X-ray Winds and Continuum Emission of AGN MCG-6-30-15 with *Chandra* HETG

Erika Hoffman[1], Anna Ogorzalek[1][2], Christopher Reynolds[1][3]

ebhoff@umd.edu

DEPARTMENT OF ASTRONOMY

Goddard Space Flight Center

WHAT ARE X-RAY WINDS?

- *Highly ionized outflows* launched from the accretion disk of a supermassive black hole (SMBH) of an Active Galactic Nuclei (AGN)
- Characterized by *blueshifted absorption lines* (10^2 – 10^5 km/s, >10^6 K) in the X-ray continuum spectrum

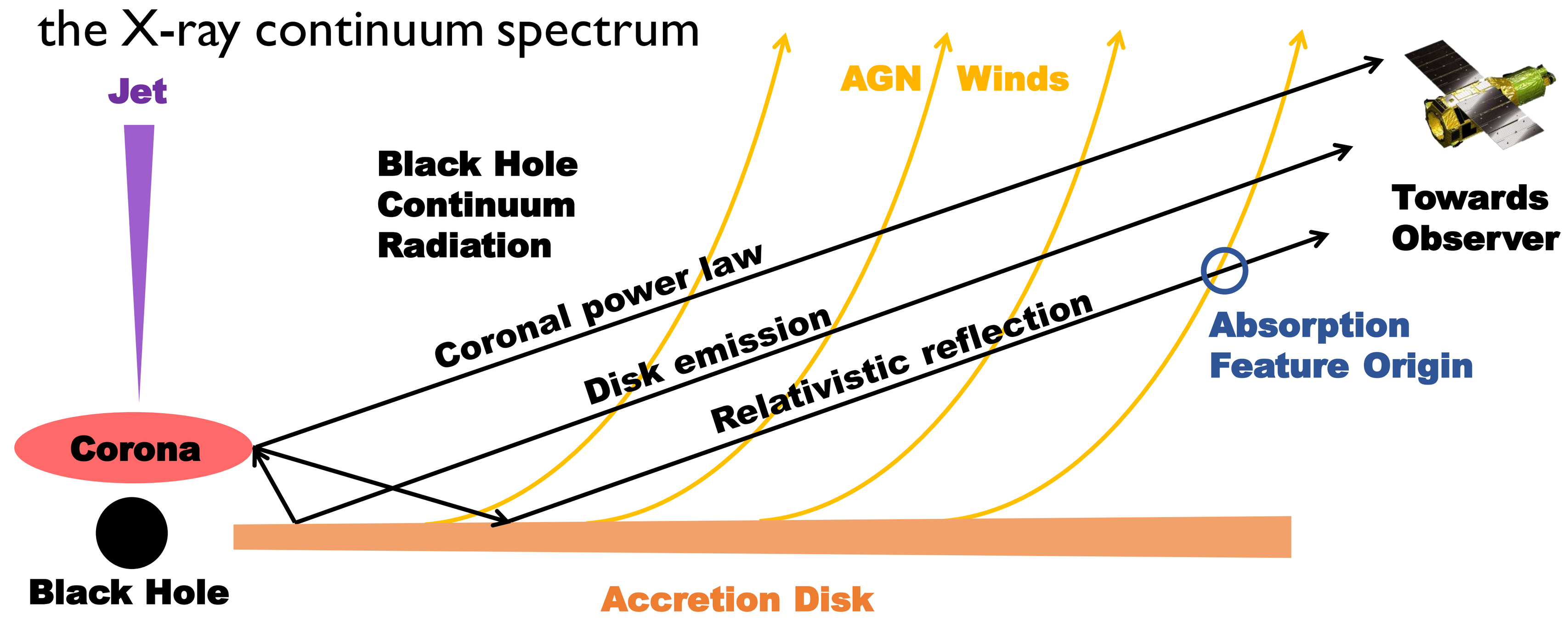

Figure 1: A cartoon of an AGN region. SMBH accretion disk (~10 pc, orange) is thermally emitting hot plasma. Disk emission is reprocessed in a corona (red) of relativistic electrons and/or also reflected off the disk. Outflowing gaseous AGN winds (yellow) yield absorption lines.

WHY STUDY X-RAY WINDS?

