Hot Milky Way halo seen in a deep HETG observation of NGC4051:

the power of self-consistent, Bayesian framework

Anna Ogorzałek
NASA GSFC/UMD

with E. Hodges-Kluck, S. W. Allen, A. L. King, J. Raymond

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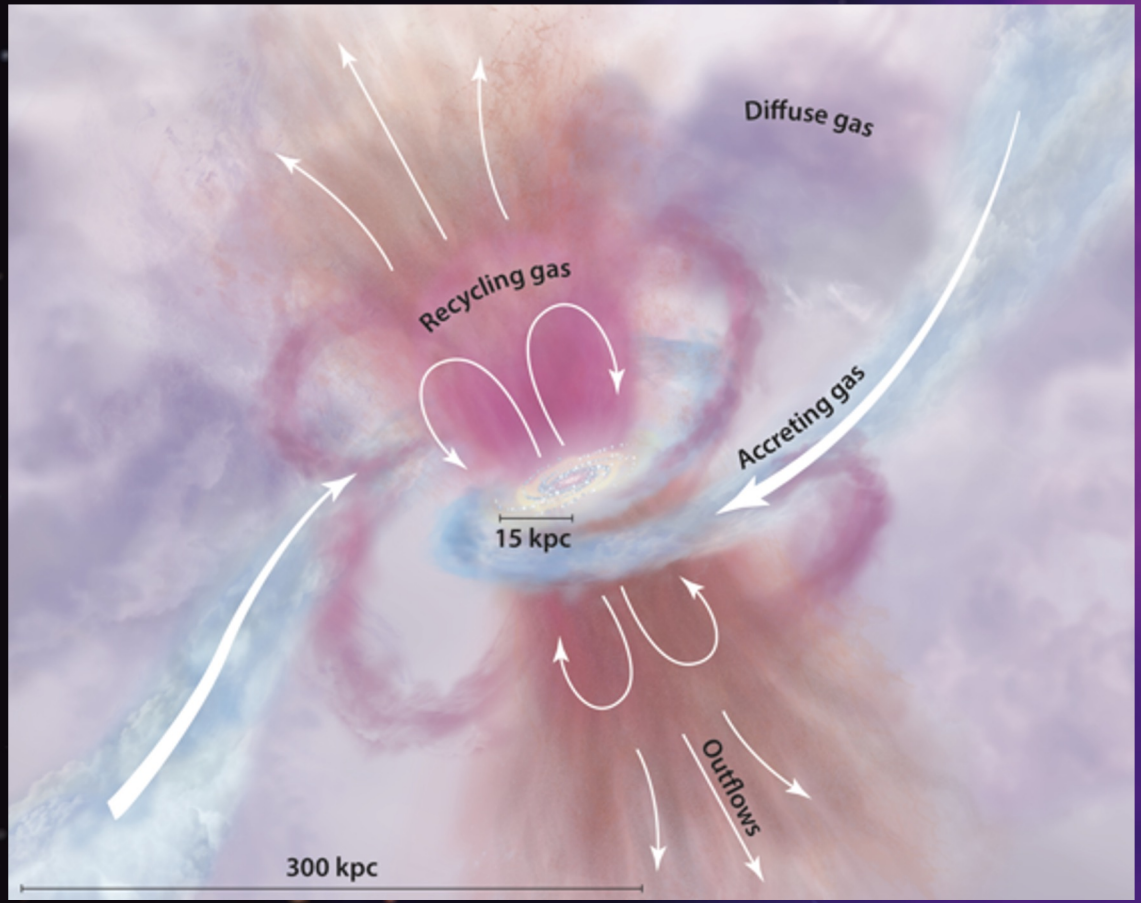
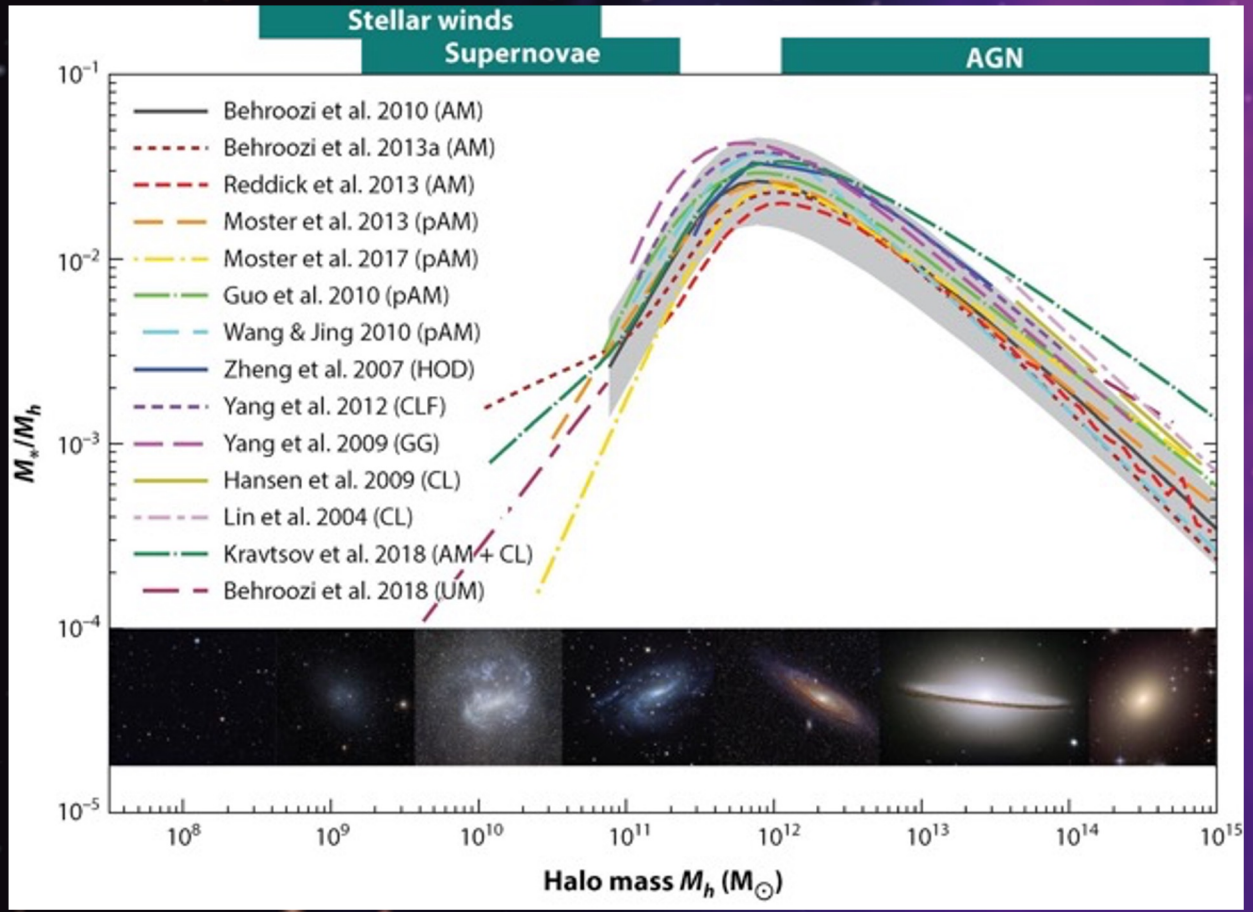


