# FROM CHANPLANS TO LYNX

## RODOLFO MONTEZ JR.

SMITHSONIAN ASTROPHYSICAL OBSERVATORY

# FROM CHANPLANS TO LYNX

## CHANDRA PLANETARY NEBULAE SURVEY

**RODOLFO MONTEZ JR.**

SMITHSONIAN ASTROPHYSICAL OBSERVATORY

*sample of planetary nebulae compiled by judy schmidt*

# CONTEXT

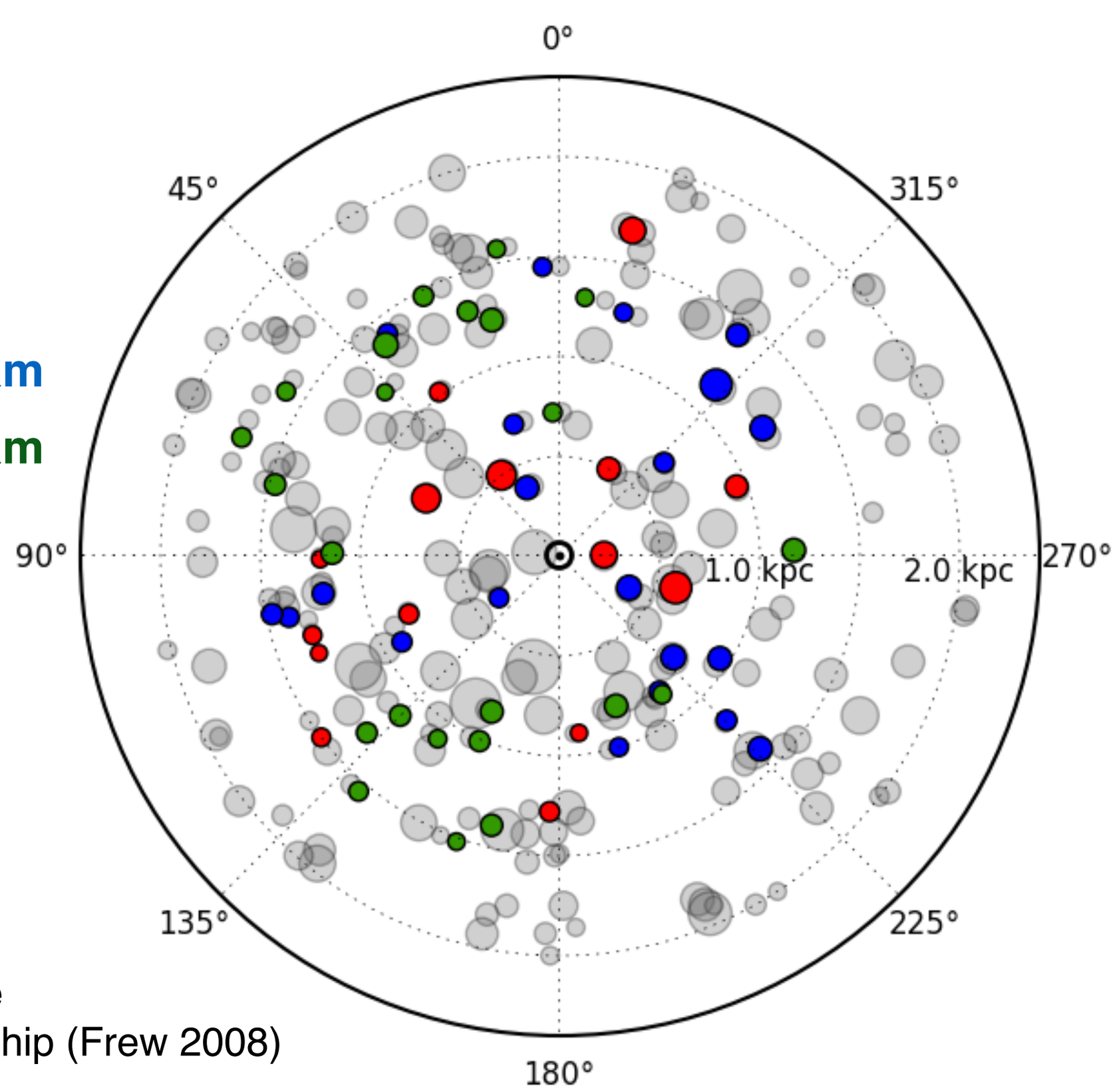
# CHANPLANS

**Archival Survey**

**Cycle 12 Large Program**

**Cycle 14 Large Program**

64 of 120




Planetary Nebulae in the
Solar Neighborhood

Distances based on surface
brightness - radius relationship (Frew 2008)

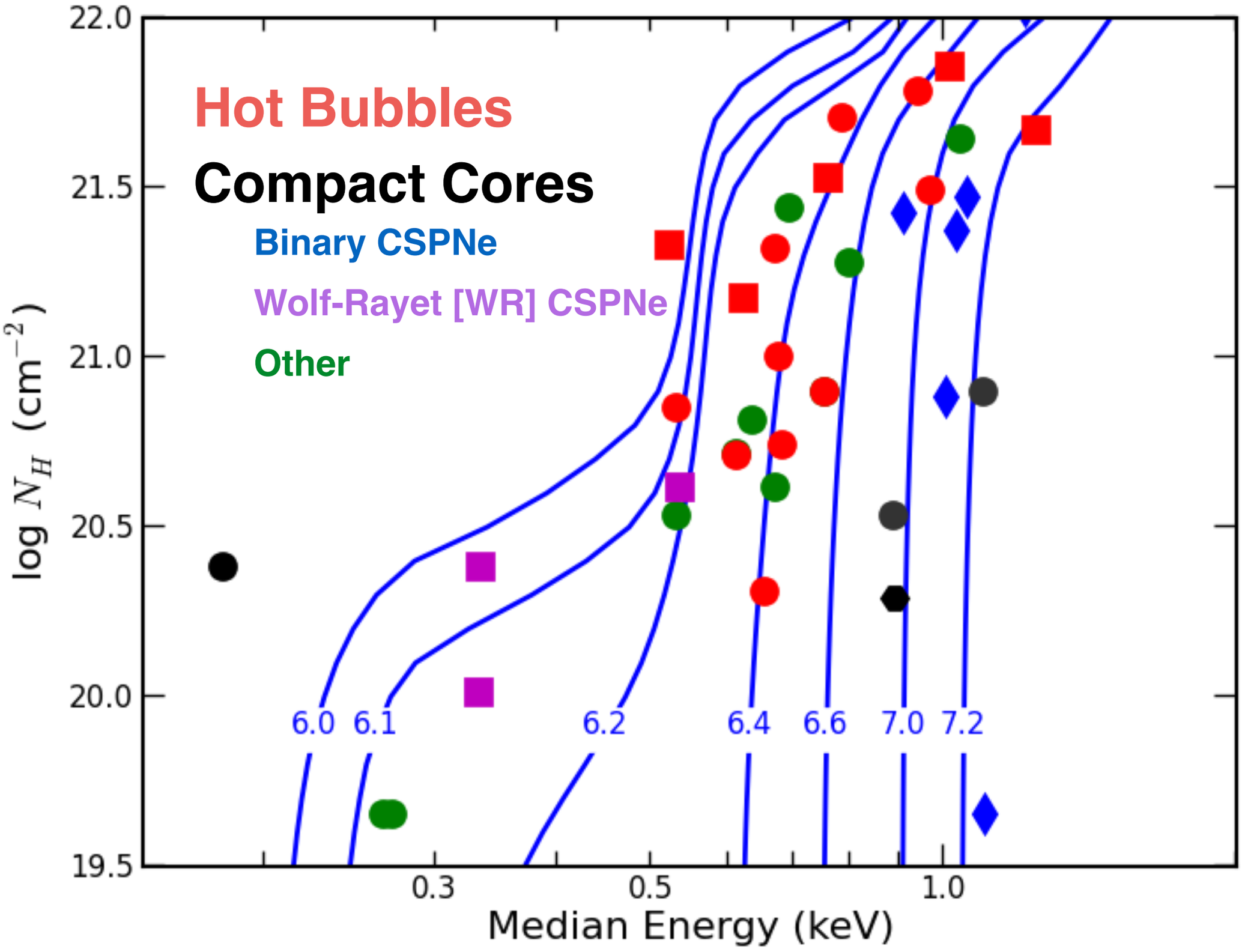
Kastner et al. 2012, Freeman et al. 2014,
Montez et al. 2016, Montez et al. 2017 [in prep]

