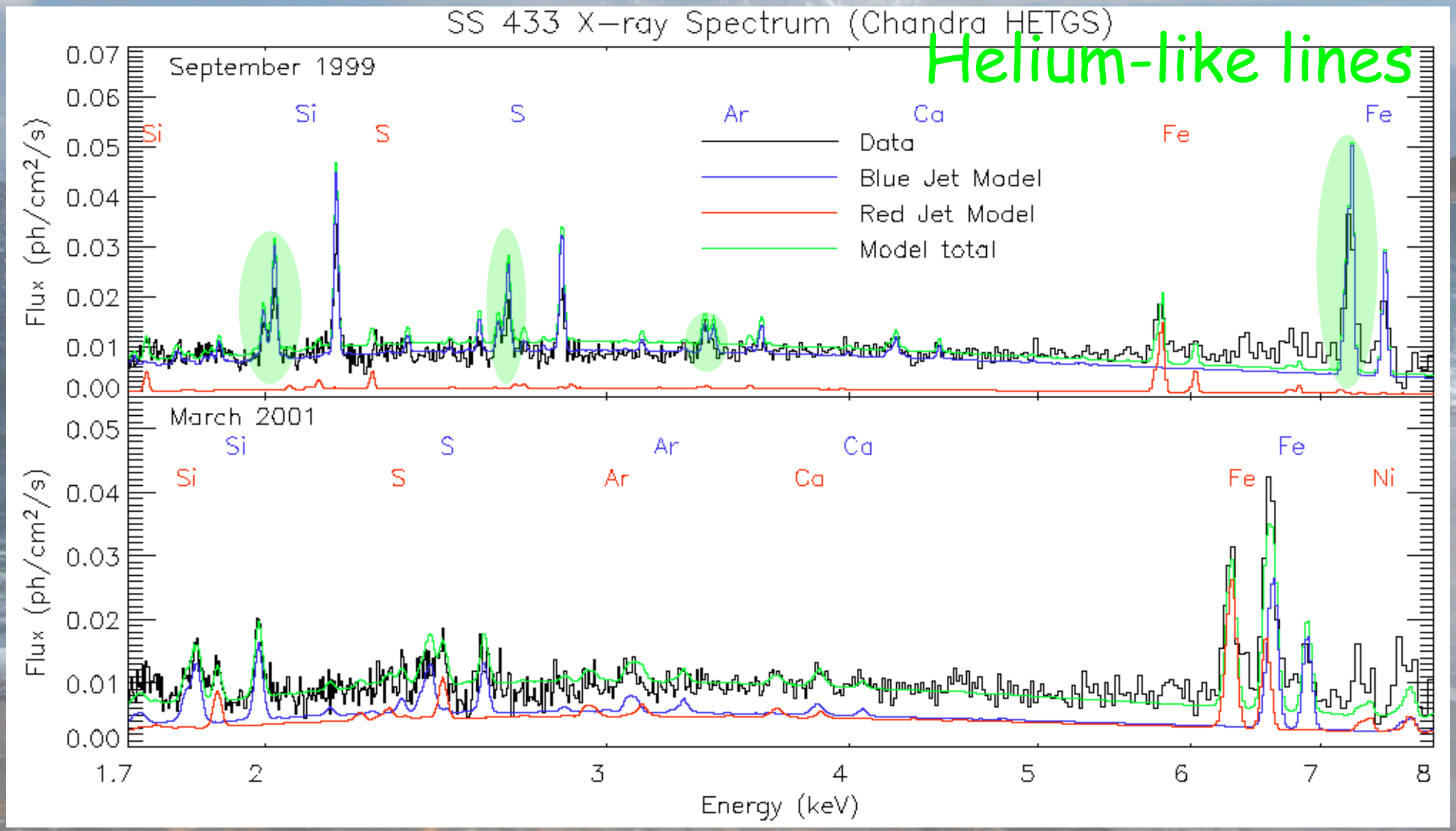

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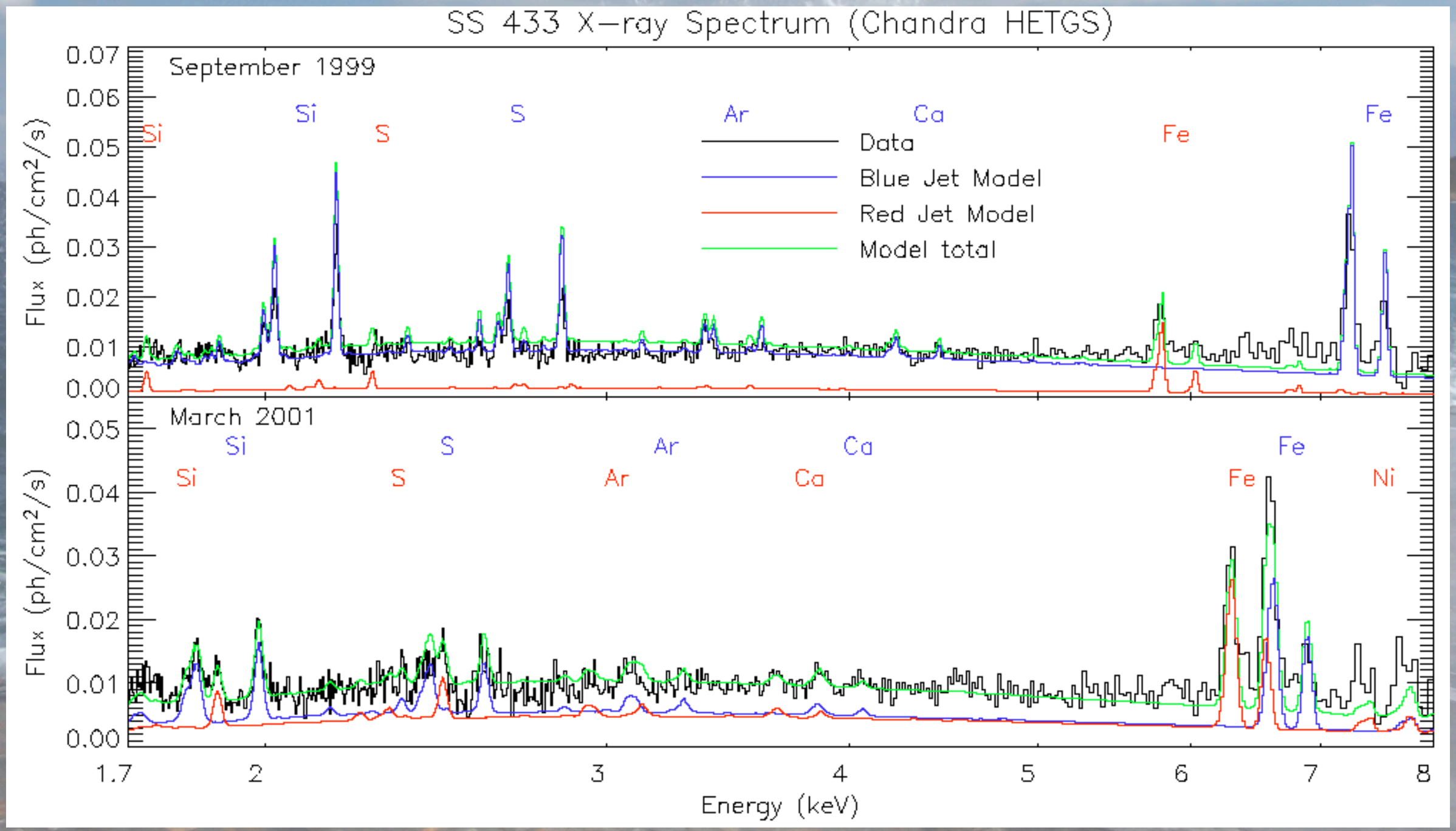

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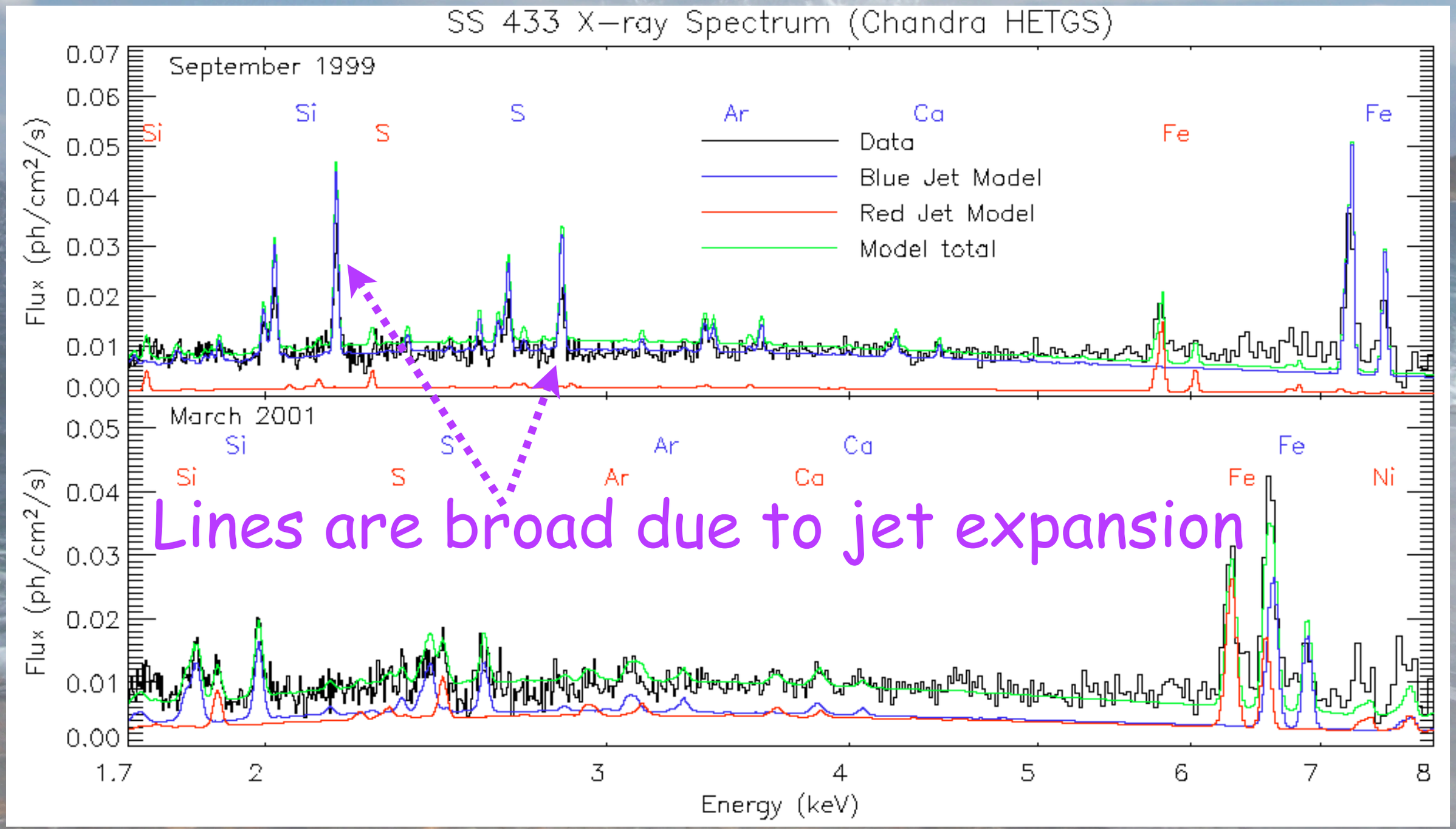

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Jet Physics from Lines

- Line Doppler shifts
  - not in acceleration zone
  - all ions accelerated to same speed
- Line widths
  - not in nozzle or flaring zone
  - opening half-angle is constant at 0.75°
- Line strengths
  - collisionally heated plasma, kT_b = 15 keV
  - EM(T), test cooling models
  - with continuum, get abundances
- Si XIII triplet: electron density ~ 10^{14} cm^{-3}

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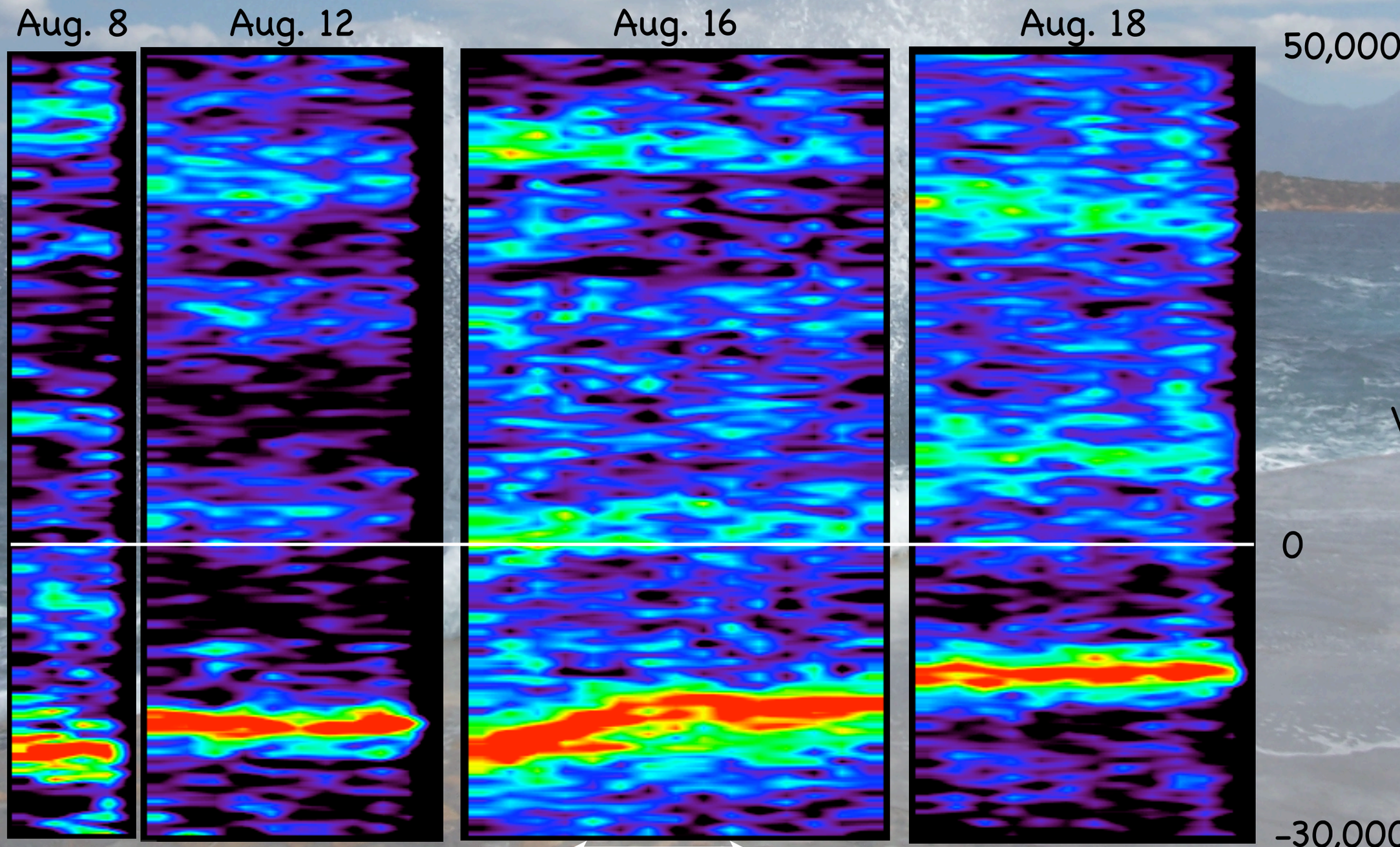
Trailed Spectra

- Made by Doppler shifting to rest frame
- Used many lines: Mg XII, Si XIV, Fe XV, etc.