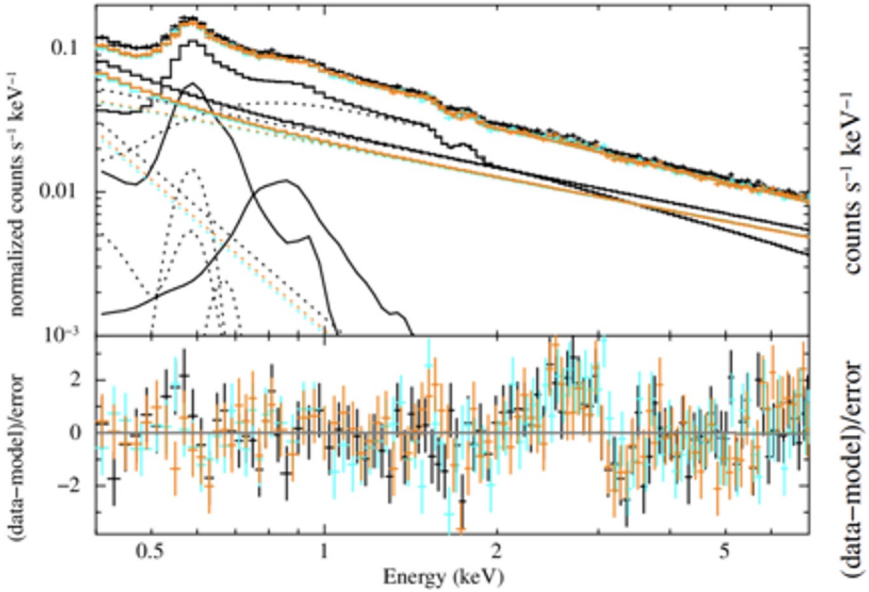
Tumlison, Peeples, Werk 2017



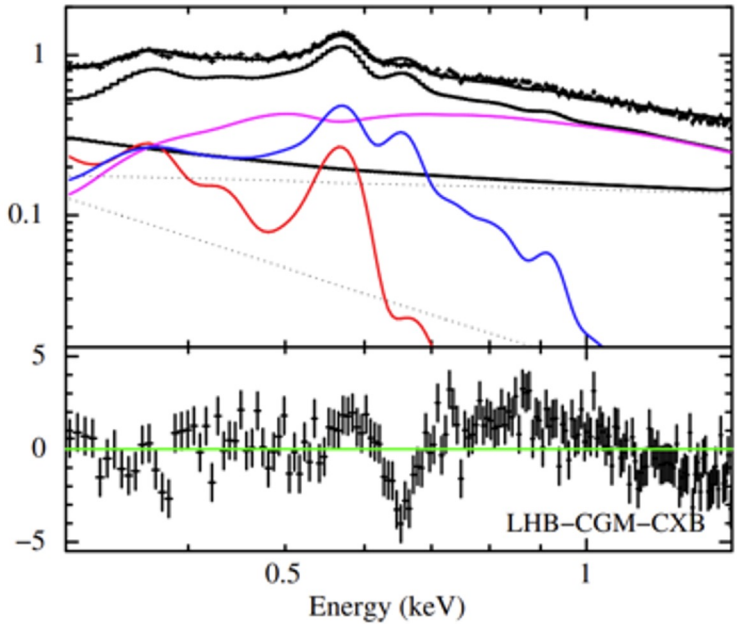
Wechsler & Tinker 2019

MWHH in emission

- integrated over large regions, low-res spectra
- typically 2T collisional ionization models