CAT'S EYE

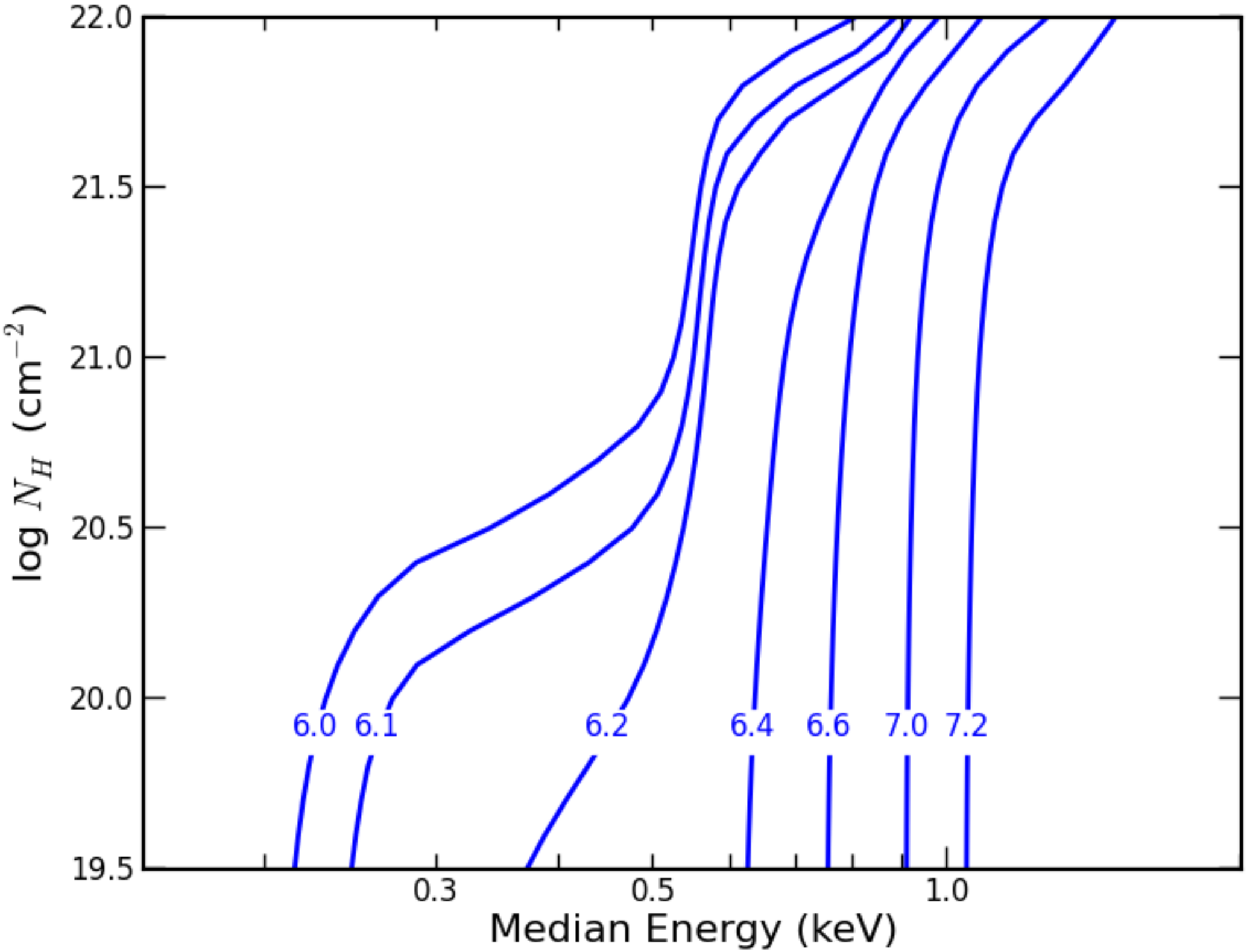
NGC 7662

NGC 7009

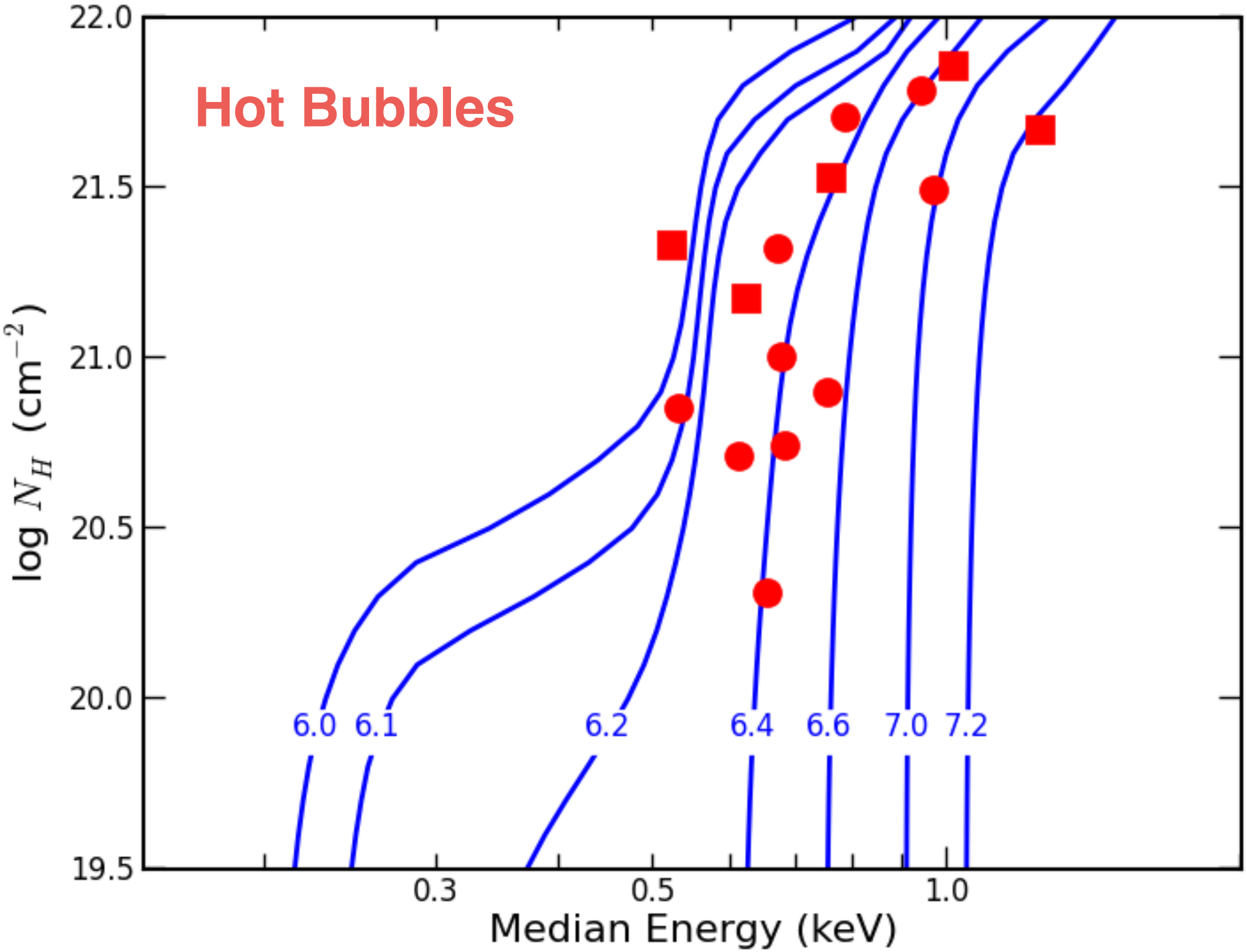
NGC 6826



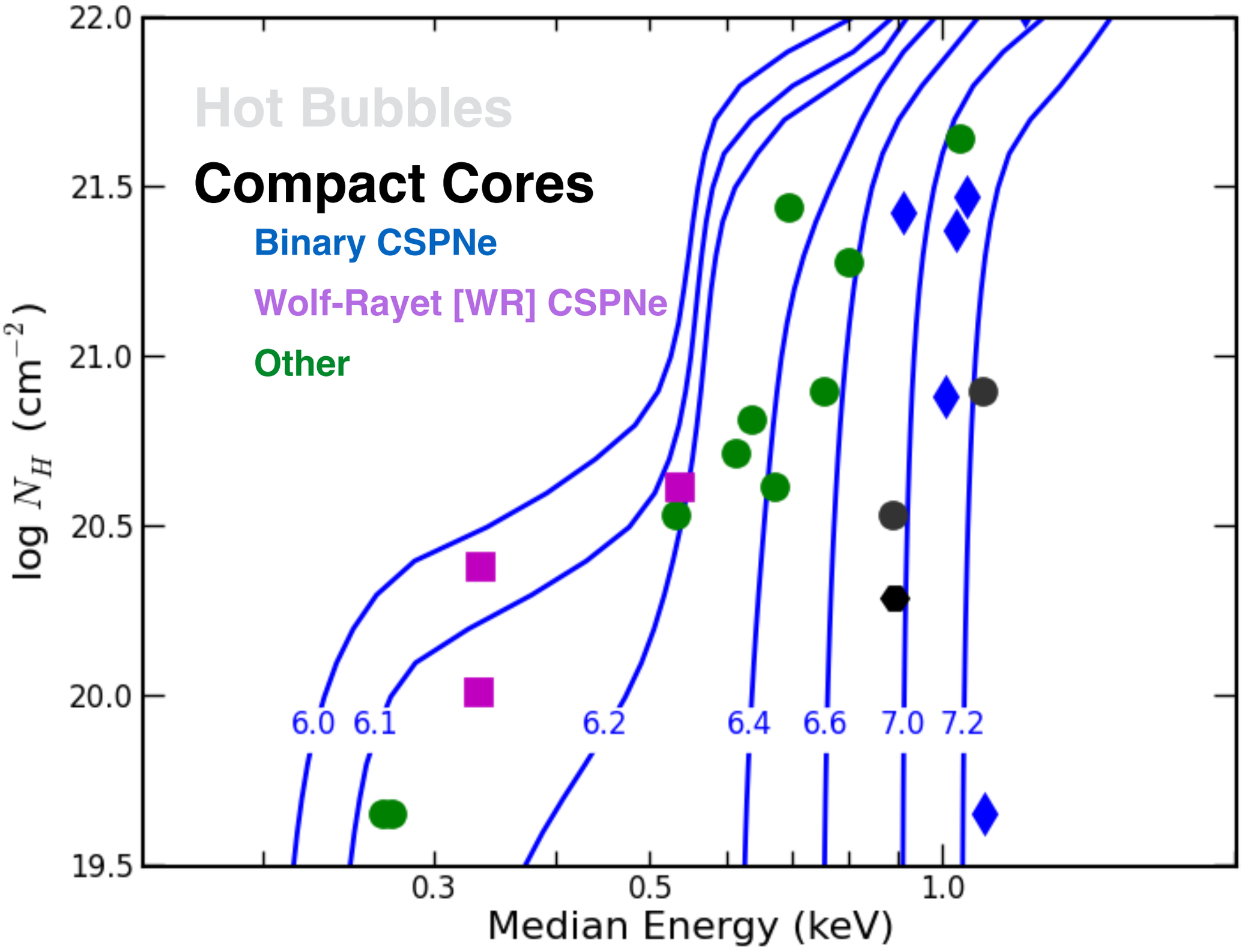

Kastner et al. 2012, Freeman et al. 2014,
Montez et al. 2016, Montez et al. 2017 [in prep]