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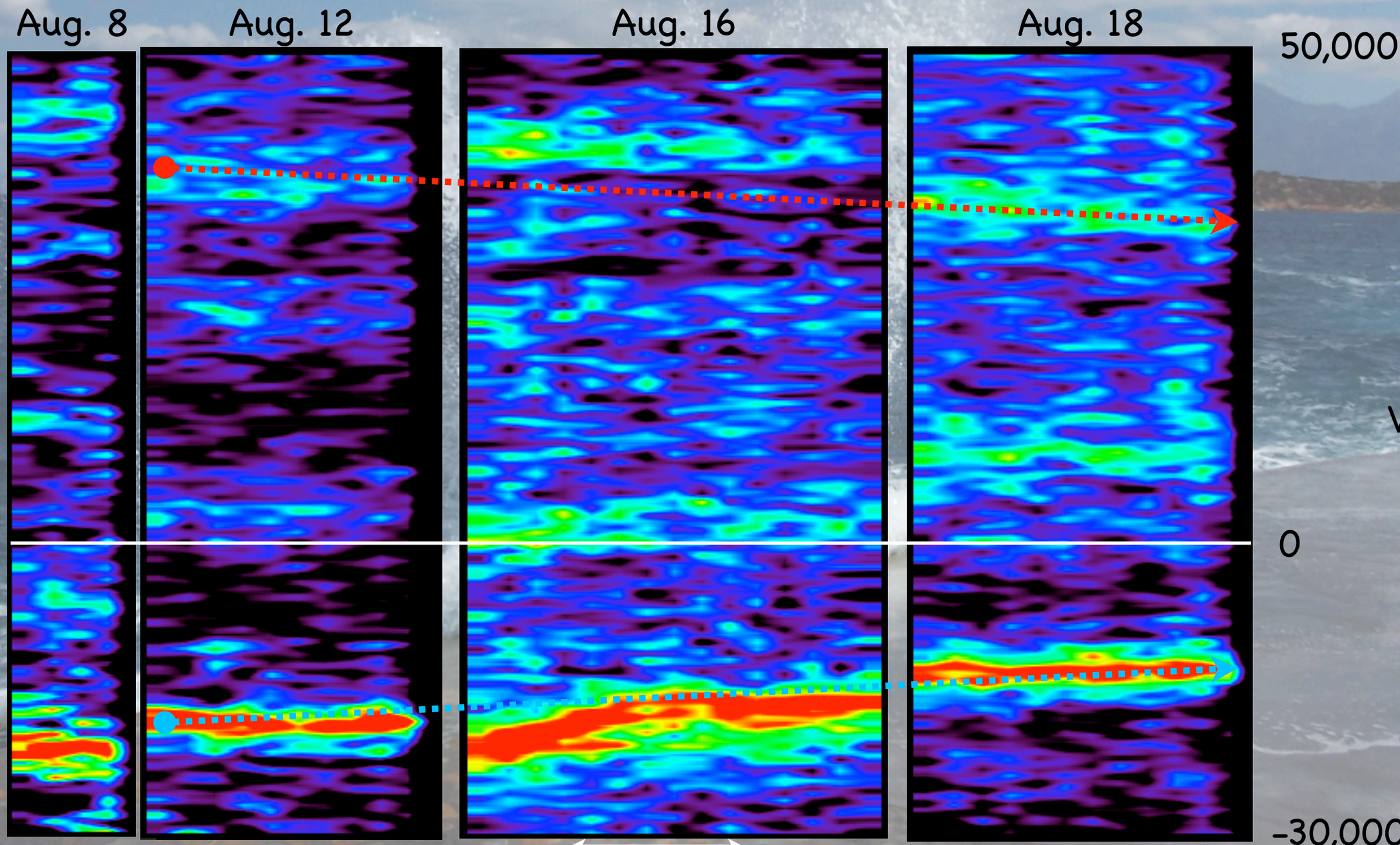

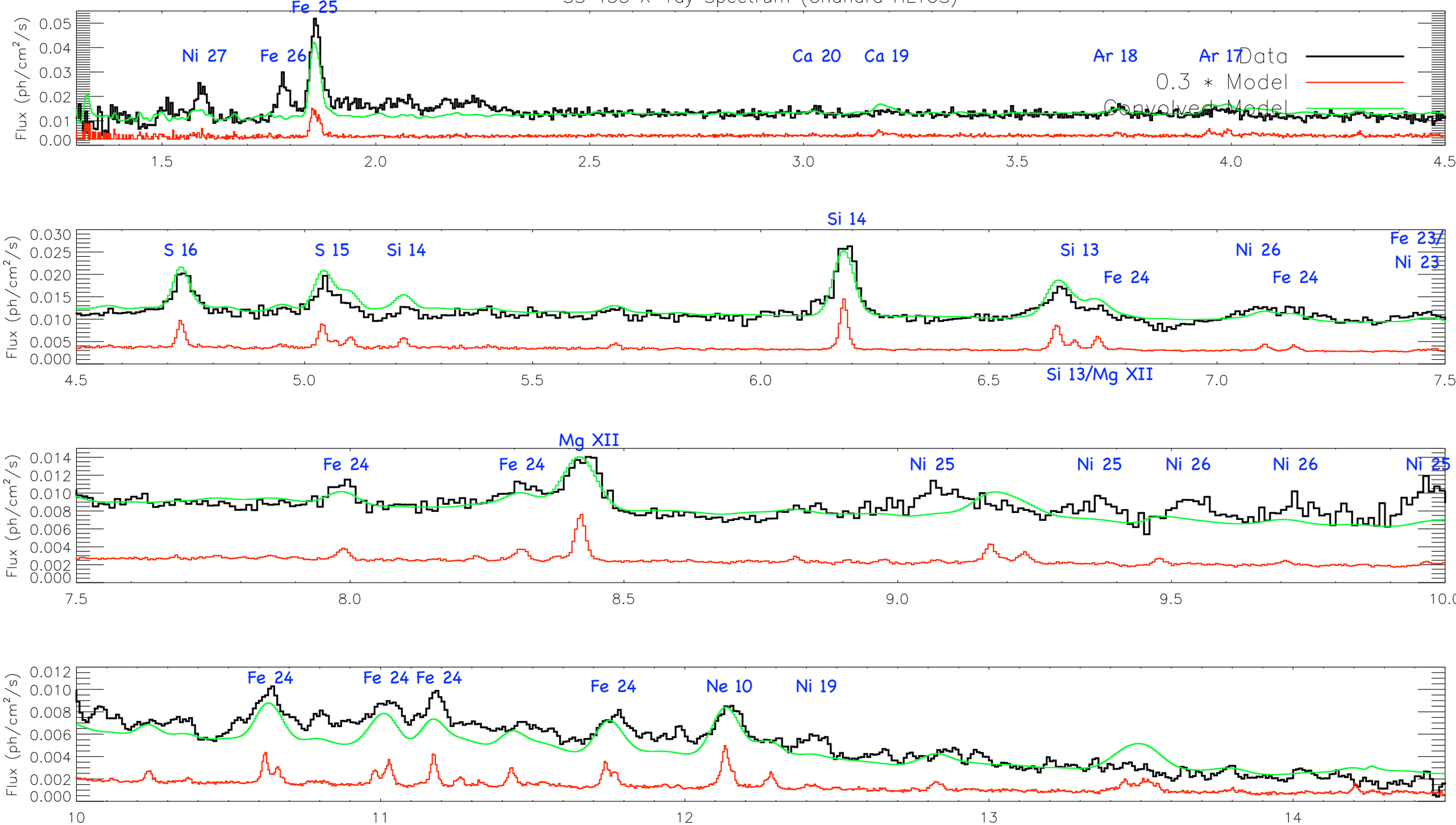

X-ray spectra corrected to blue jet rest frame

Model is from O-star observation

Jet Cooling Model

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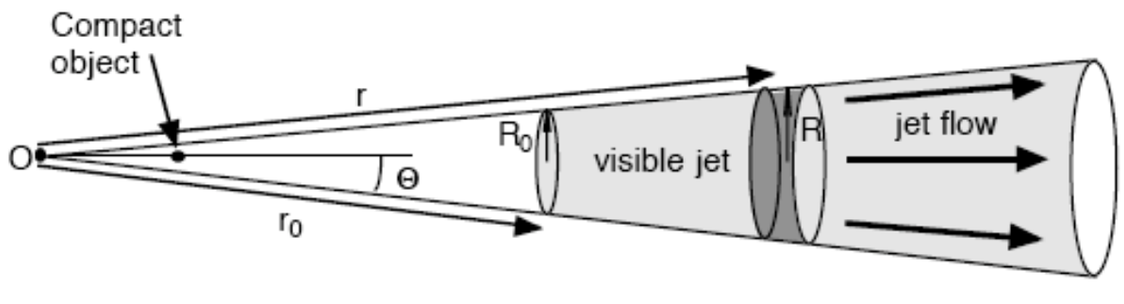

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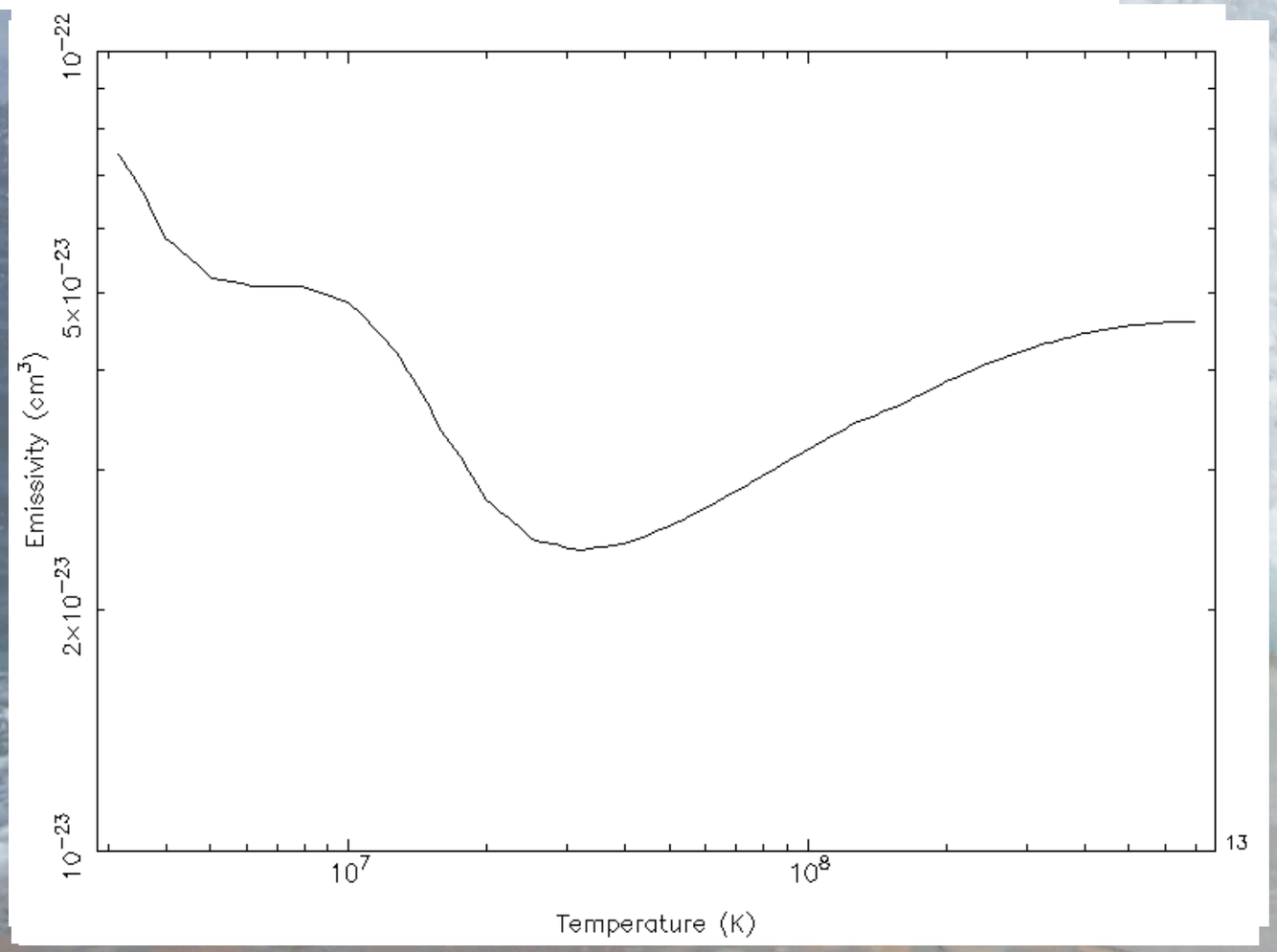
$n_{0,11}$	1	3	1	3	1	1
P_{38}	1	10	3	1	3	3