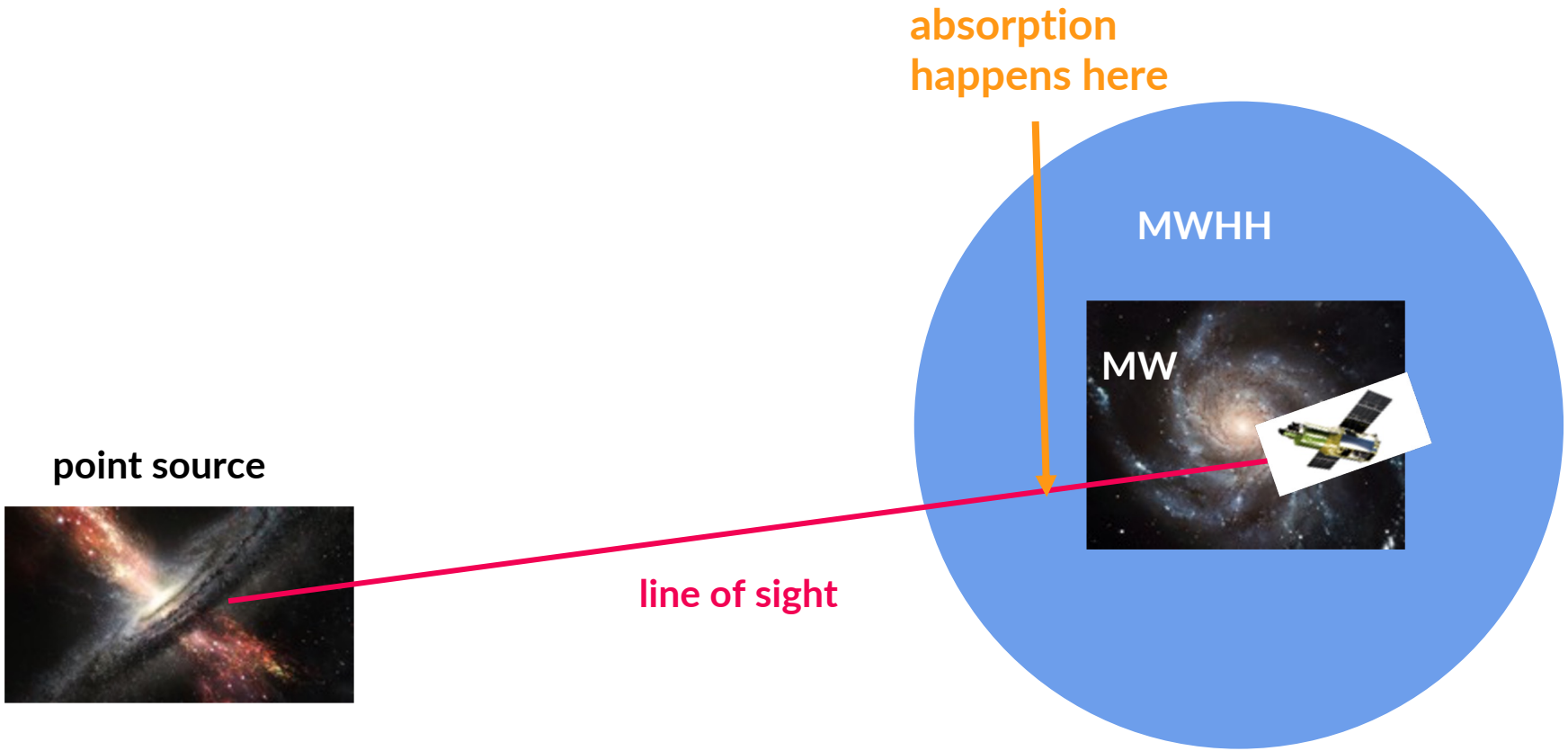


Bluem+2022 / HaloSAT



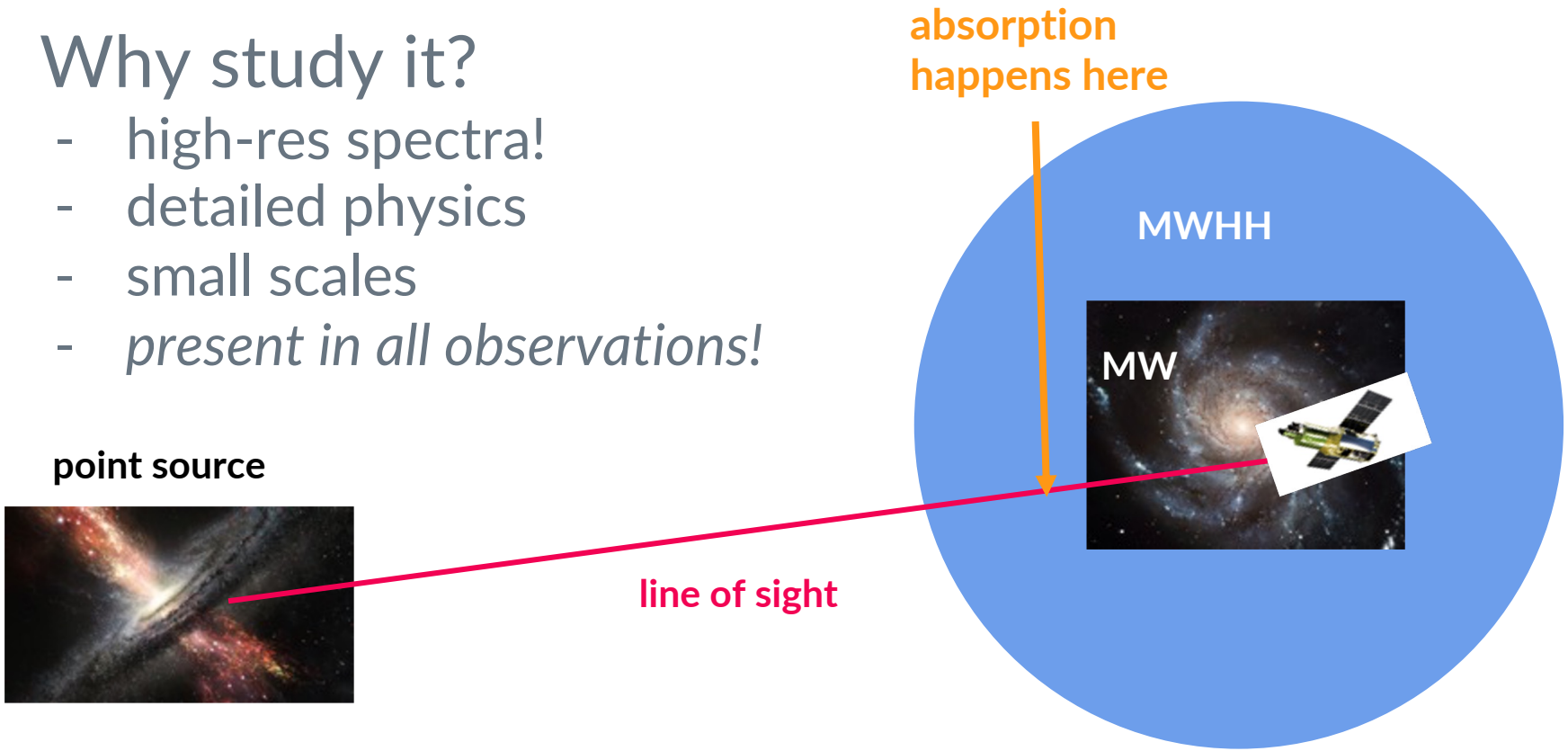
Ponti+ 2023 / eROSITA

MWHH in absorption towards point srcs



MWHH in absorption towards point srcs

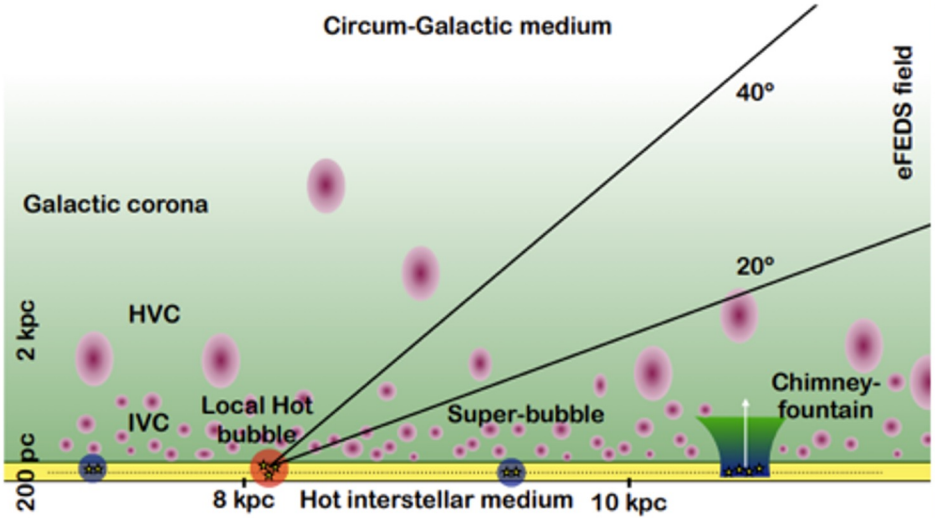
- Why study it?
  - high-res spectra!
  - detailed physics
  - small scales
  - *present in all observations!*

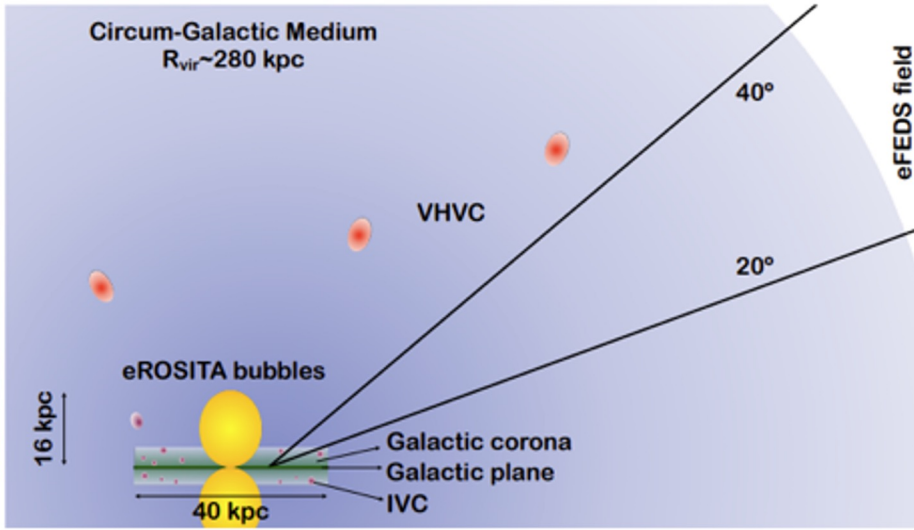


MWHH in absorption towards point srcs

- Why study it?
  - many lines of sight!

Ponti+ 2023 / eROSITA





MWHH in absorption towards point srcs

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    - many, many deep data sets now and in the future
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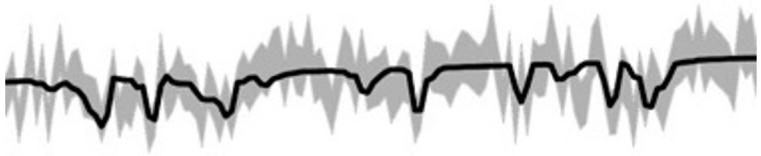
Ingredient 1: self-consistent treatment

- we use global models of absorption by the MW hot halo
- this way we get ALL of the information that is available to us
- ***critically, no parameters are fixed***

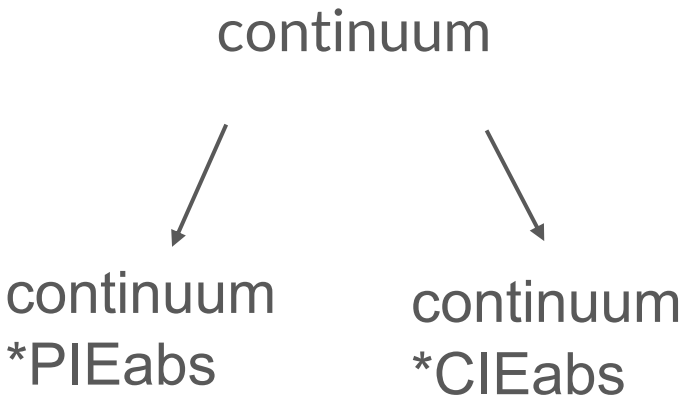
  (not in AGN model & not in MW model!)



Ingredient 2: A Bayesian approach

- Using MCMC
- Open parameter space
- Self-consistent
- **Deviance Information Criterion (DIC) : Robust model selection**