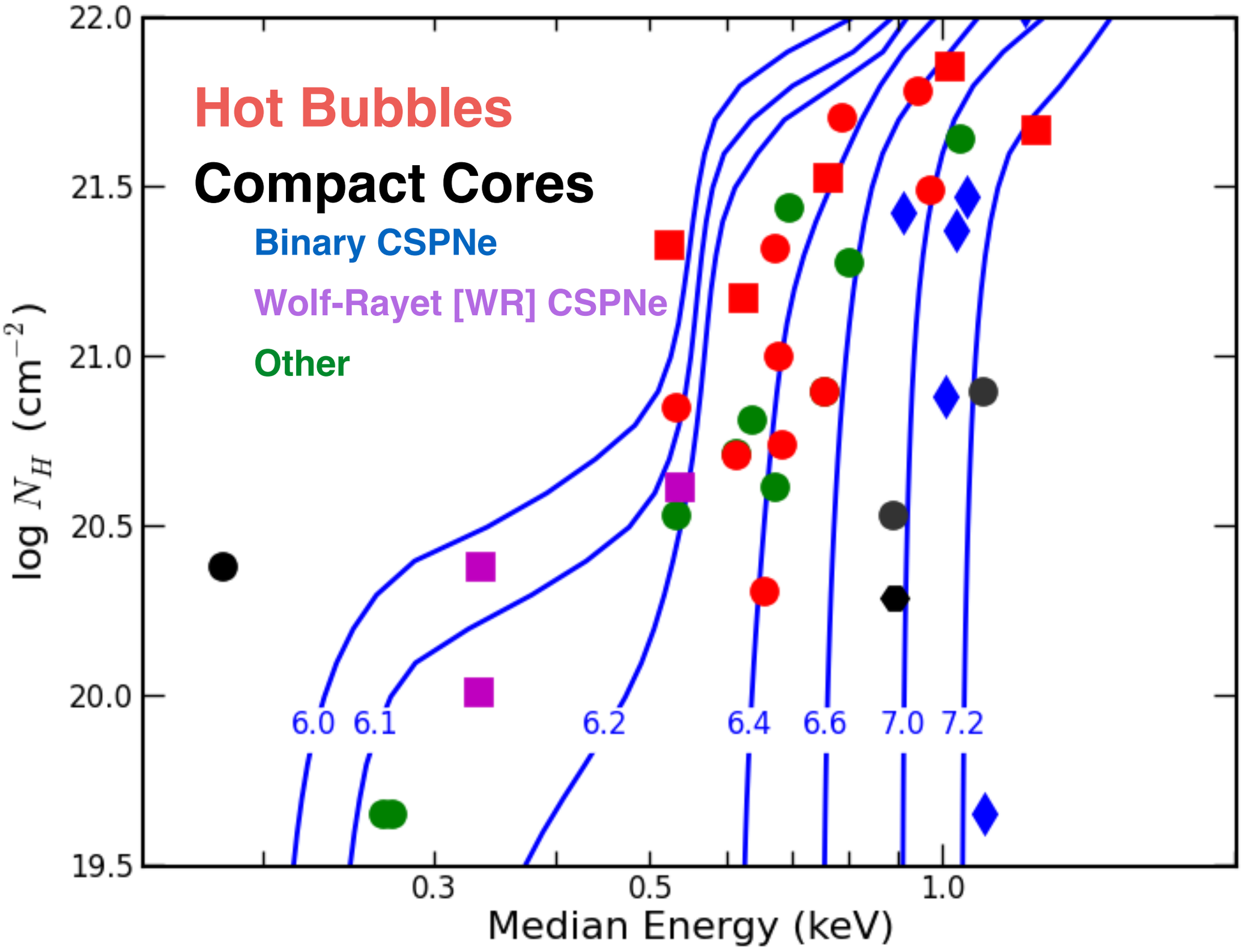

Kastner et al. 2012, Freeman et al. 2014,
Montez et al. 2016, Montez et al. 2017 [in prep]



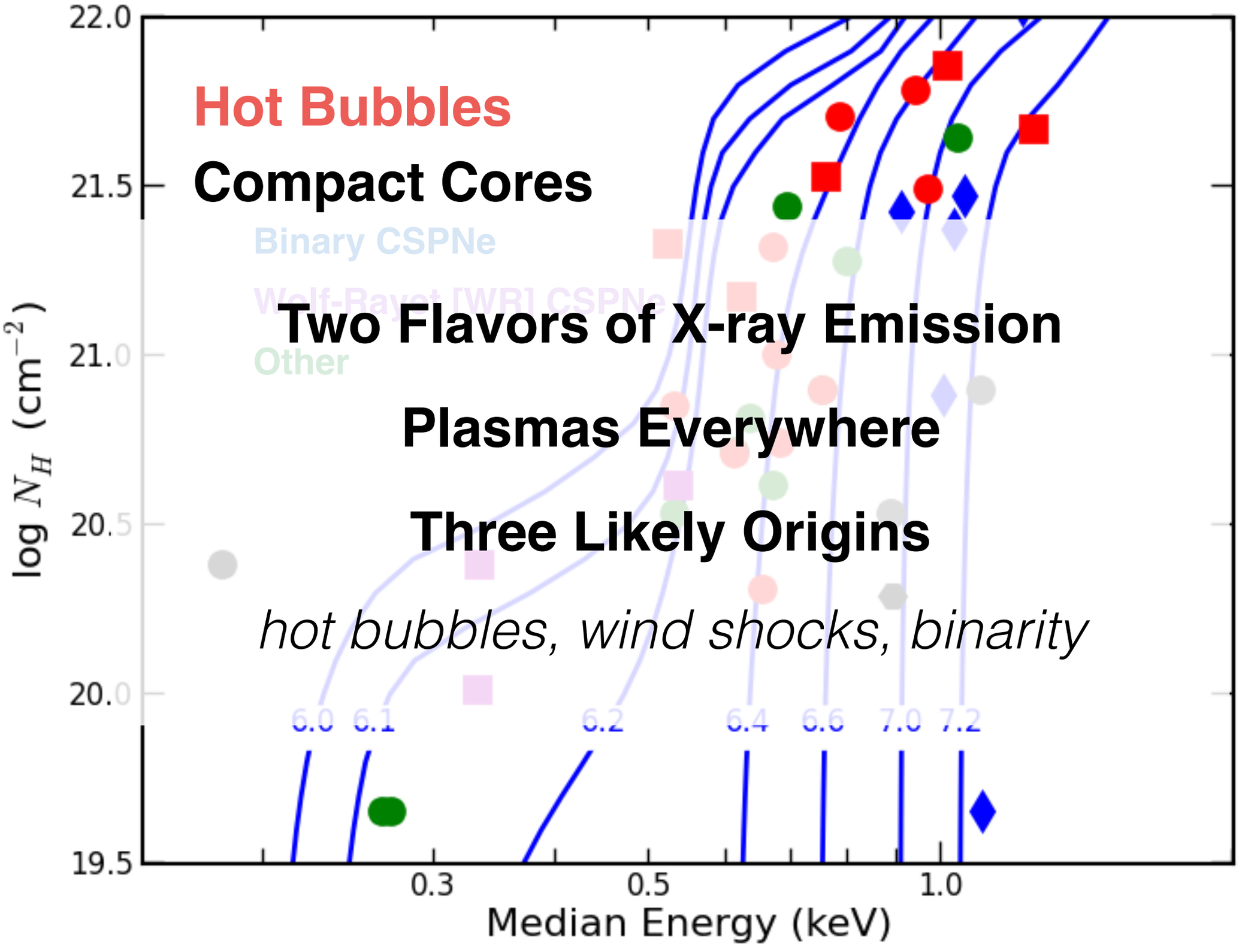

Kastner et al. 2012, Freeman et al. 2014,
Montez et al. 2016, Montez et al. 2017 [in prep]