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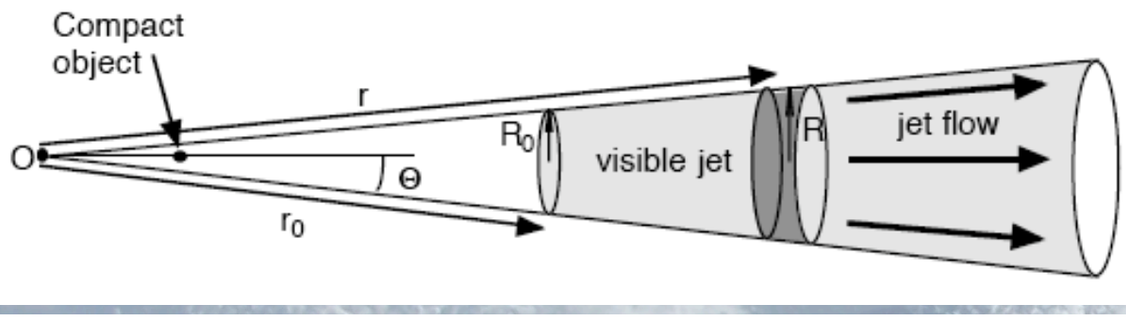

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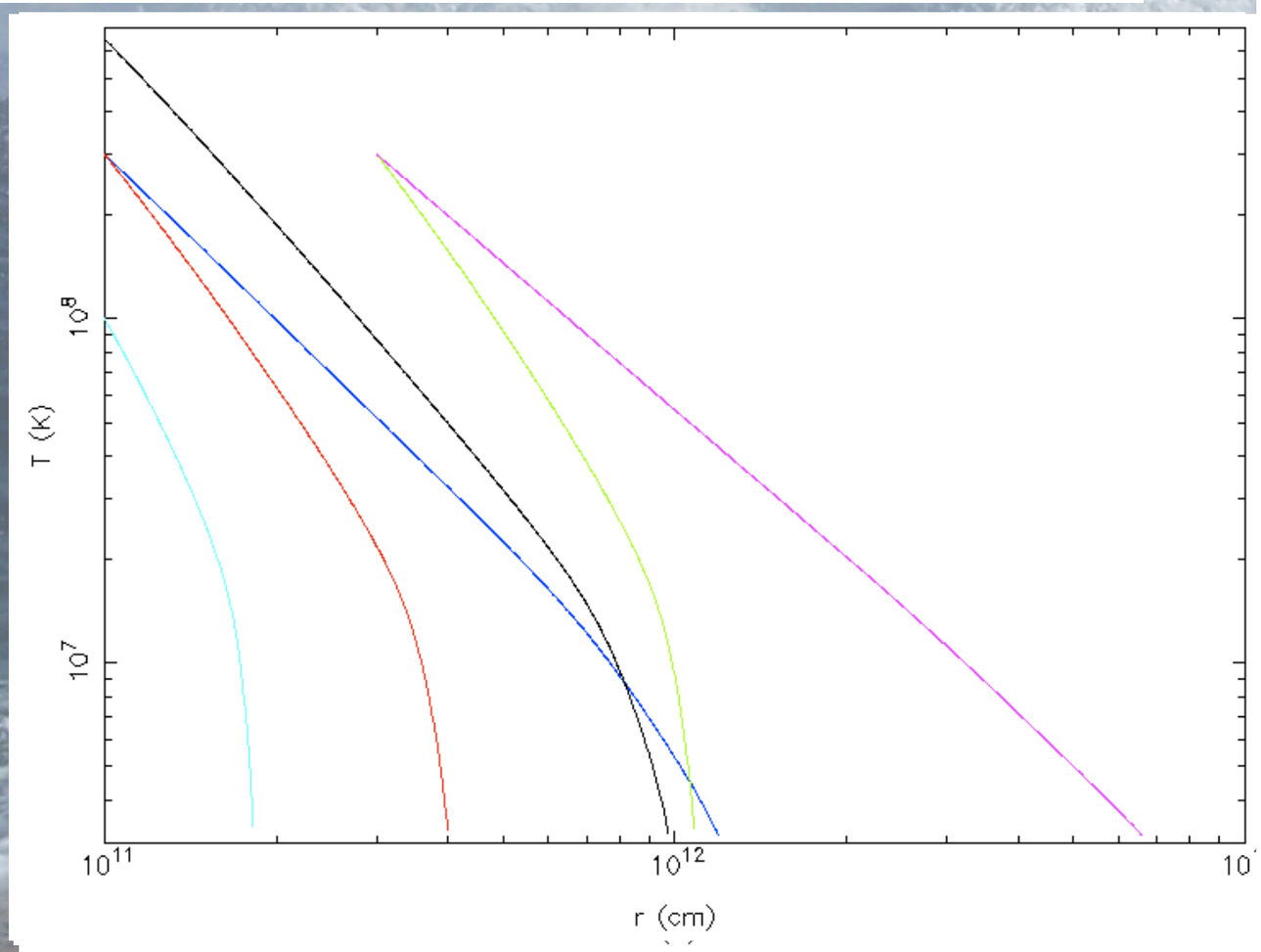

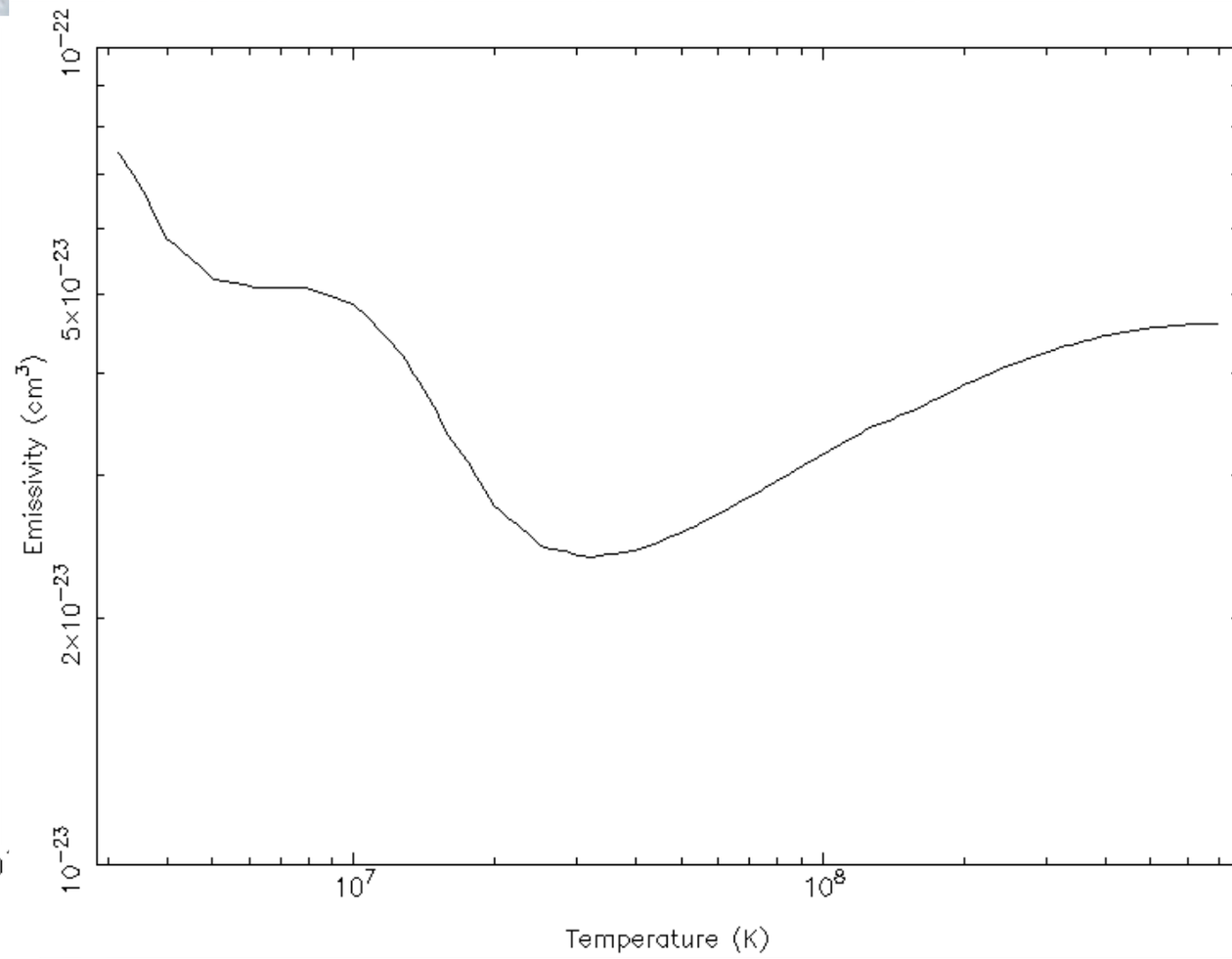

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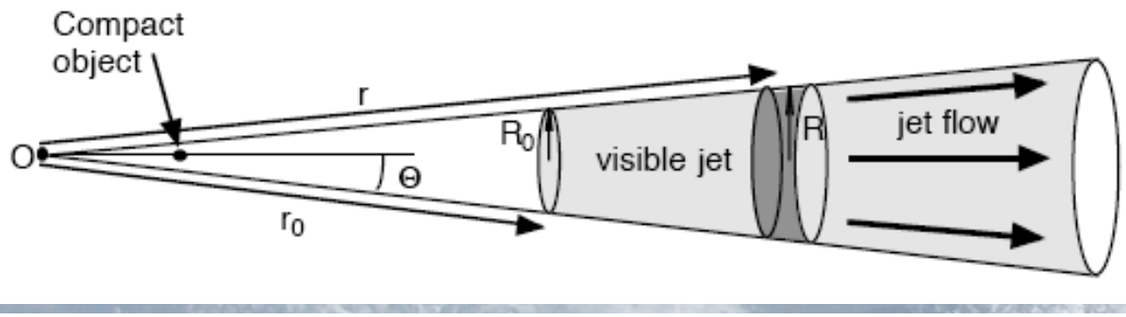

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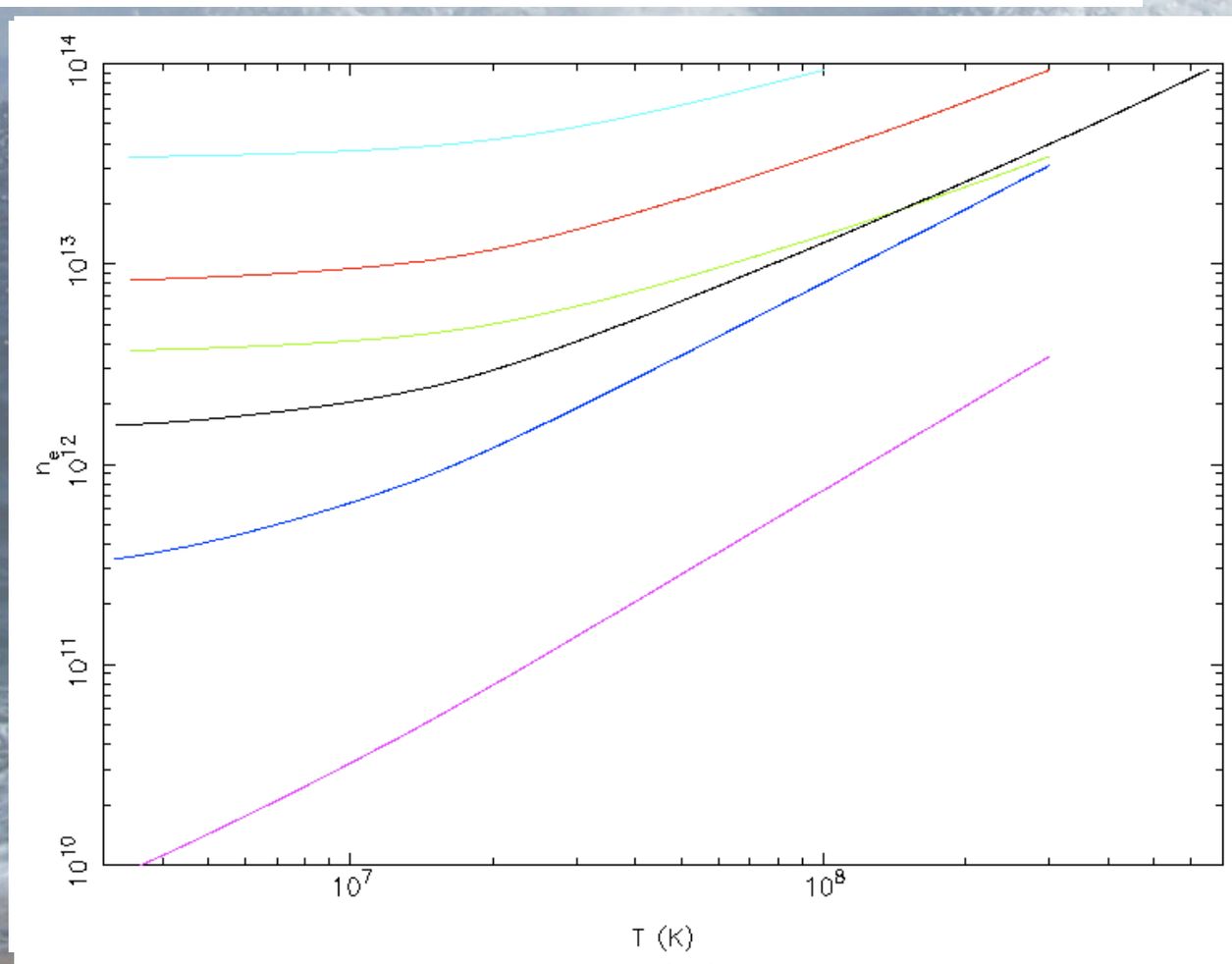