Spiegelhalter et al. 2002

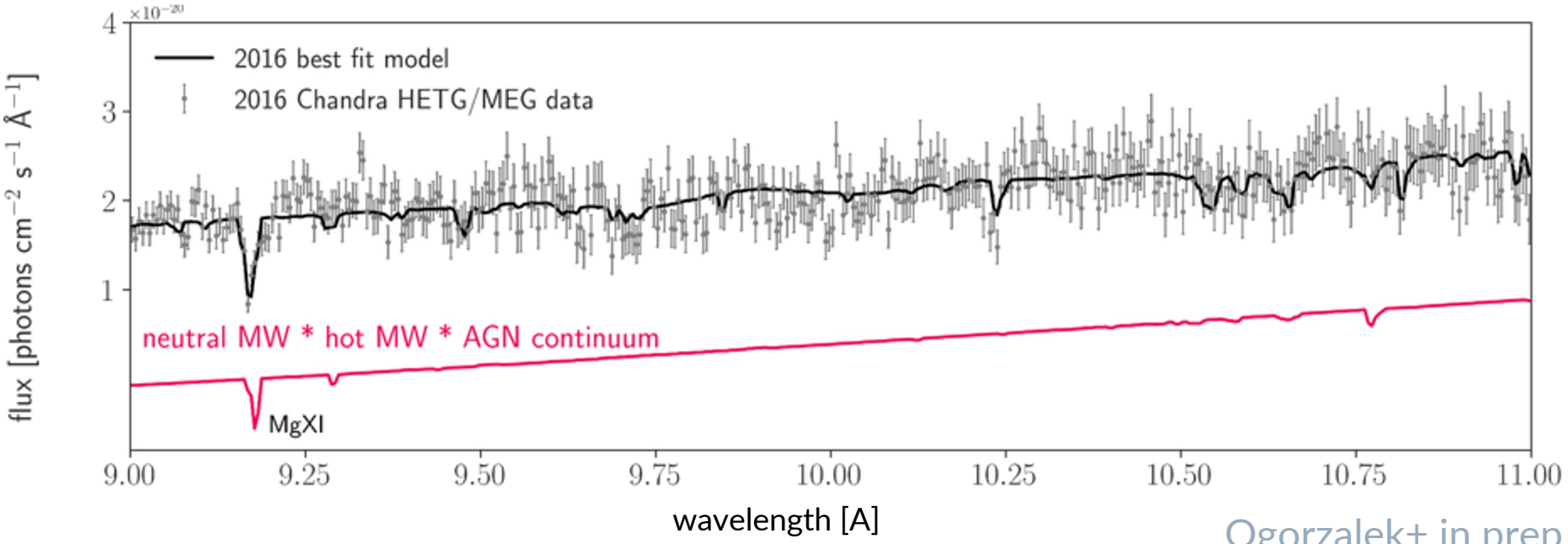


Which model component is more supported by the data?

Ogorzalek+2022

NGC 4051: 700 ks of HETG

- agnostic Bayesian fitting: **we never assume where the absorption is coming from**



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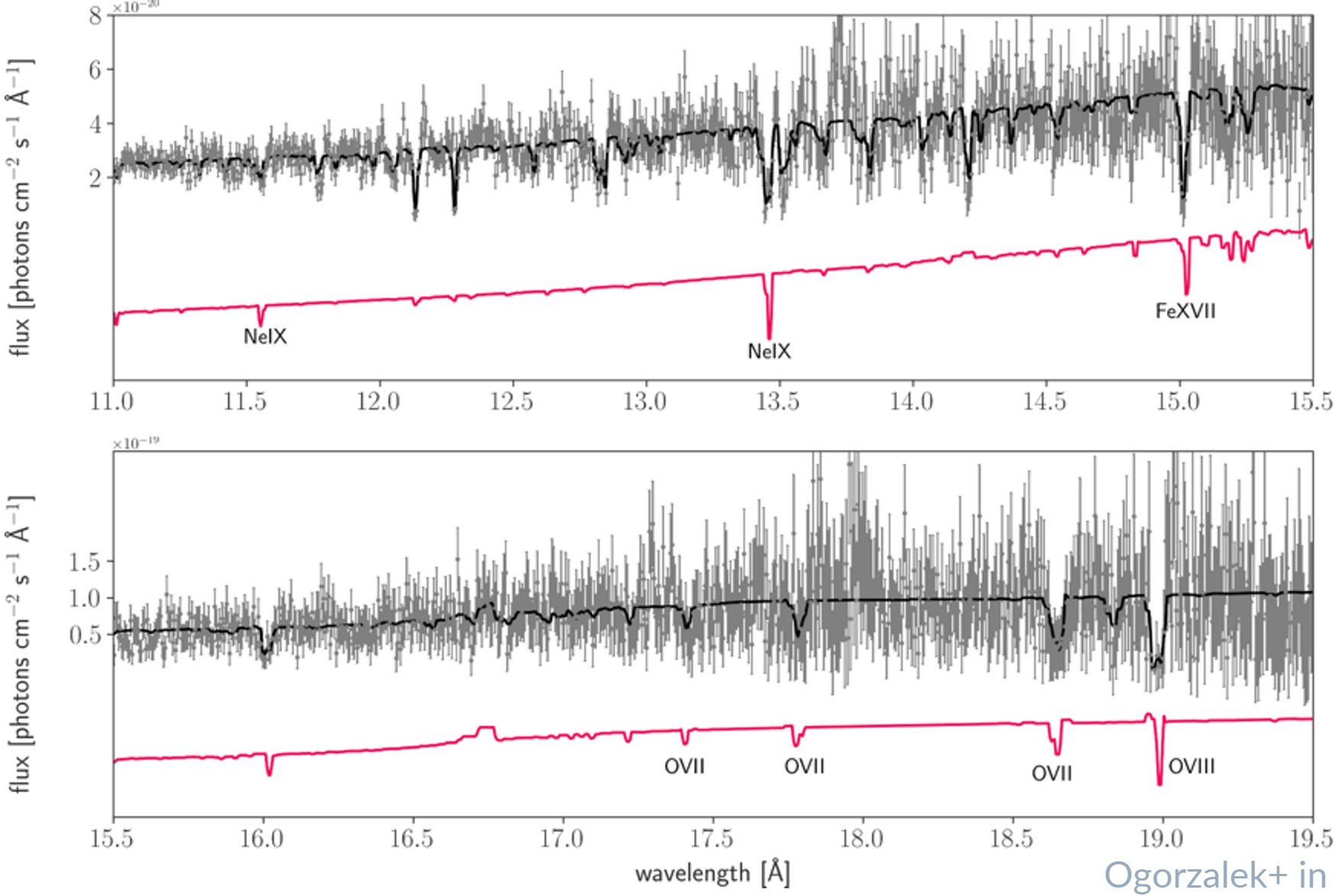