Kastner et al. 2012, Freeman et al. 2014,
Montez et al. 2016, Montez et al. 2017 [in prep]

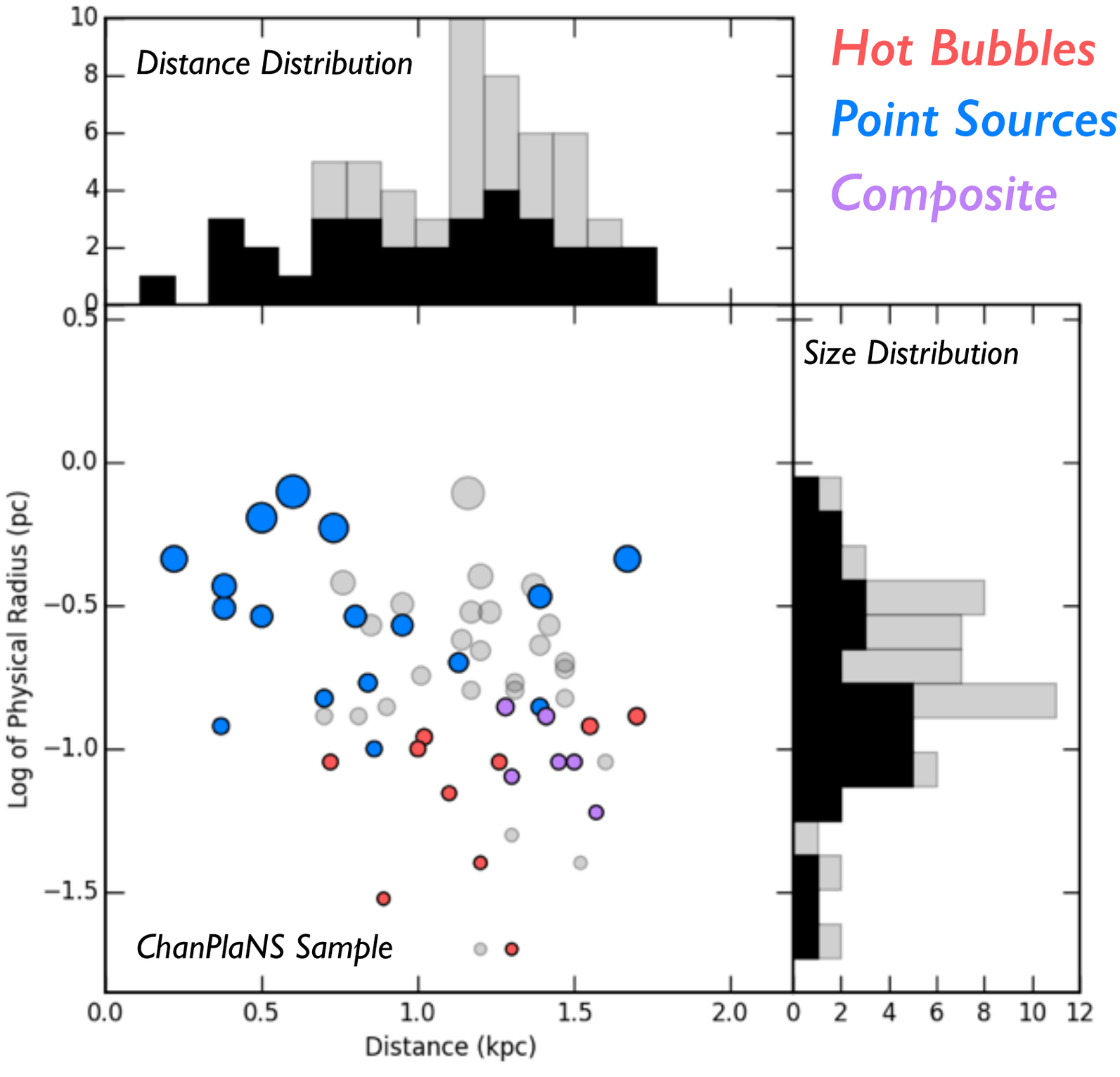



Kastner et al. 2012, Freeman et al. 2014,
Montez et al. 2016, Montez et al. 2017 [in prep]