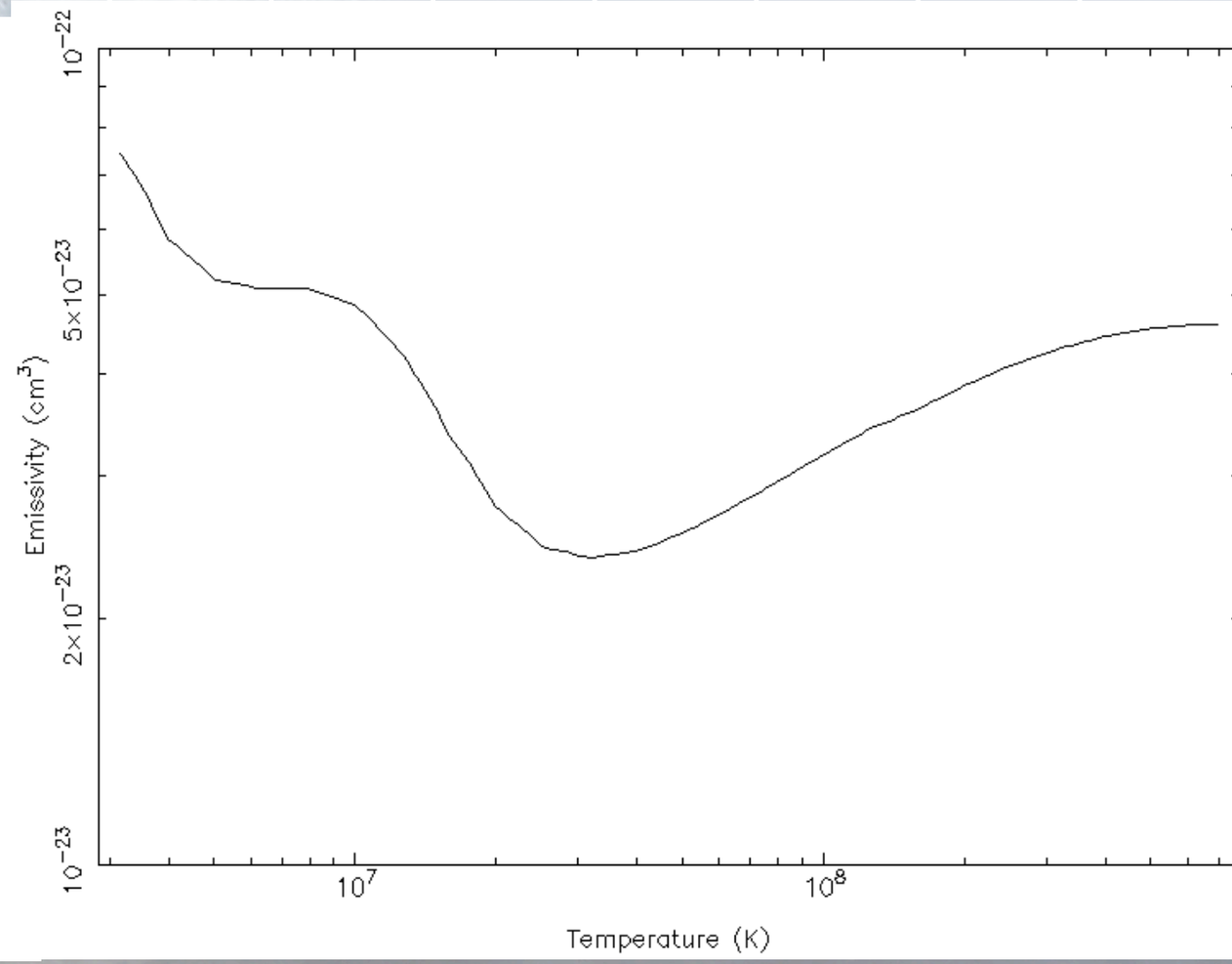

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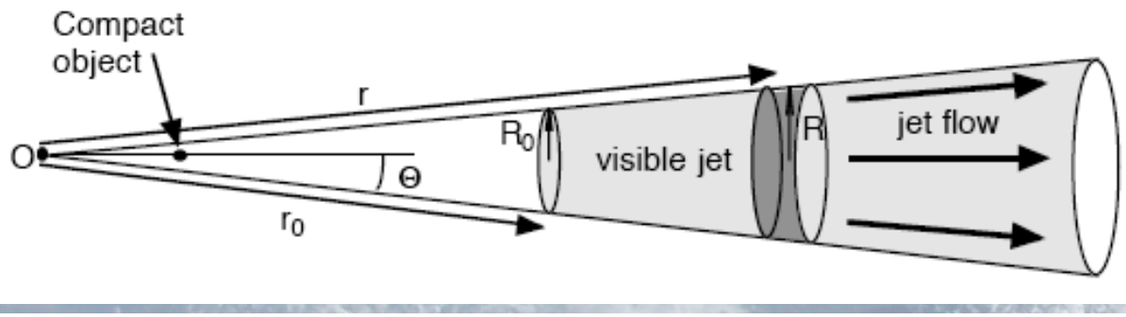

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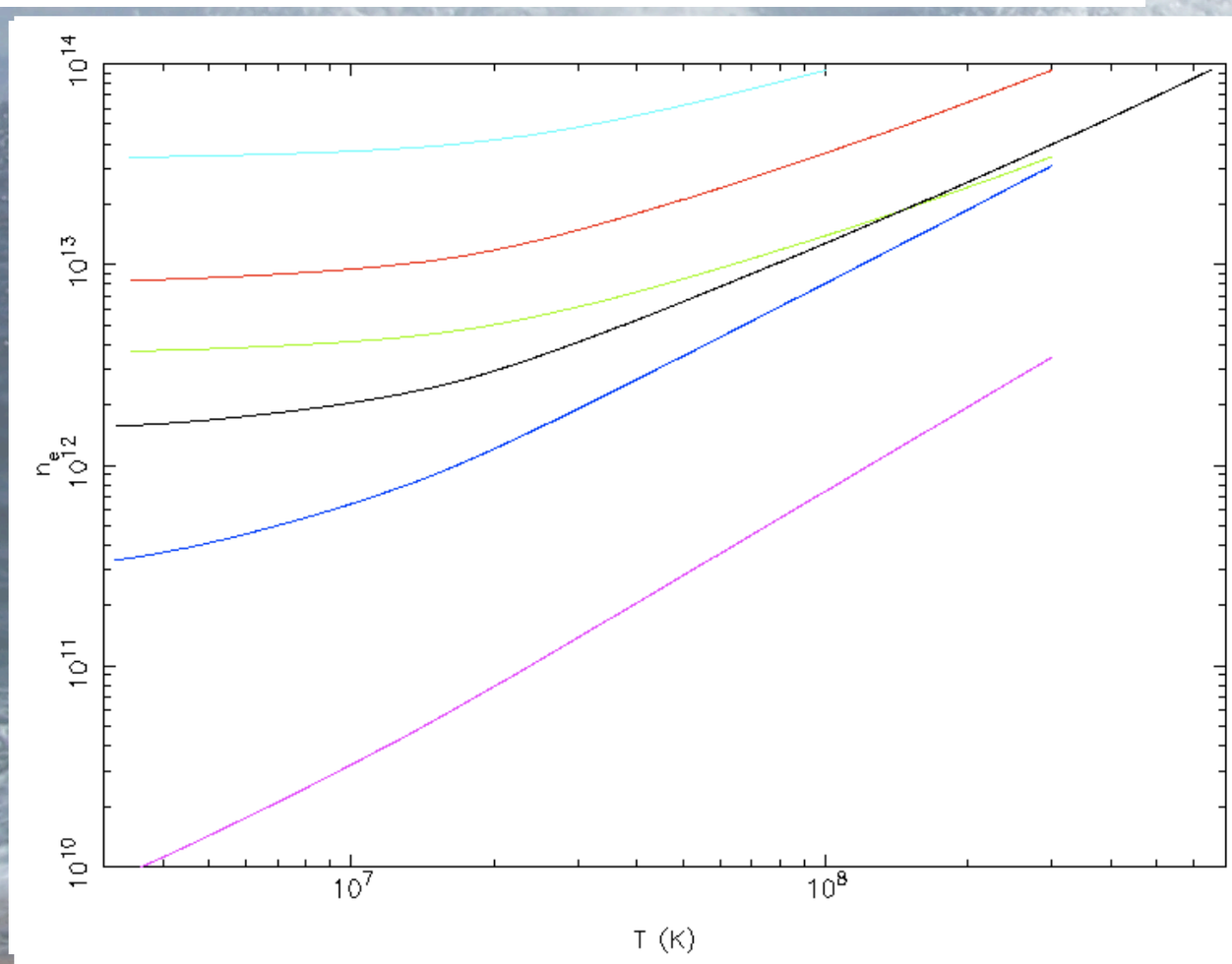

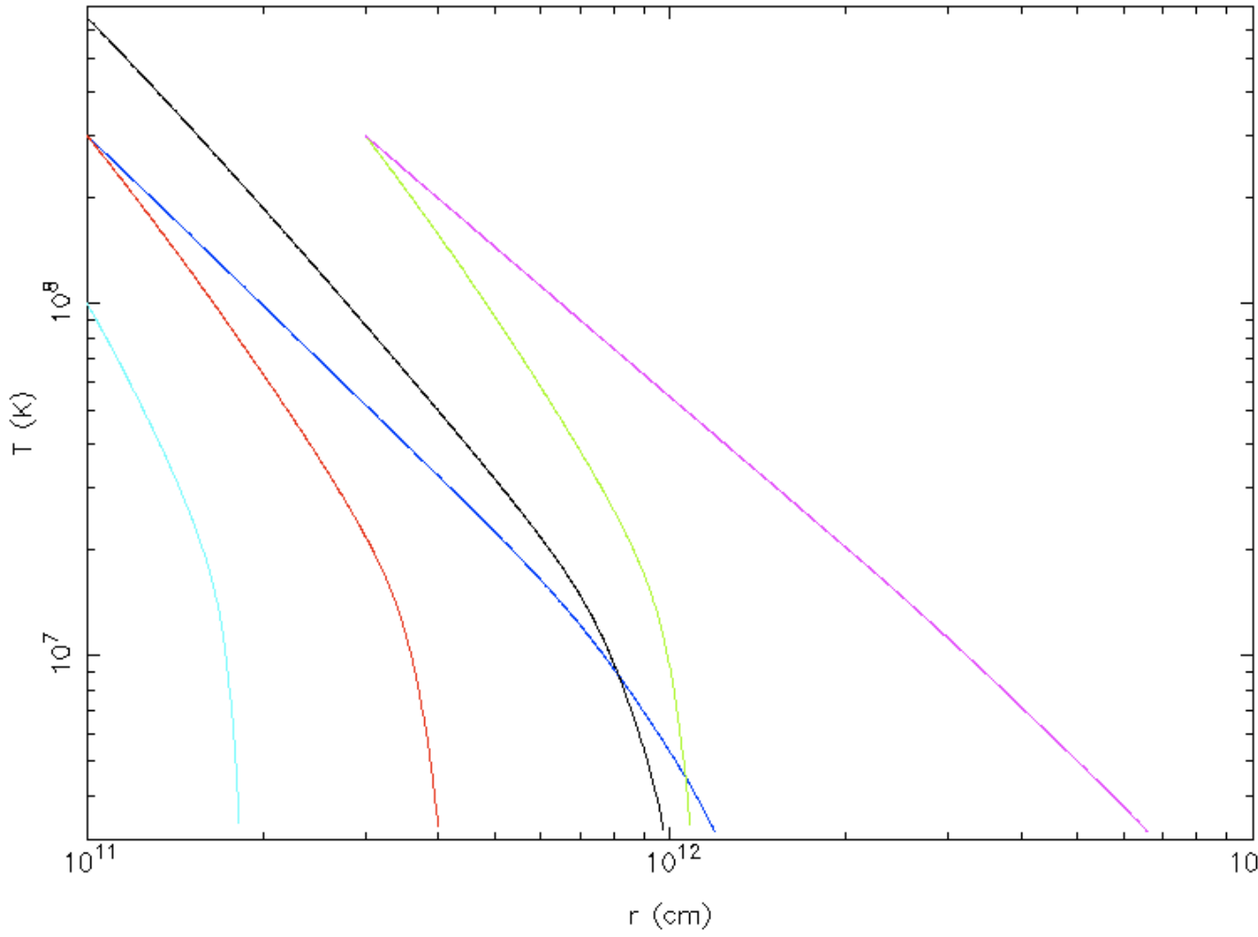

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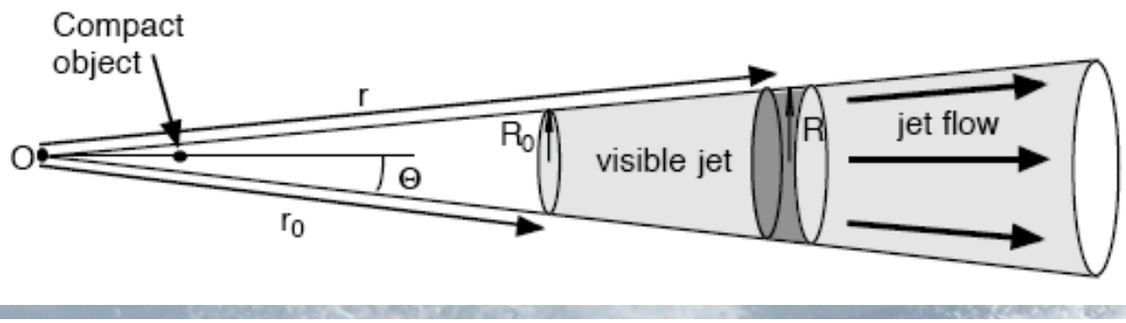