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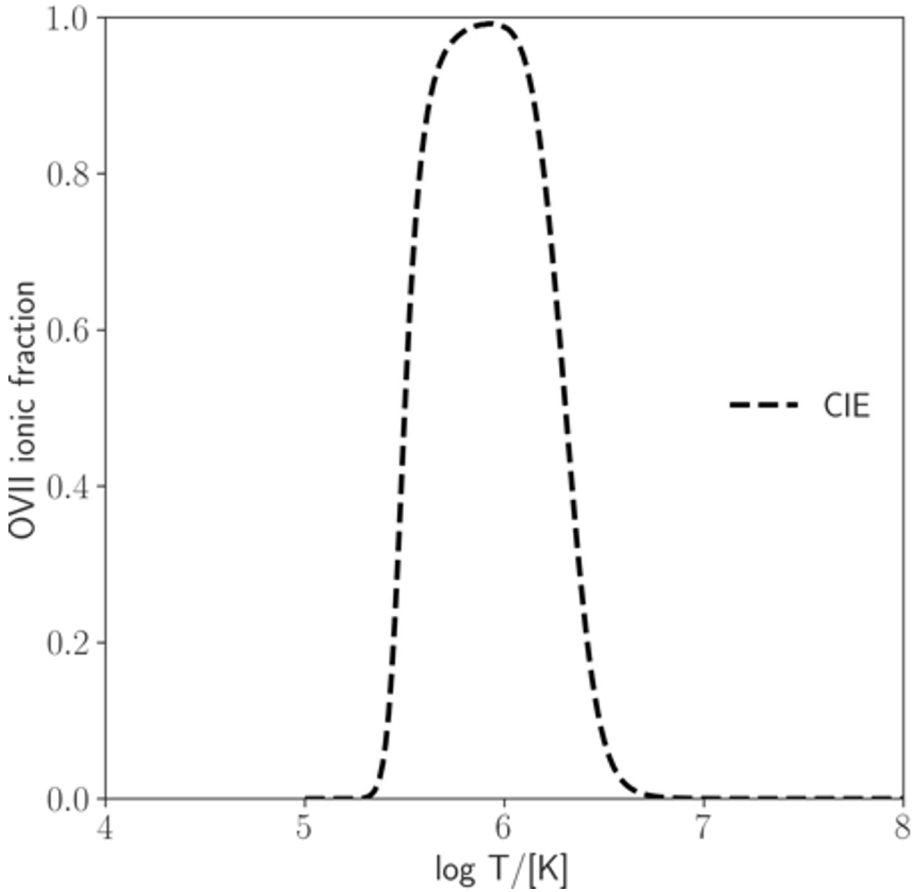
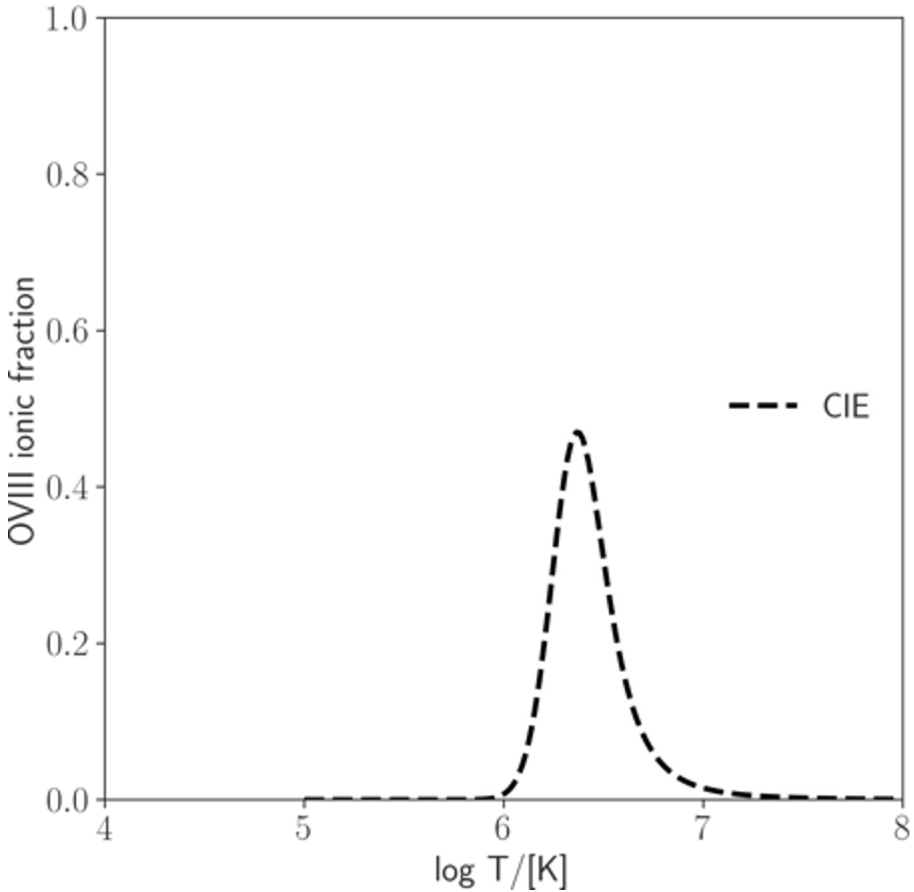
Ingredient 3: photoionization by Cosmic Background

- most studies assume that the gas is in collisional ionization equilibrium (CIE, e.g. APEC model)
- **but for low density gas, ionization by the Cosmic Background can be important!**
  - see e.g. Churazov+2001, Khabibullin & Churazov 2019
- Cosmic Background is definitely there!





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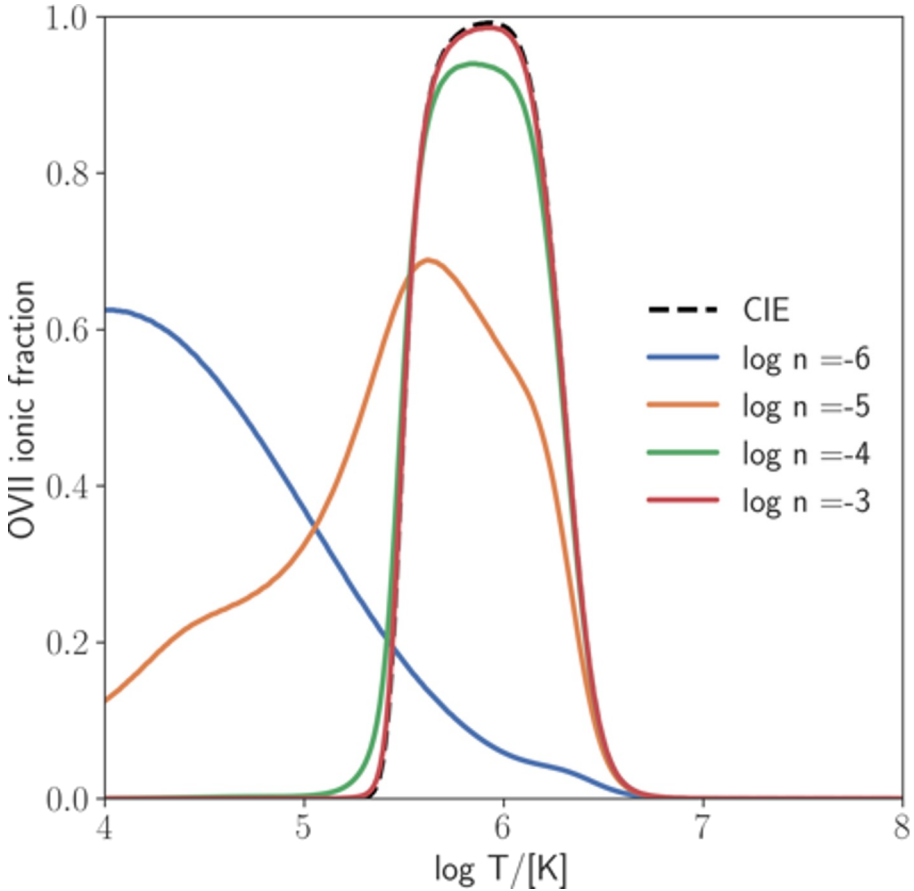