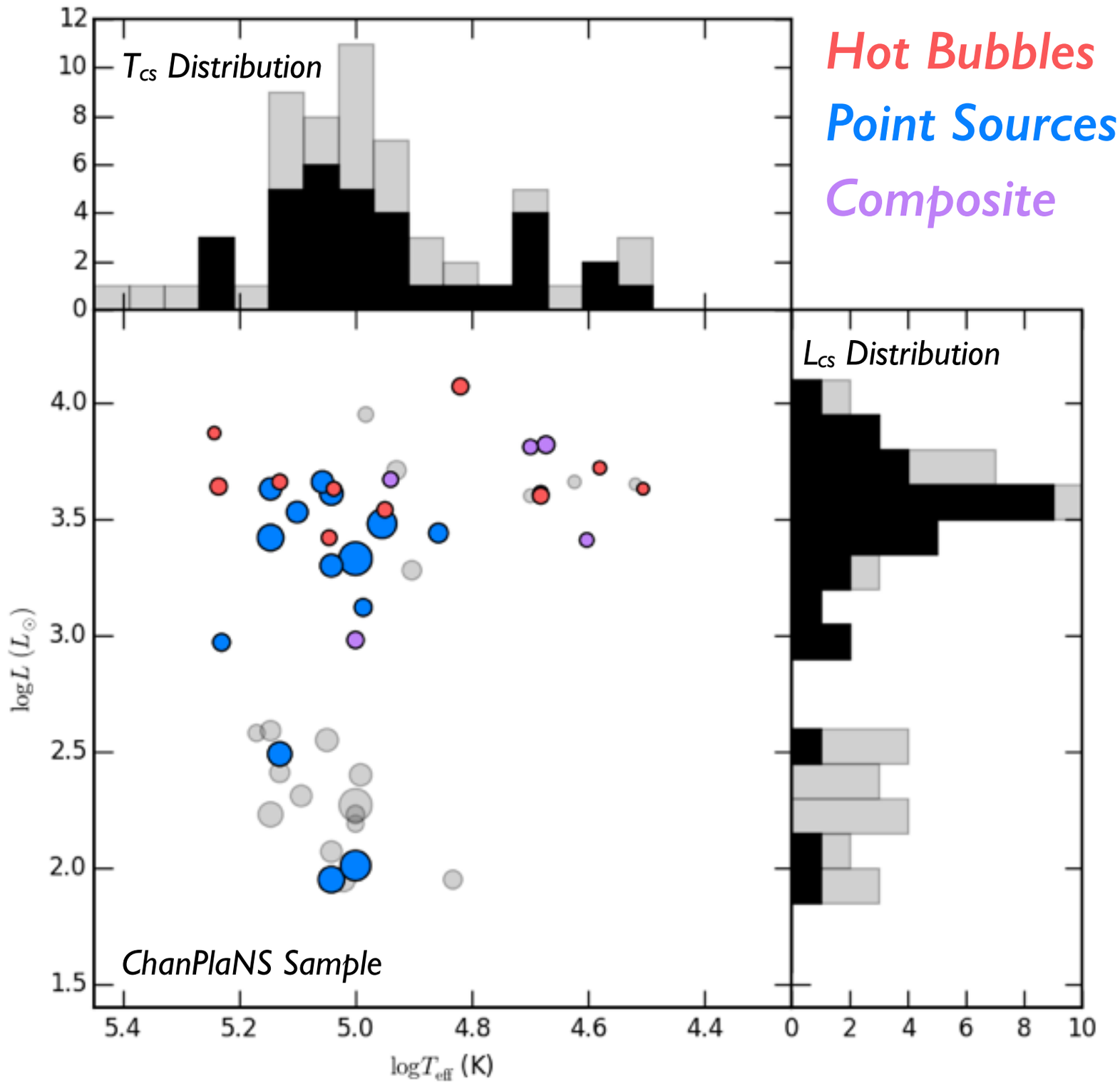


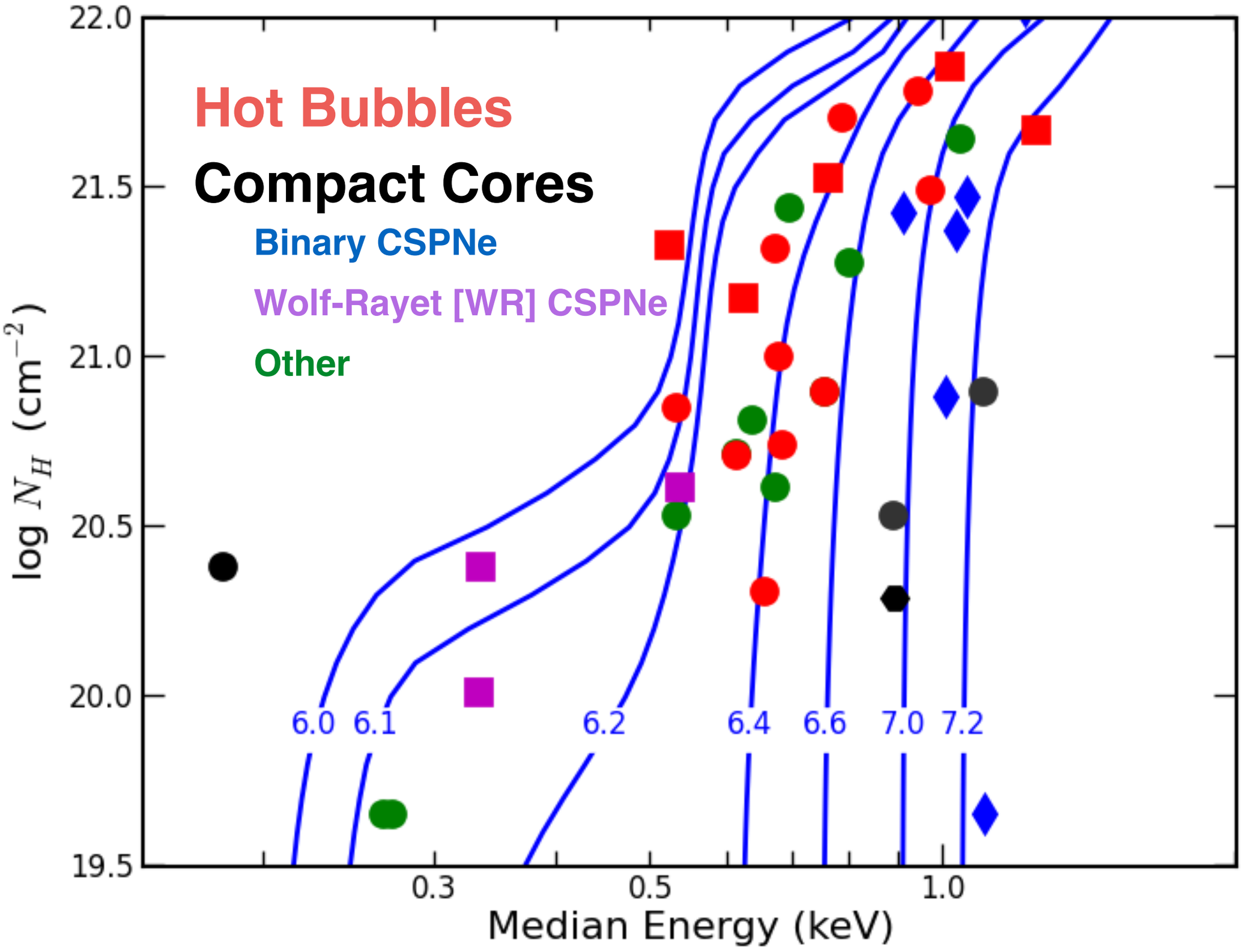

Kastner et al. 2012, Freeman et al. 2014,
Montez et al. 2016, Montez et al. 2017 [in prep]