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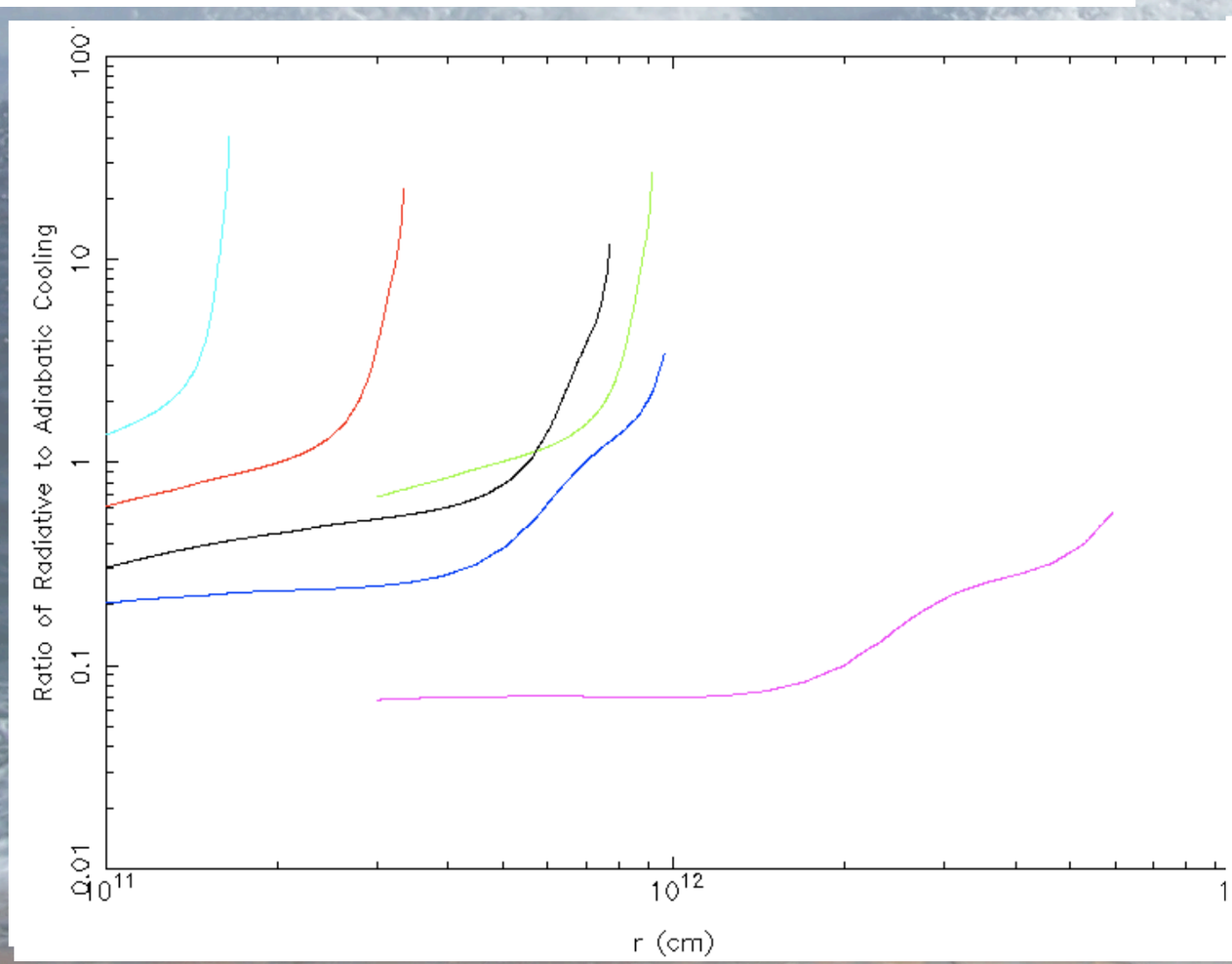

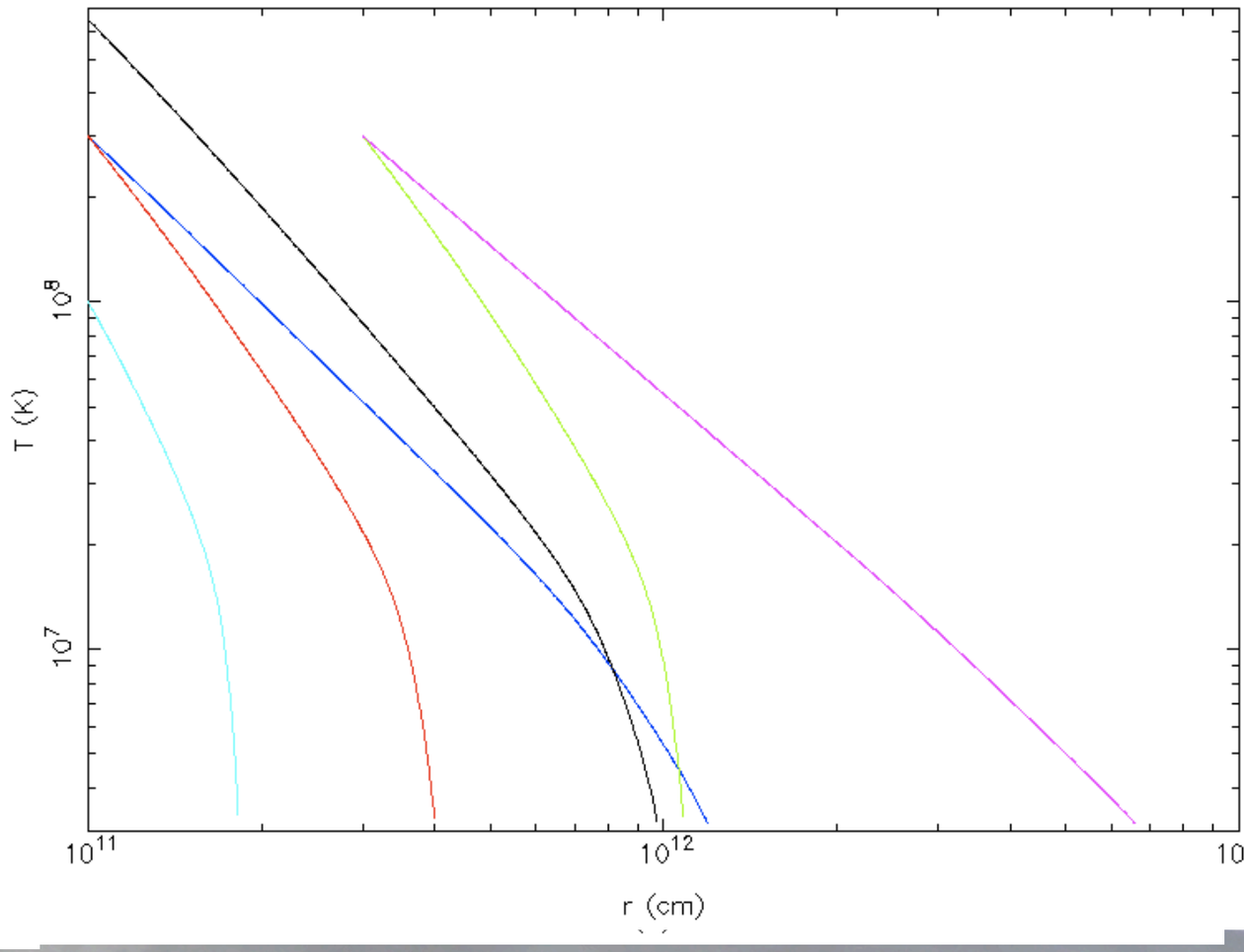

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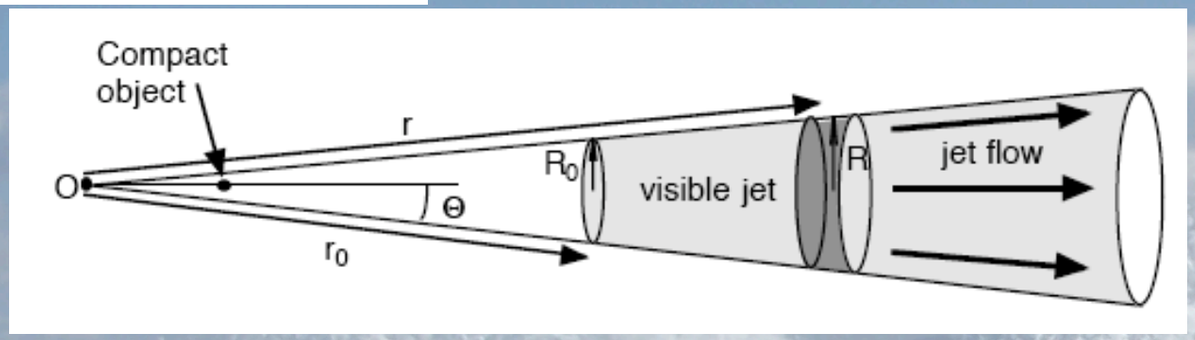

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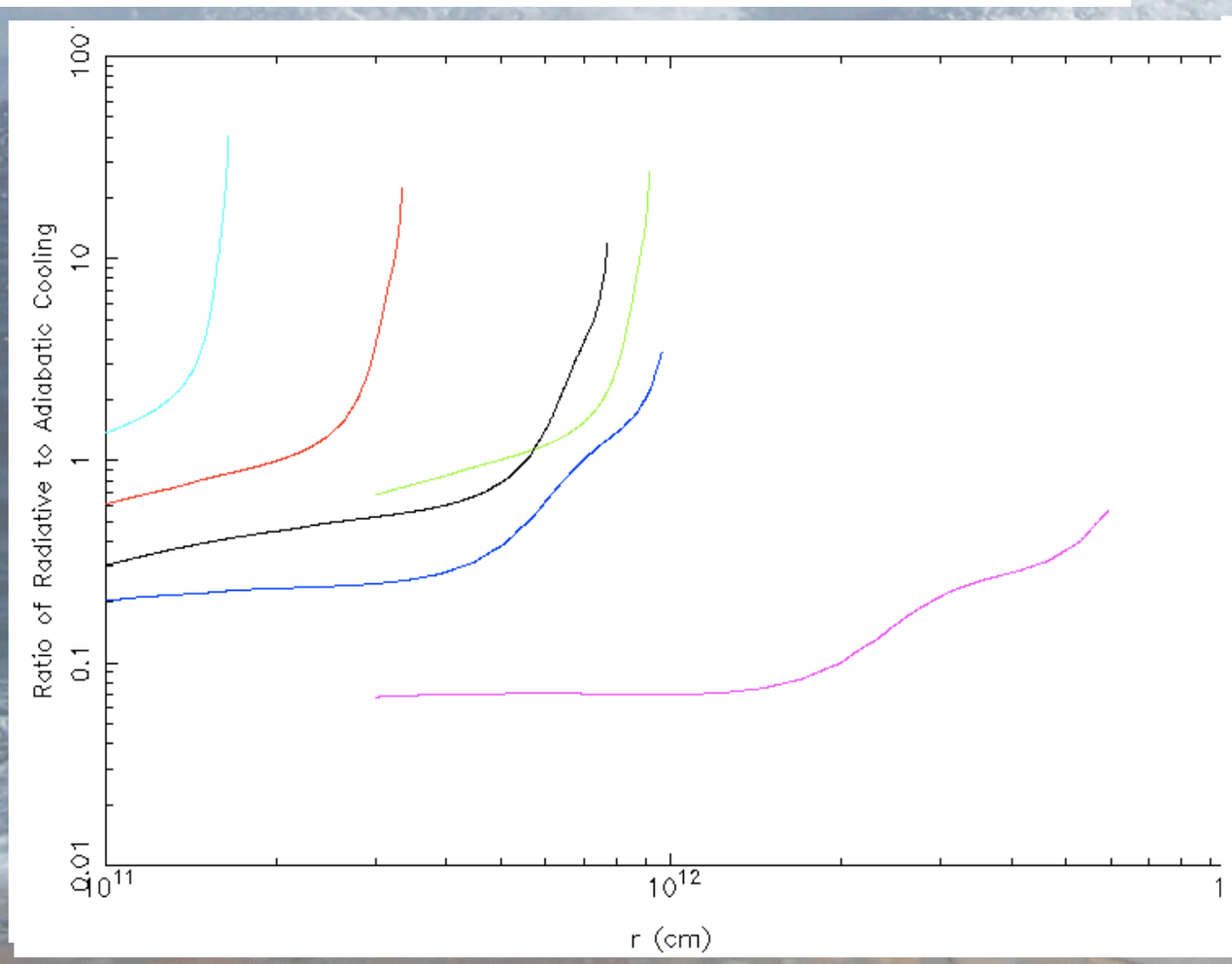