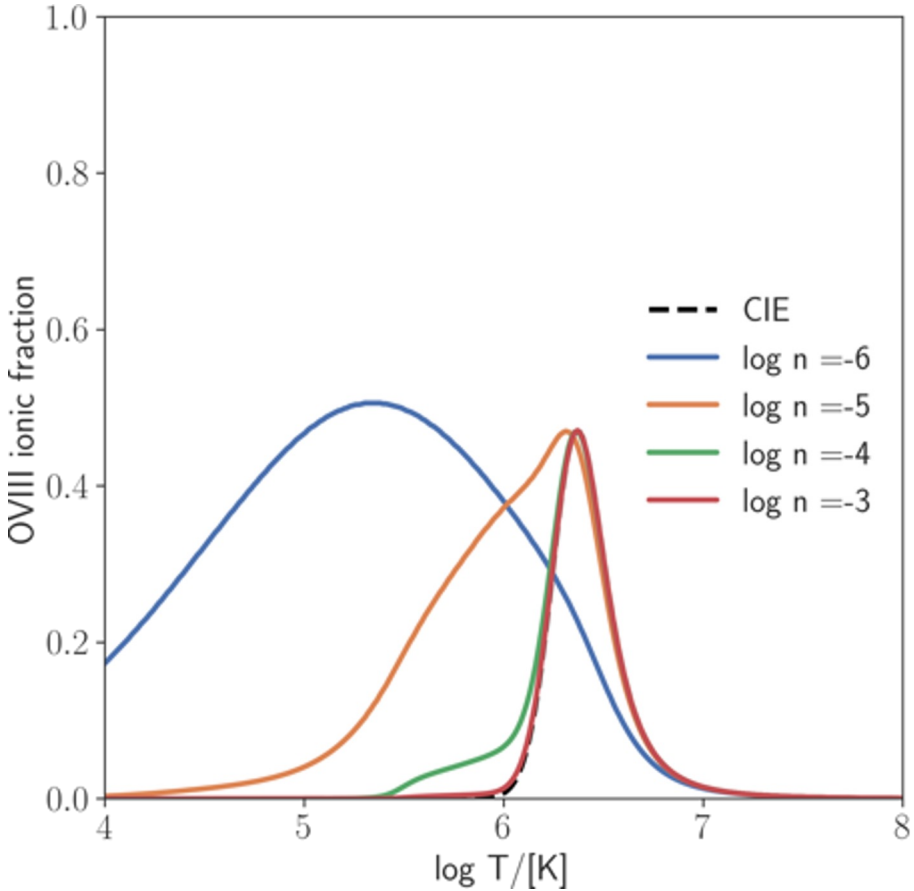

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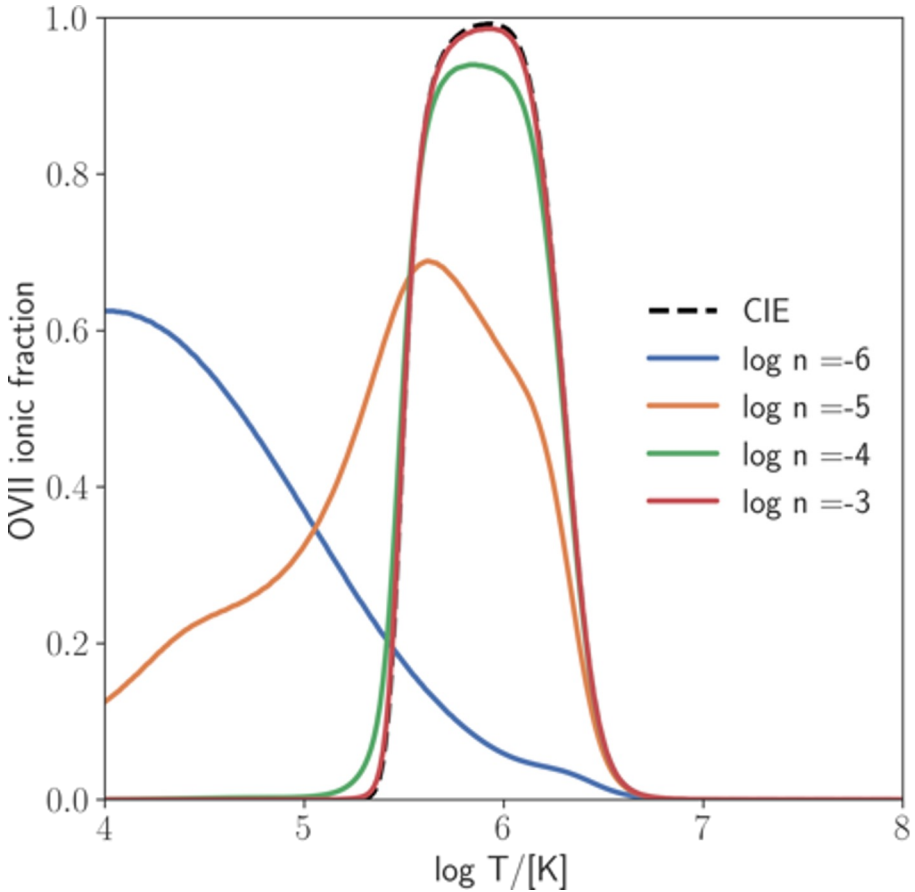

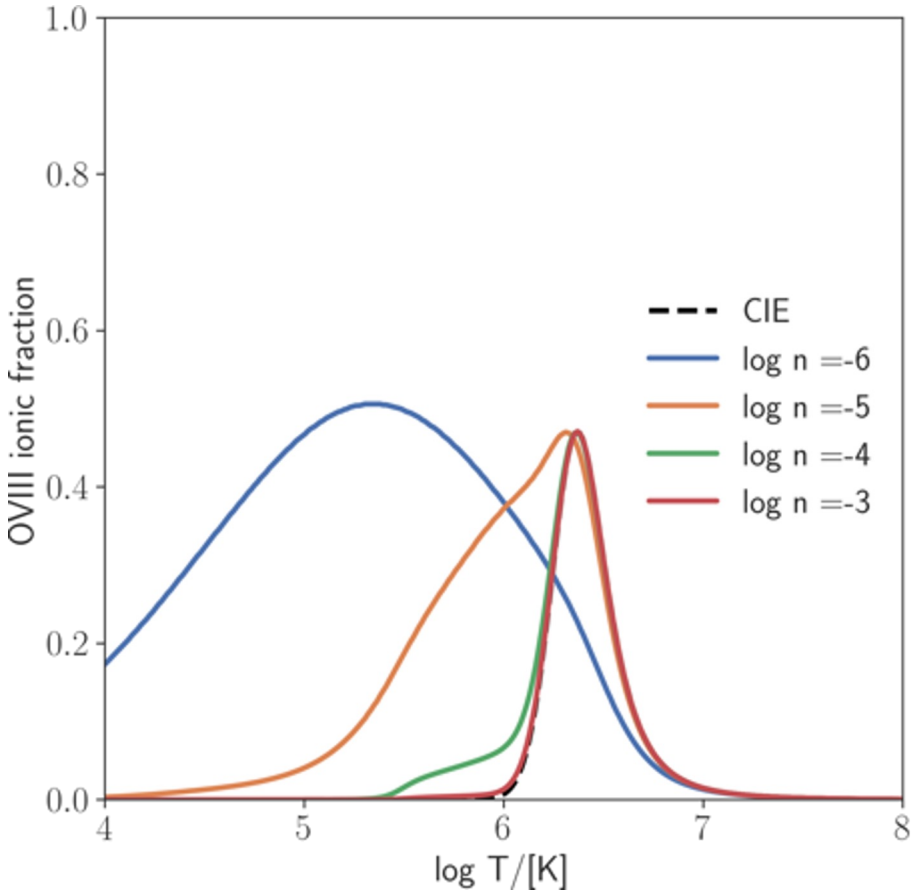

Photoionization by Cosmic Background affects low density gas as a function of density!

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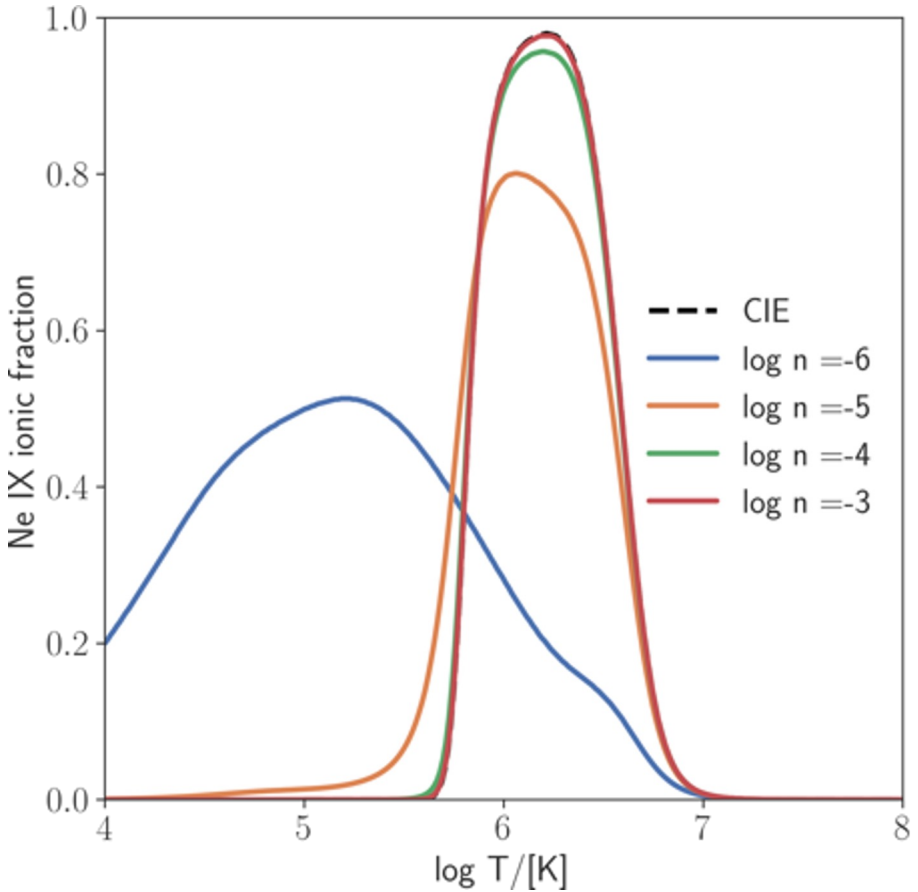