# CHANPLANS IN EVOLUTIONARY CONTEXT



# CHANPLANS IN EVOLUTIONARY CONTEXT

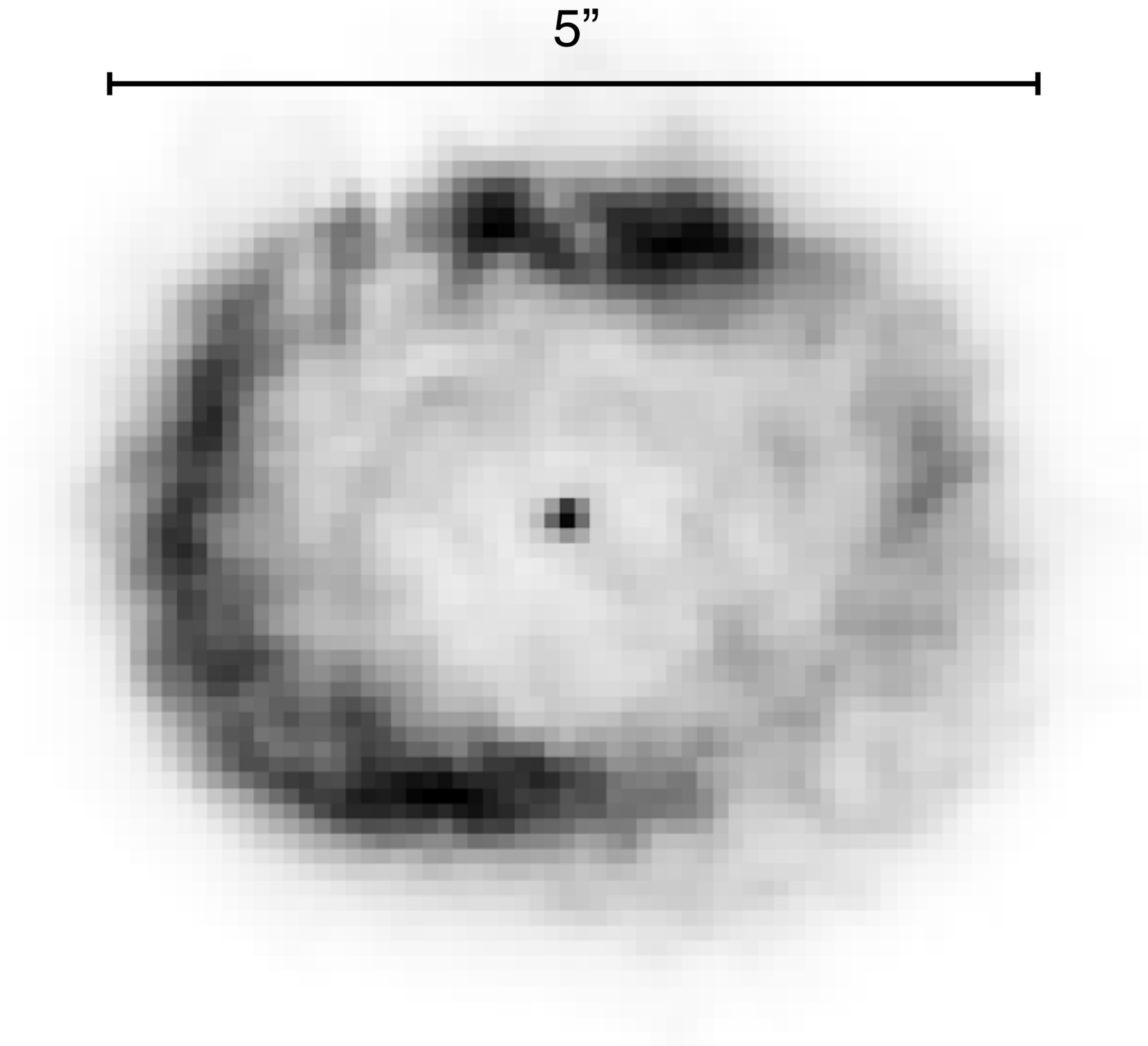





Kastner et al. 2012, Freeman et al. 2014,
Montez et al. 2016, Montez et al. 2017 [in prep]