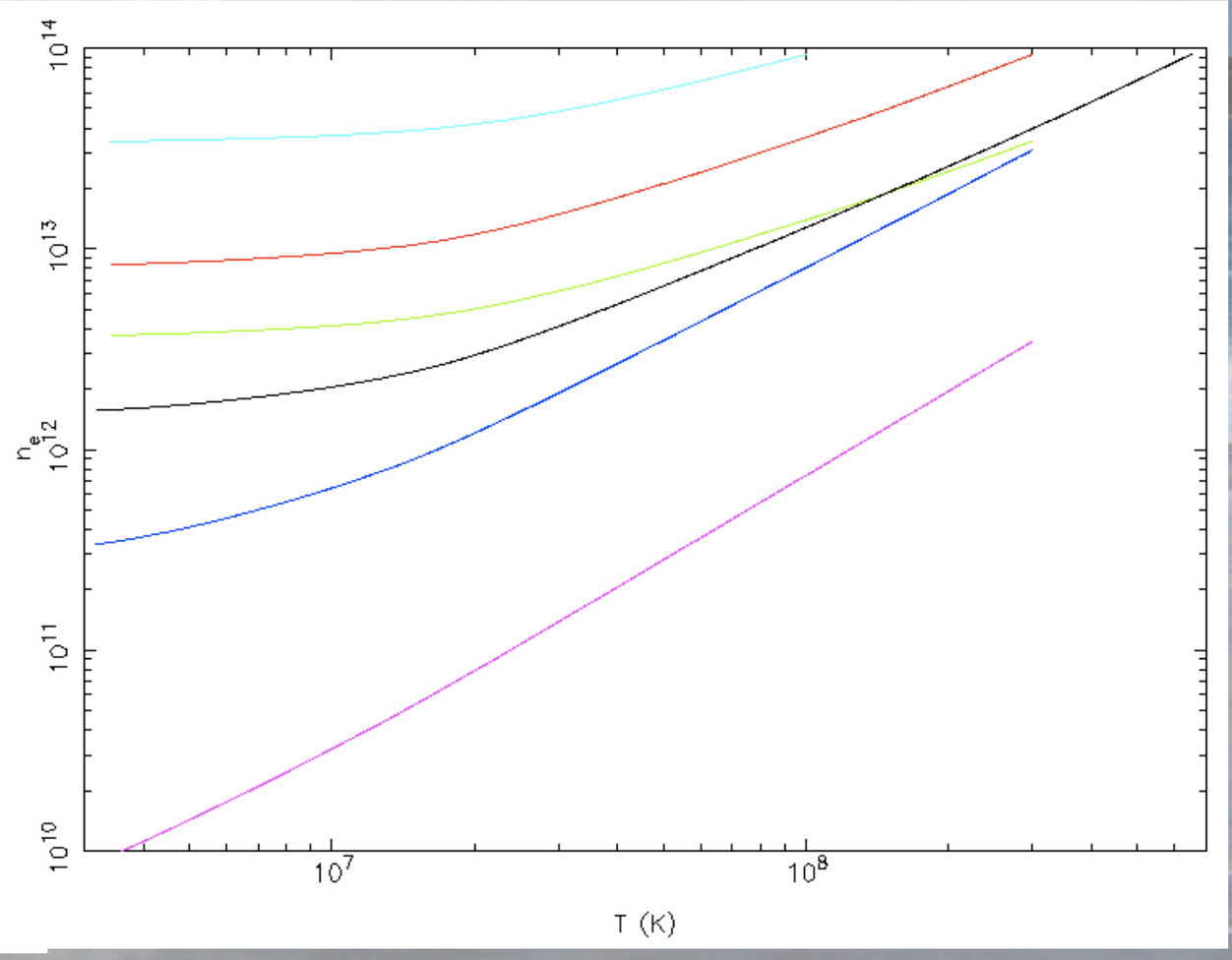

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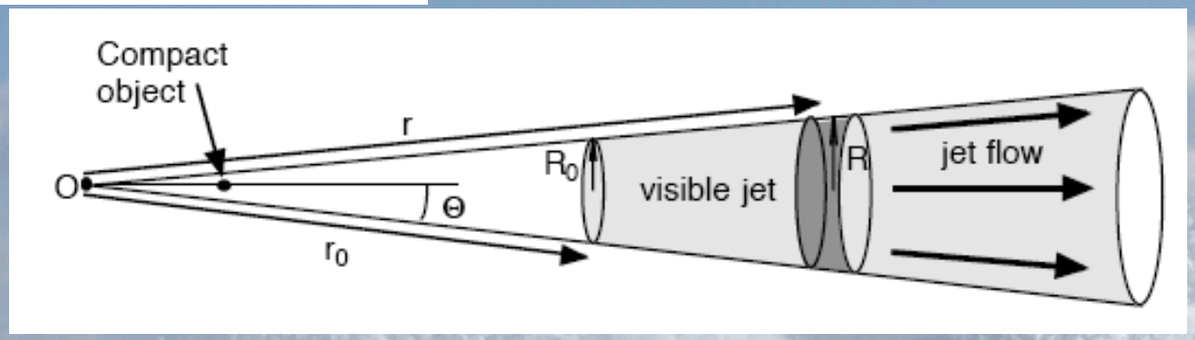

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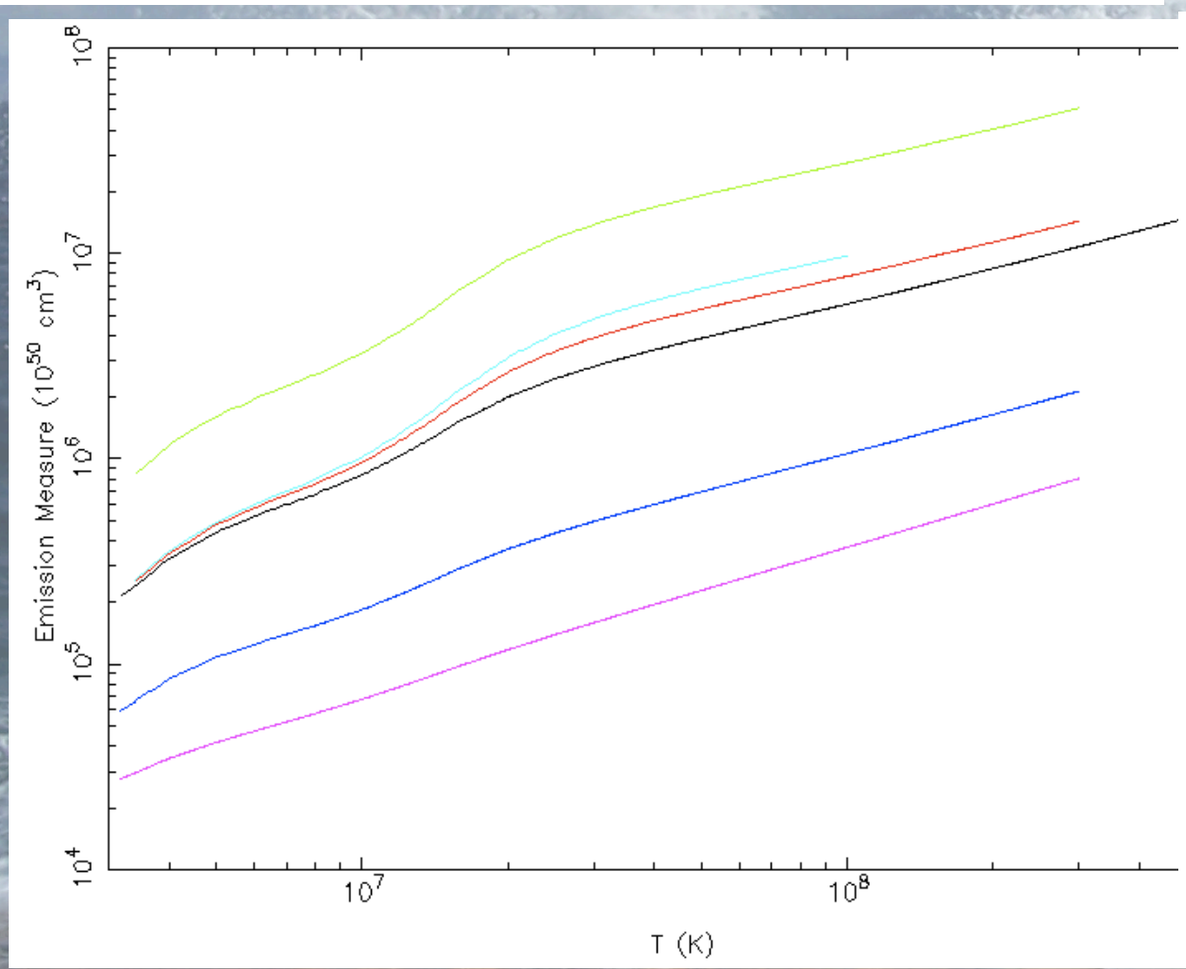

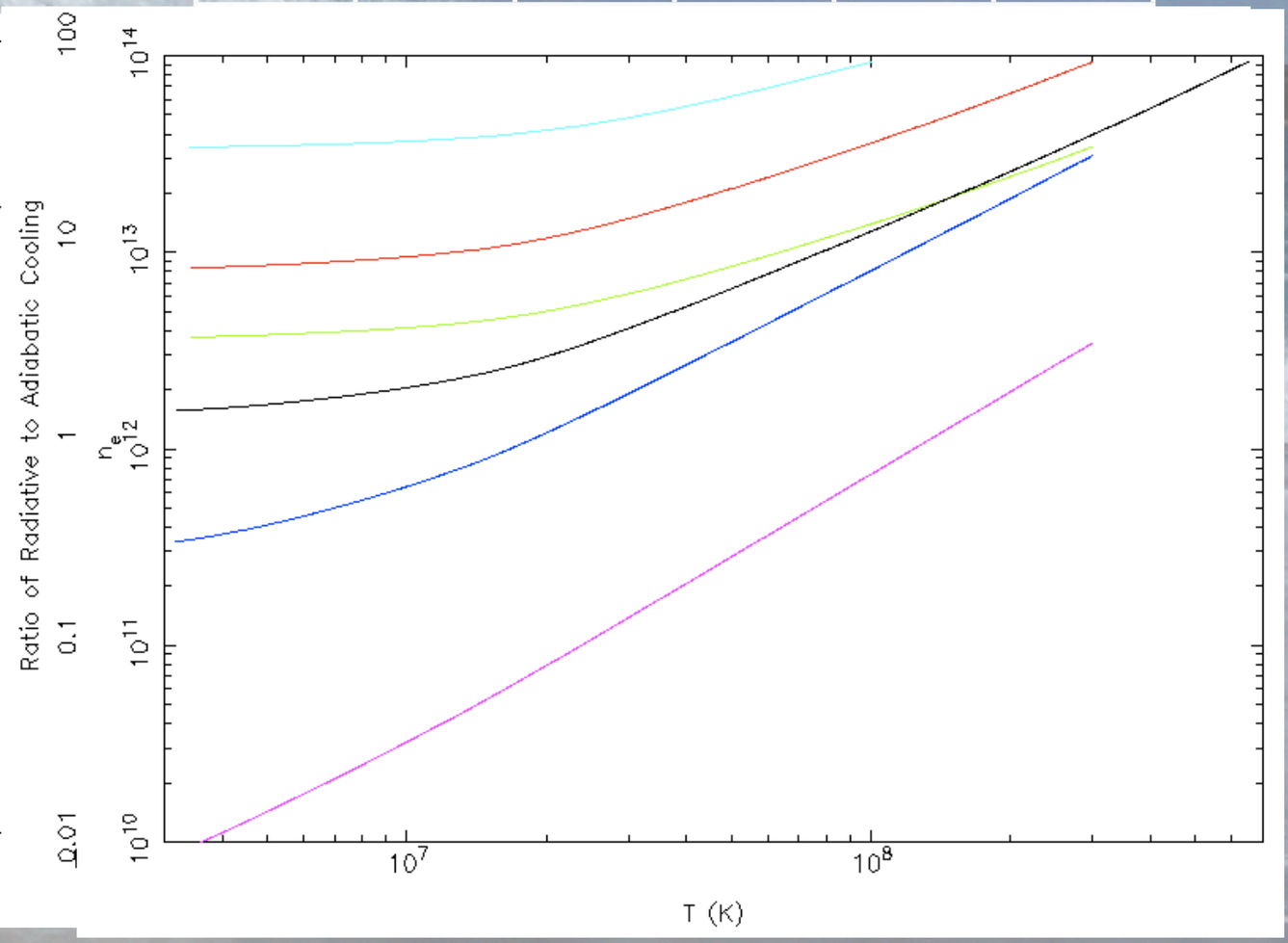

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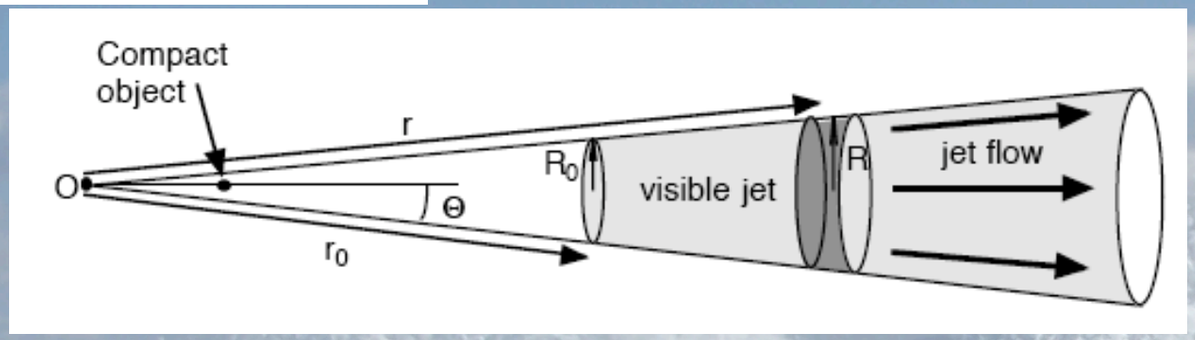