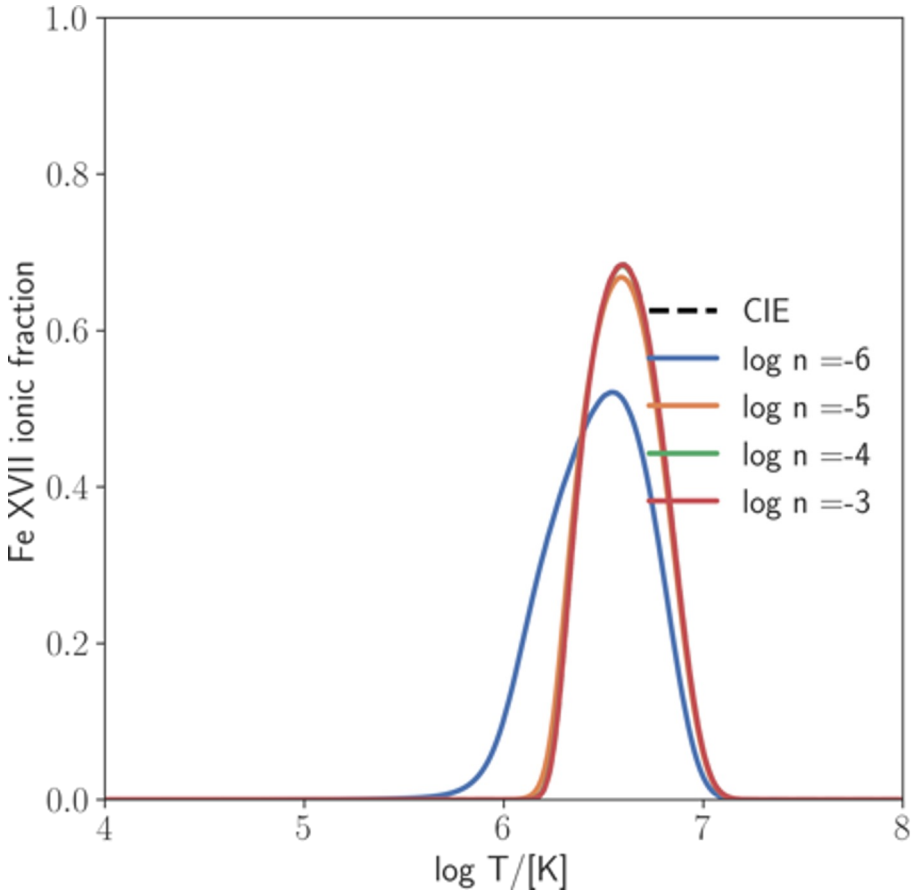

Many ions are affected, each differently

-> need to fit all of them at once in a self-consistent manner

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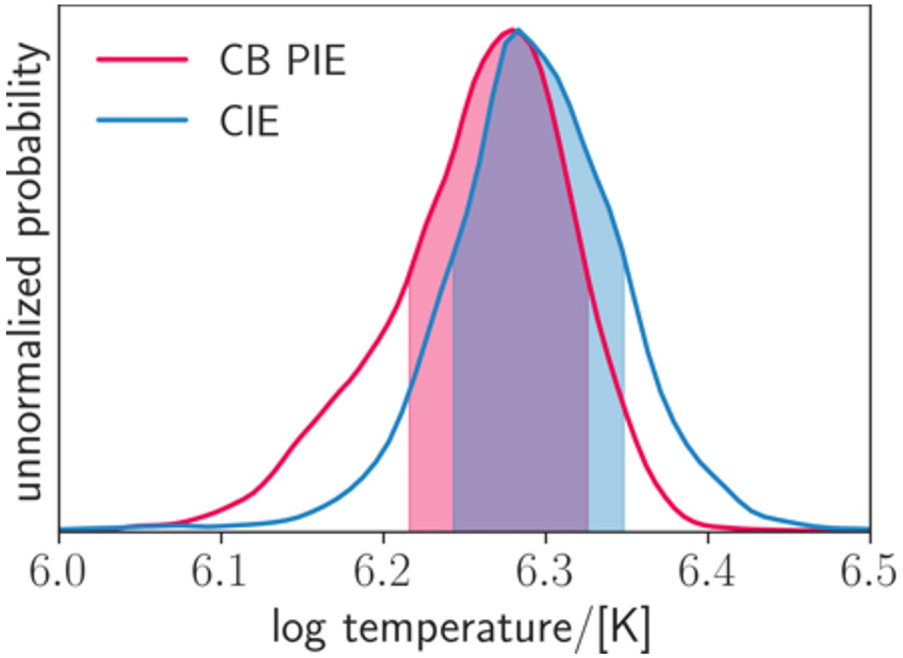
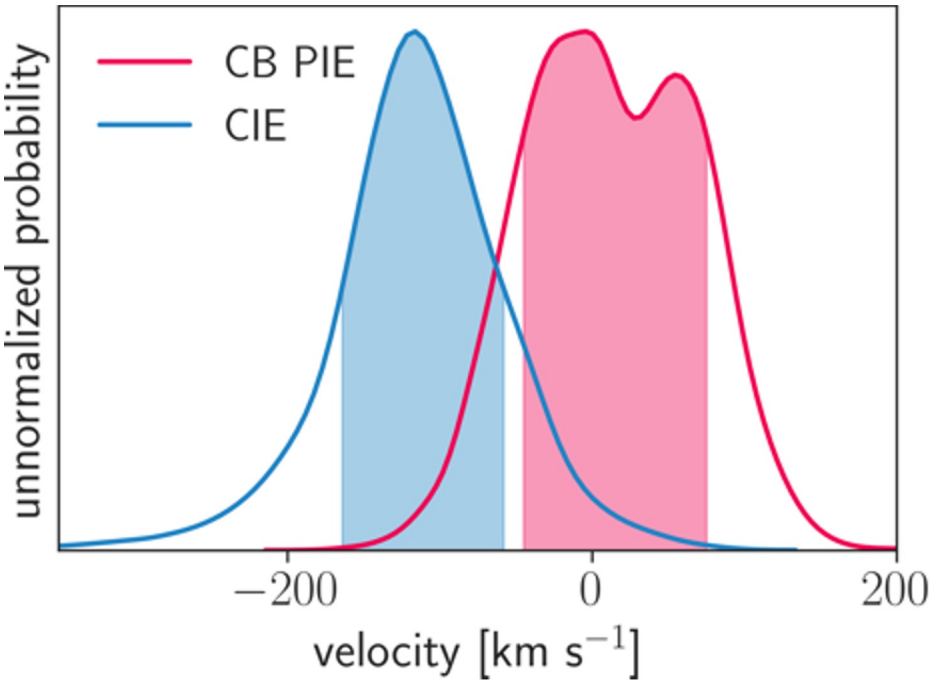
Cosmic Background PIE vs CIE





- temperature consistent with virial (no 2nd T component)