To better understand *AGN-galaxy coevolution*, we need to study the *physical mechanics* of AGN feedback. X-ray winds are a strong culprit of feedback because they are *widespread* (~65% nearby Seyfert X-ray AGN spectra[1].)

WHY STUDY MCG-6-30-15 WITH HETG?

- *Deep* (~1week) & *Bright* (10^{44} ergs/s) data → good statistics
- *Small* (10^6 $M_\odot$) supermassive black hole → can study accretion disk variability on shorter timescales (~years)
- Performance Verification Phase *XRISM target* → future work

Chandra's **H**igh **E**nergy **T**ransmission **G**rating (HETG) has the *best spectral resolution* to study absorption line properties and improve wind constraints with archival data, when paired with:

- *New models* to test for continuum and absorption
- *New computational power* to explore parameter space
- *New methods* to agnostically choose models

METHODS

1: MONTE CARLO MARKOV CHAIN

Start Goodman-Weare MCMC algorithm near the best fit found after running a steepest descent algorithm 1000s of times with random starting positions. Use the chains to *increase best-fit confidence, calculate errors*, and ***retrieve posterior distributions*** (See Figure 4).

2: DIVERGENCE INFORMATION CRITERION

The DIC[2] is an *approximation of Bayesian evidence* using MCMC samples of the best-fit likelihood. We compare models to minimize the DIC, where a larger relative change in DIC indicates model preference.

3: REPEAT FOR EACH MODEL & COMPARE

Only competing models with the *lowest DIC* are *chosen* at each step, and the DIC must change from the previous step by at least 10, which is a strong preference according to Jeffery's Scale[3] (ΔDIC > 10).