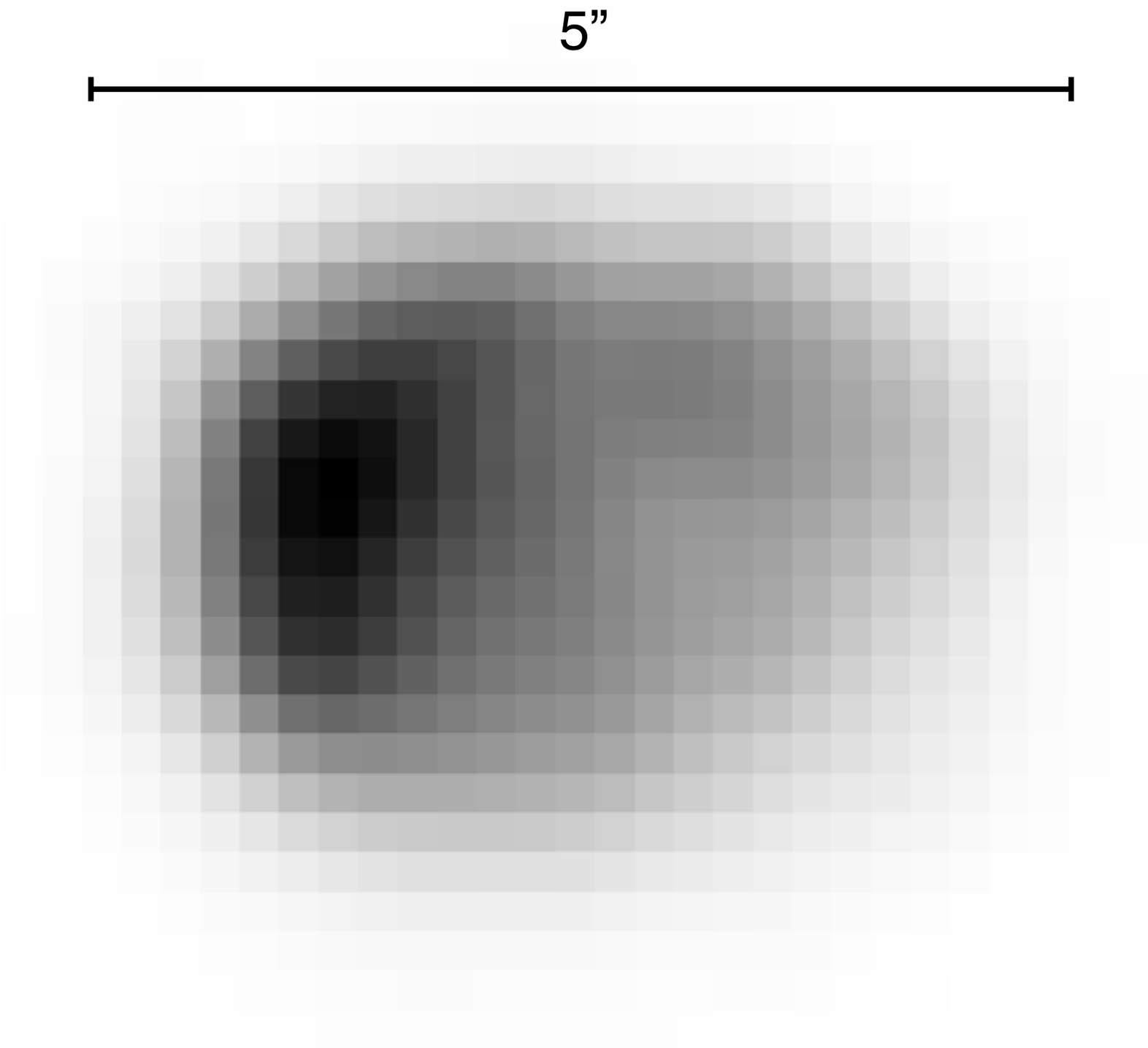
# BD+30 3639

# BD+30 3639



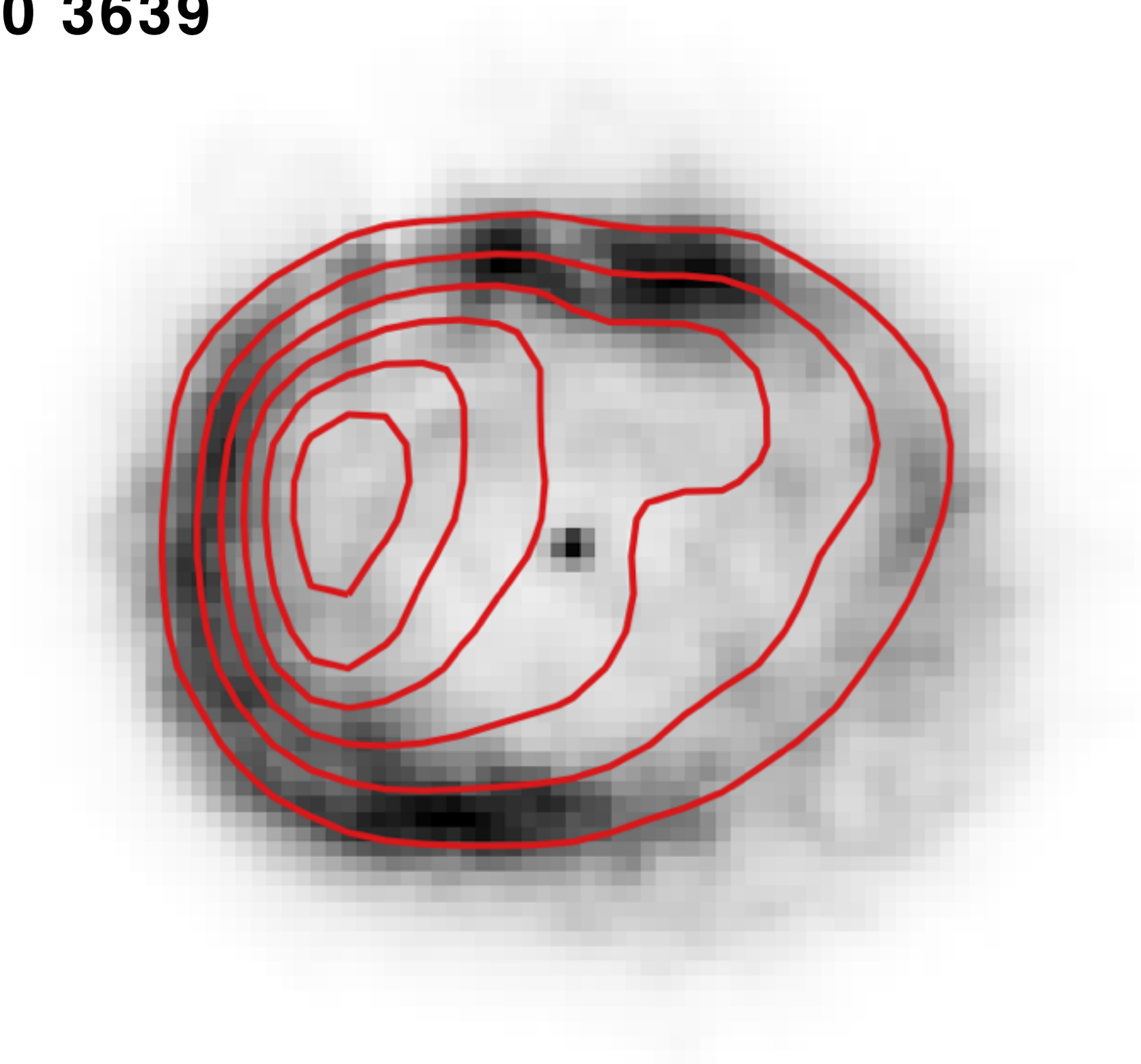

*HST H-alpha Image*