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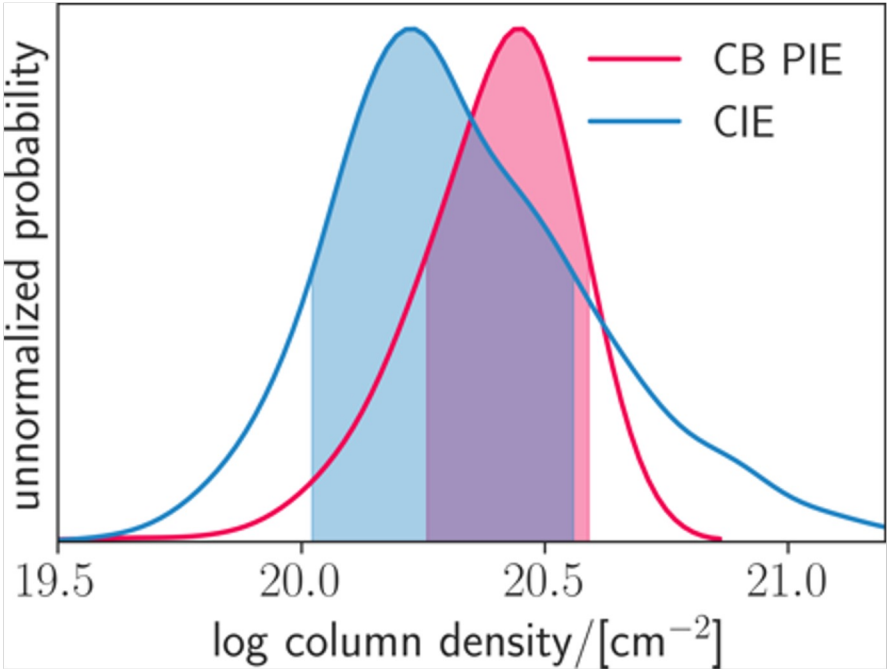
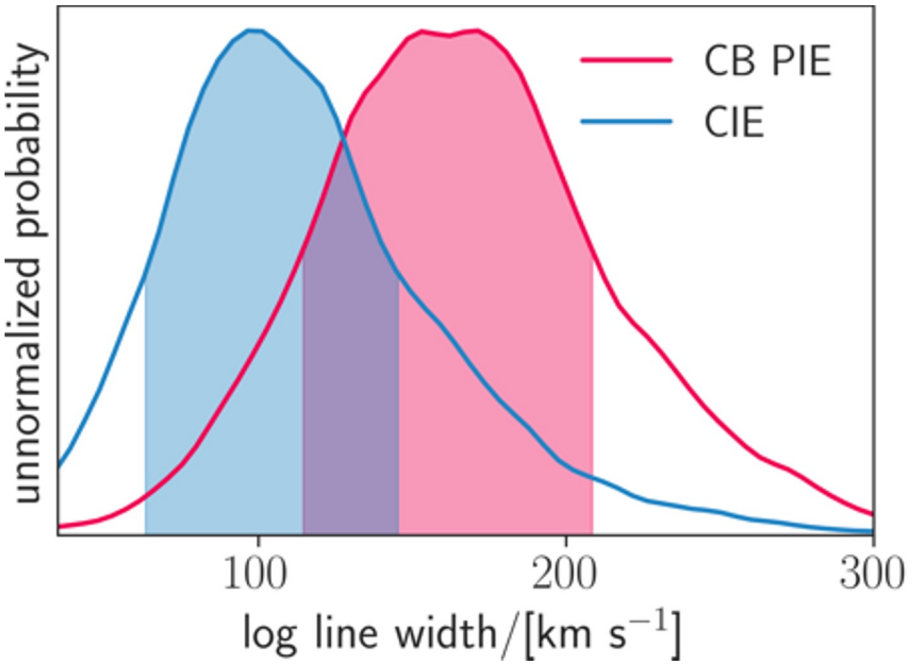
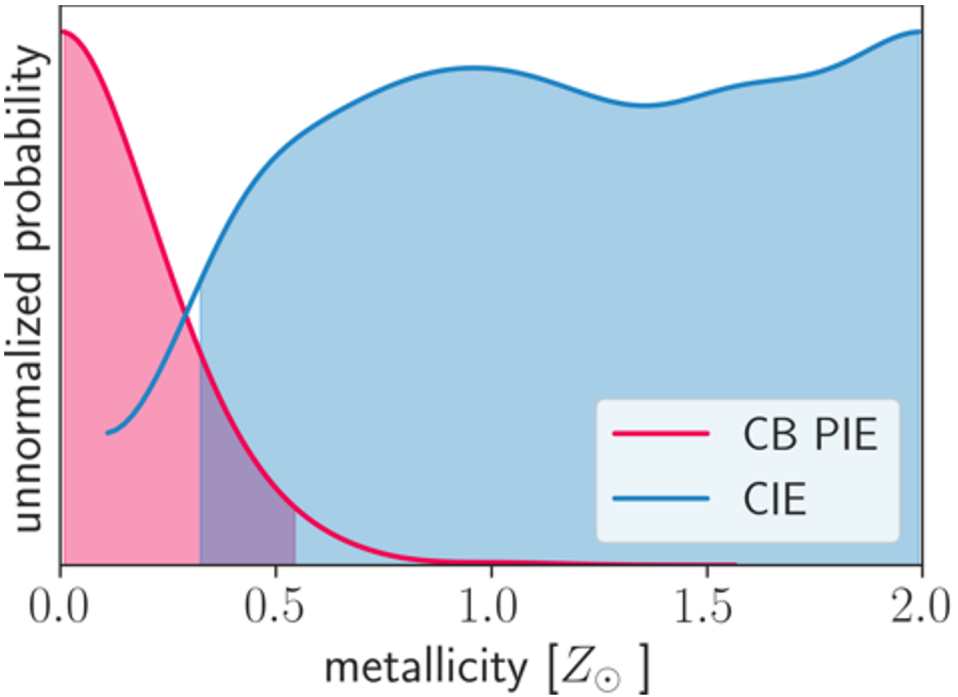
Cosmic Background PIE vs CIE





- nH and line width consistent with prev studies
- *note: line width is not necessarily all turbulence* Ogorzalek+ in prep

CB PIE shows low abundances



- our CIE model shows high abundance, consistent with other CIE absorption work
- **CB PIE model preferes low abundances**

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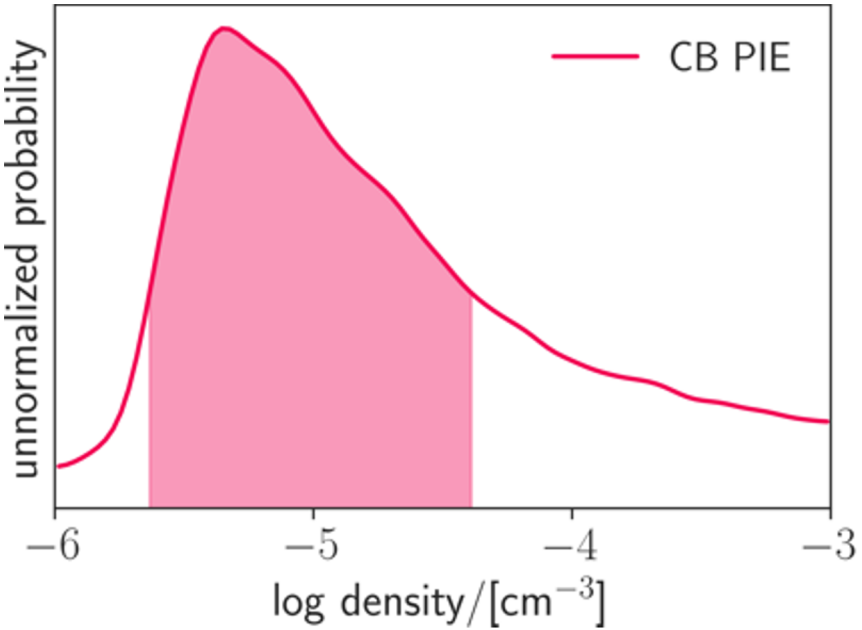
Can we constrain density?...

First ever direct density constraints!



- **data suggests that gas is low density and therefore CIE assumption is not valid!**
- **this means we can measure the density for the first time!**

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Summary

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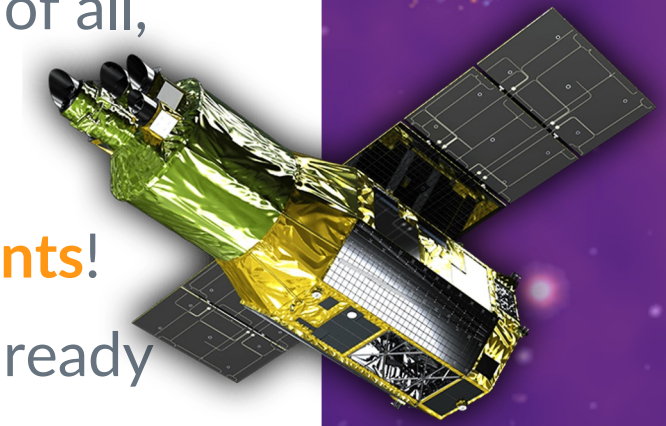
- Robust Bayesian model selection allows to model both AGN and MW absorption
- Self-consistent fitting takes advantage of all, even small, spectral features
- Accounting for Cosmic Background photoionization yields **density constraints**!
- Many deeper data sets around the sky ready to be analyzed!
- **Many XRISM obs will include MW signal!**
- Ask me about proposing for Resolve :)



XRISM launch Aug 25th!!

Line Emission Mapper:

X-ray Probe for 2030s

www.lem-observatory.org

- Wide FOV X-ray IFU (1eV)
- All-sky survey@2eV!! MWHH, Fermi Bubbles, large galactic structures…
- Also: CGM, IGM, SNRs, stars, planets, AGN, XRBs, dust, and much more!