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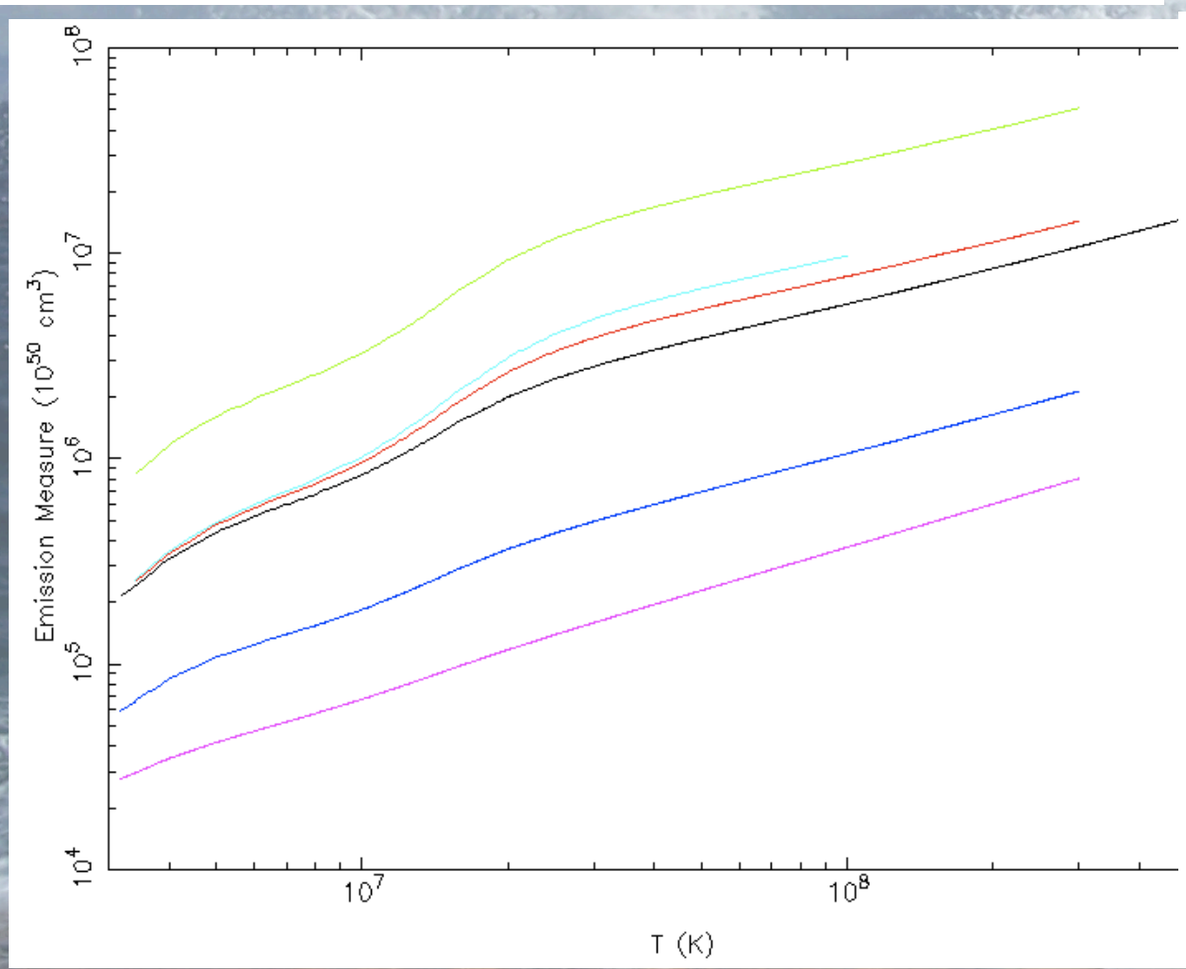

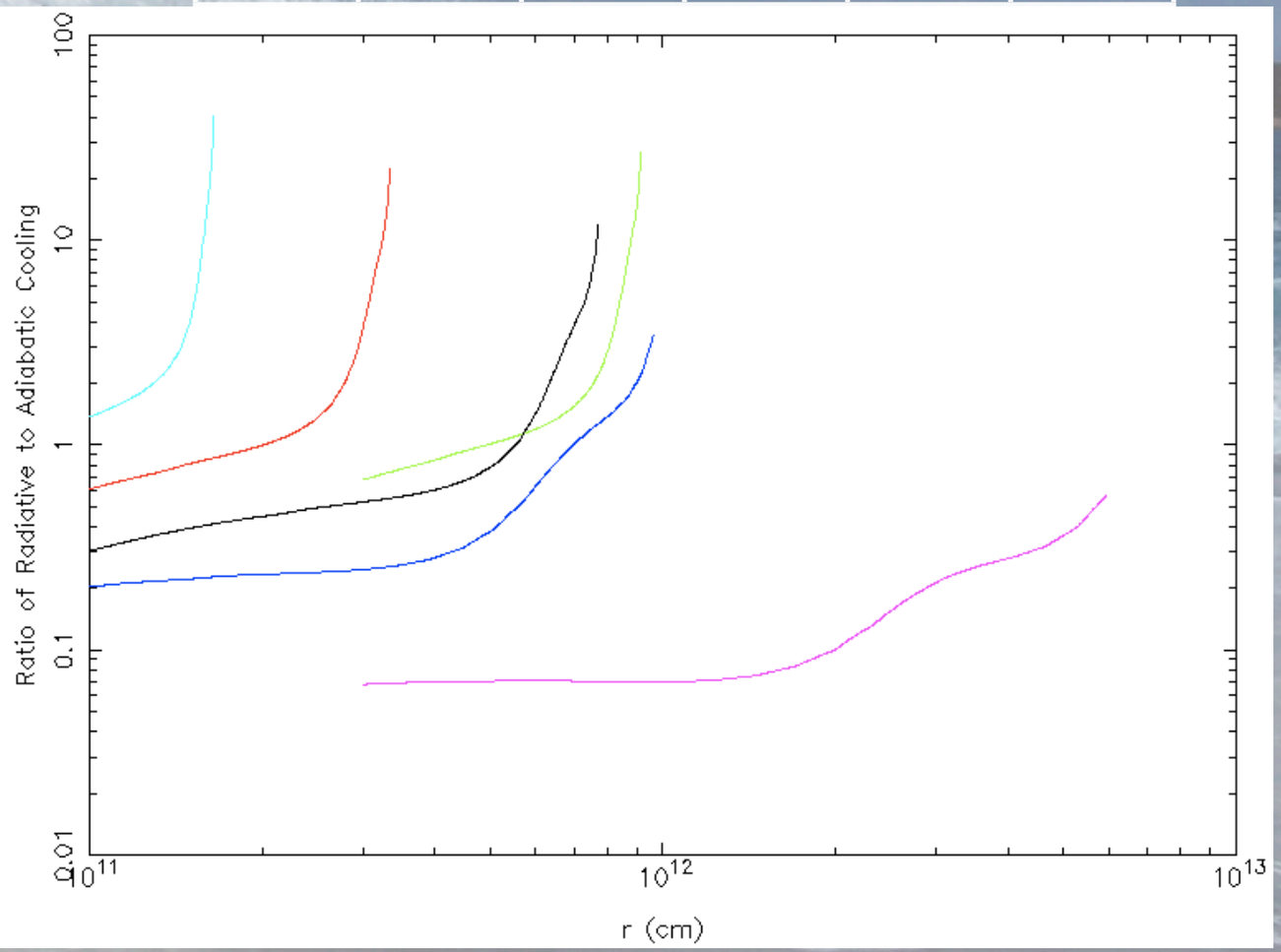

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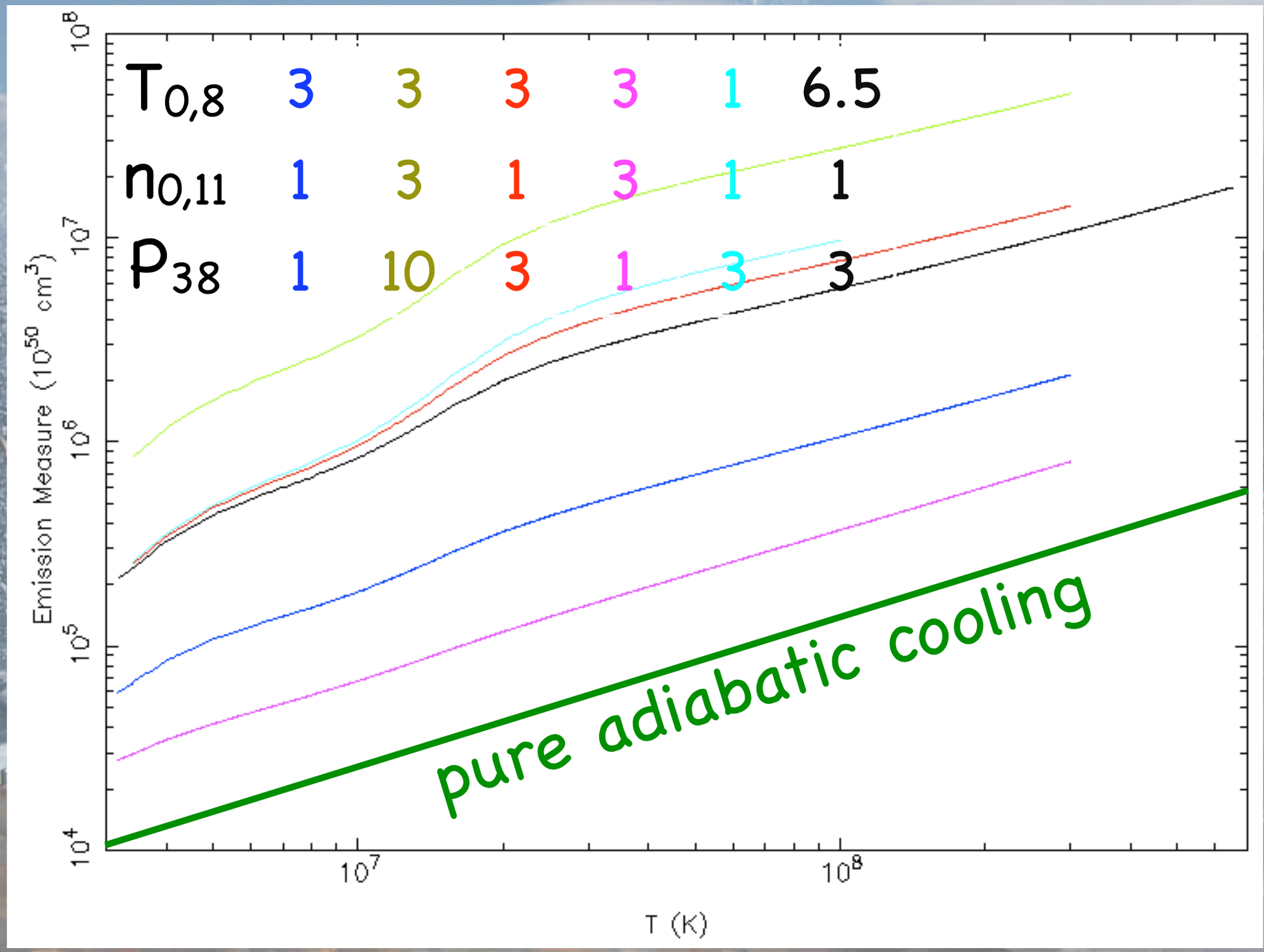
Spectral Modeling



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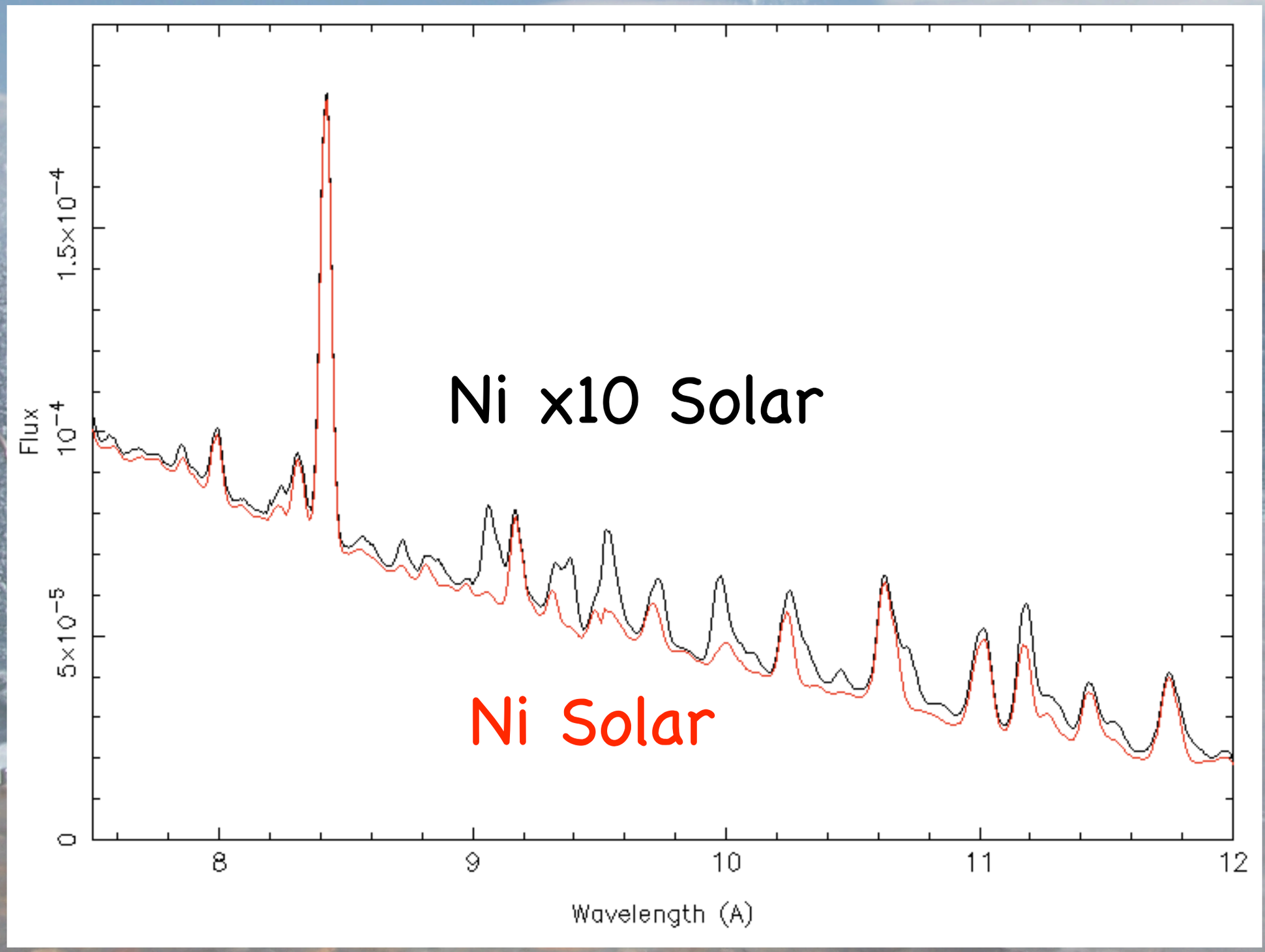