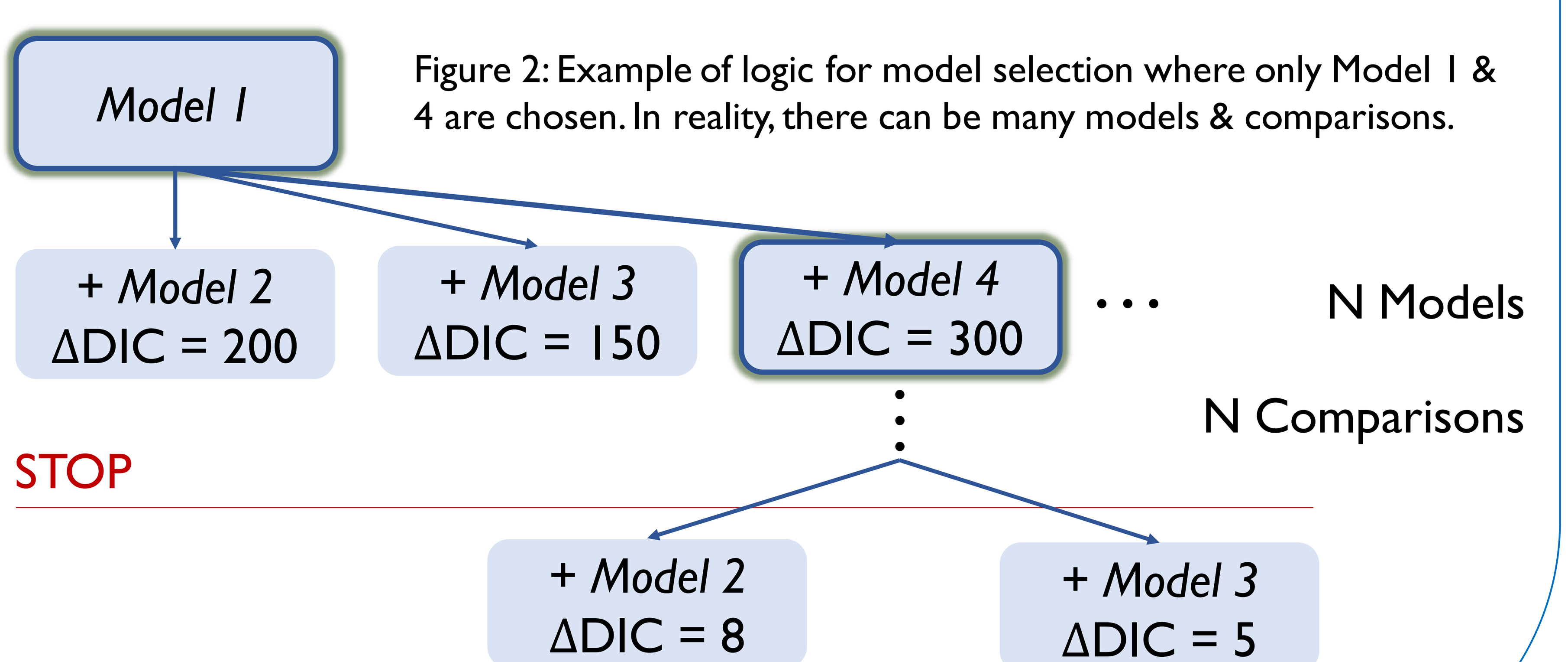

Figure 2: Example of logic for model selection where only Model 1 & 4 are chosen. In reality, there can be many models & comparisons.

PHASE 1: CONTINUUM, PHASE 2: WINDS

CONTINUUM EMISSION RESULTS

Model selection results in addition to a power law and galactic absorption:

2000: + (relativistic reflection) + (disk blackbody)

2004: + (relativistic reflection) + (disk blackbody) + (neutral reflection)