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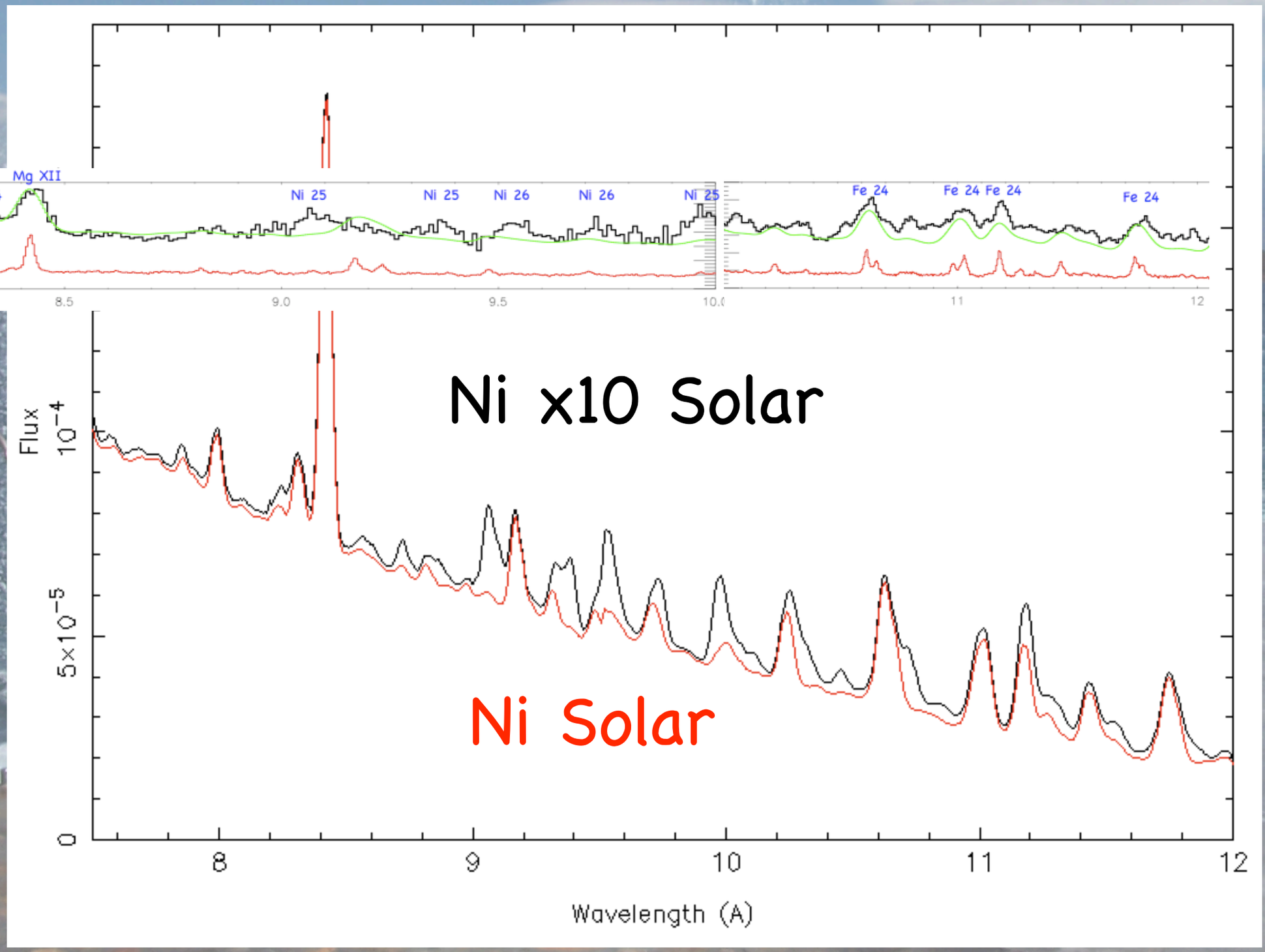

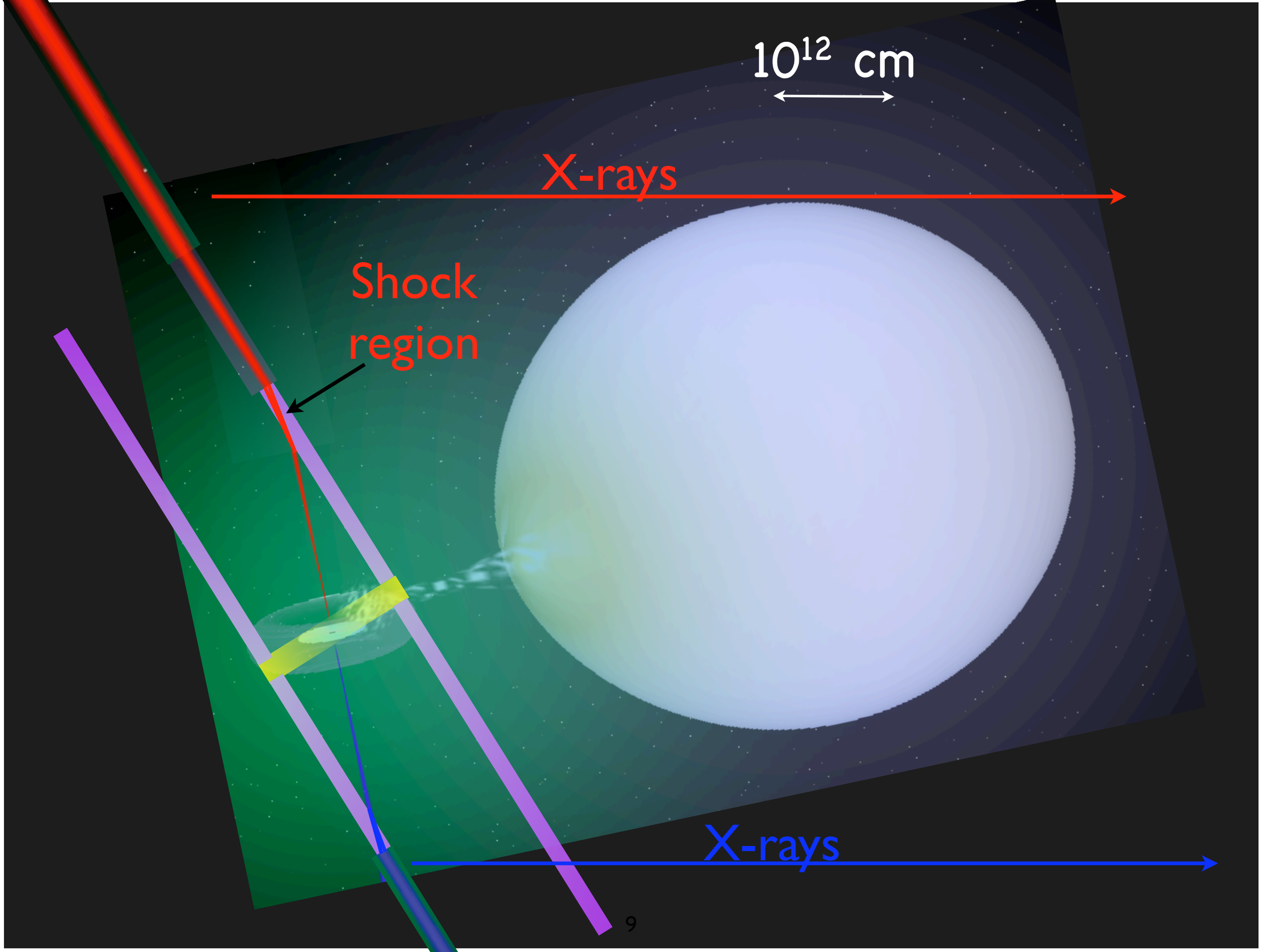
10^{12} cm
X-rays
Shock
region
X-rays

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Conclusions

- X-ray region cooling time < 5000 s
  - Radiative cooling of thermal plasma < 10 s
  - X-ray emission < 4 x 10^{13} cm (0.05 mas) from shocks that redirect jet and heat gas
  - spectral fit: r_{min} = 5 x 10^{11} cm, L_{jet} = 3 x 10^{39} erg/s (L_x ~ 10^{35})
- Jet redirected on 0.2d time scale by 2°
  - Blue, red jets different
  - Perturbed by local effects where jet is directed
  - --> supports a redirection model
- Eclipsed region spectrum: hard, weak Fe XXV line
  - Most of jet is not eclipsed; > 2 x 10^{12} cm from disk
  - Supports redirection model (or internal shocks)
- Ni overabundance, enhanced metals --> gas from companion that was coated with SN products

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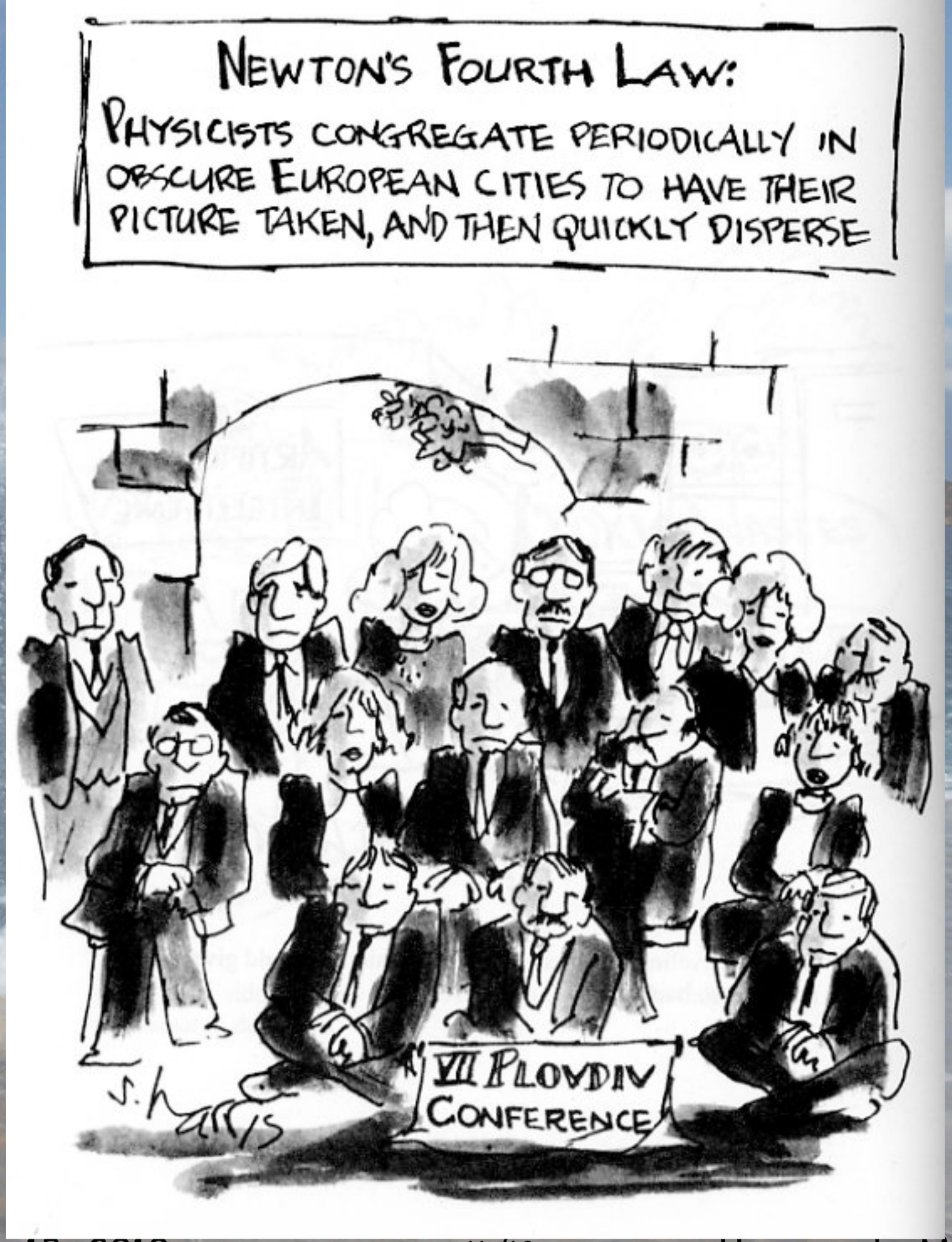

Over raki, one of the Cretan locals points out errors in Titarchuk's saturation model.