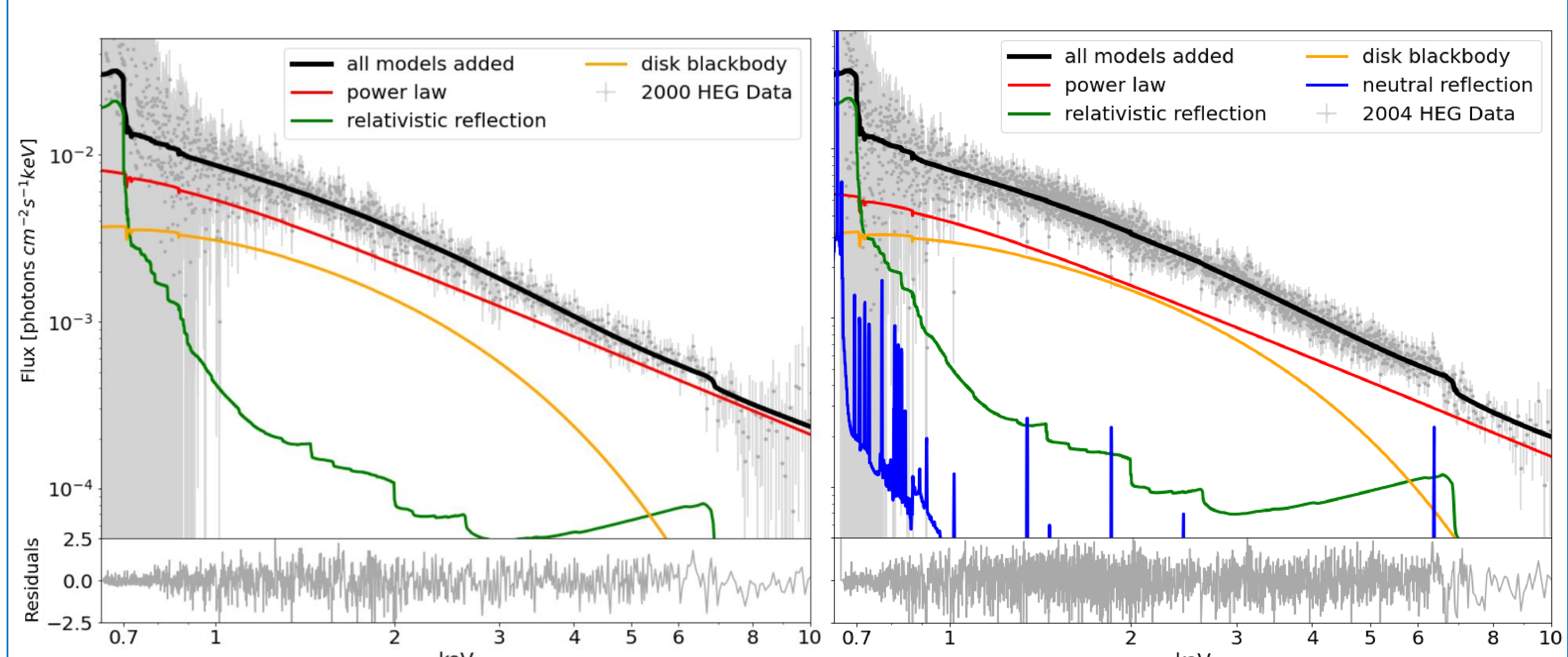

Figure 3: *Chandra* HETG 2000 (left) & 2004 (right) MCG-6-30-15 *observations (grey) with best emission fit (black).* Components: power-law (red), relativistic reflection (green), disk blackbody (yellow), neutral reflection (blue). All include galactic absorption. Residuals: (data - model)/error (bottom). The models *do not include wind absorption* yet.

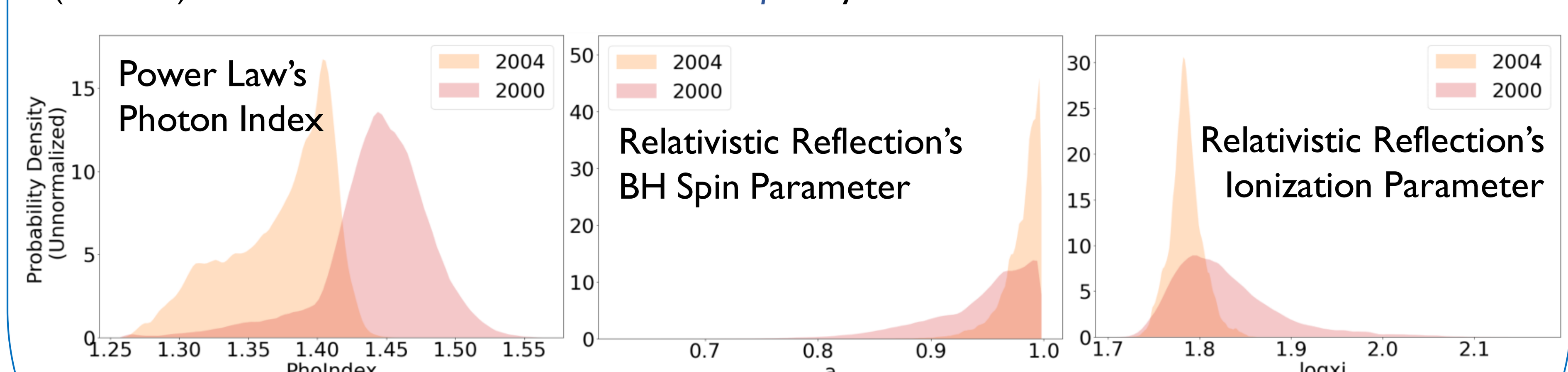

Figure 4: Posterior distributions of epochs 2000 (pink) and 2004 (yellow) for photon index (left), black hole dimensionless spin parameter (center), and relativistic reflection's ionization parameter (*erg cm* s^{-1}) (right).

CONCLUSIONS

- *Relativistic reflection* is the most *strongly preferred* model
- A *neutral reflection* model is *sufficiently preferred* in the 2004 data, but does not satisfy the ΔDIC > 10 condition for the 2000 data
- Photon index and disk ionization do not change, see Figure 4
  → no notable AGN variability between epochs 2000 & 2004
- A *rapidly rotating black hole*, (spin parameter near ~0.998) see Figure 4
- High density disk (N >10^{20} cm^{-3}) beyond model atomic calculations
- Iron abundance 2.2 ± .2 Solar, disk inclination 37.6 ± .02 °

FUTURE WORK: MODELING WINDS

We will use the same methodology to test at each step for both:

collsionally ionized and photoionized absorbers.

Using the *Cloudy*[4] spectral synthesis code and computer clusters to generate grids of ionized gas absorption line *parameters, all kept free*:

- Ionization parameter
- Hydrogen density
- Column density
- Velocity dispersion (turbulence)
- Outflow velocity

Affiliations
[1] Department of Astronomy, University of Maryland, College Park, 20742, USA
[2] NASA Goddard Space Flight Center, Code 662, Greenbelt, MD 20771, USA
[3] Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 OHA, UK

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