# BD+30 3639




*Chandra X-ray Image*

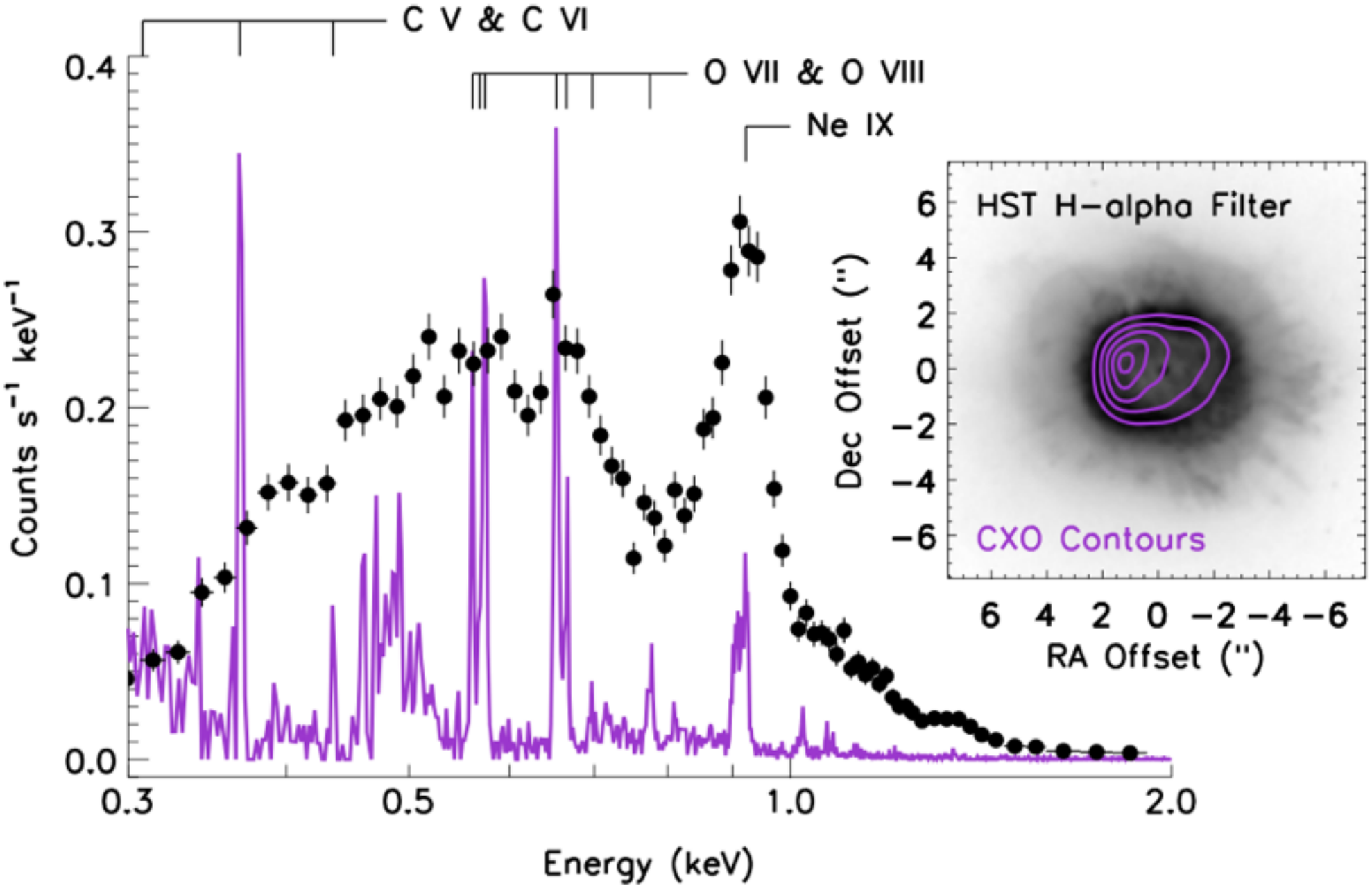
# BD+30 3639



*X-ray Contours on H-alpha Image*

# BD+30 3639

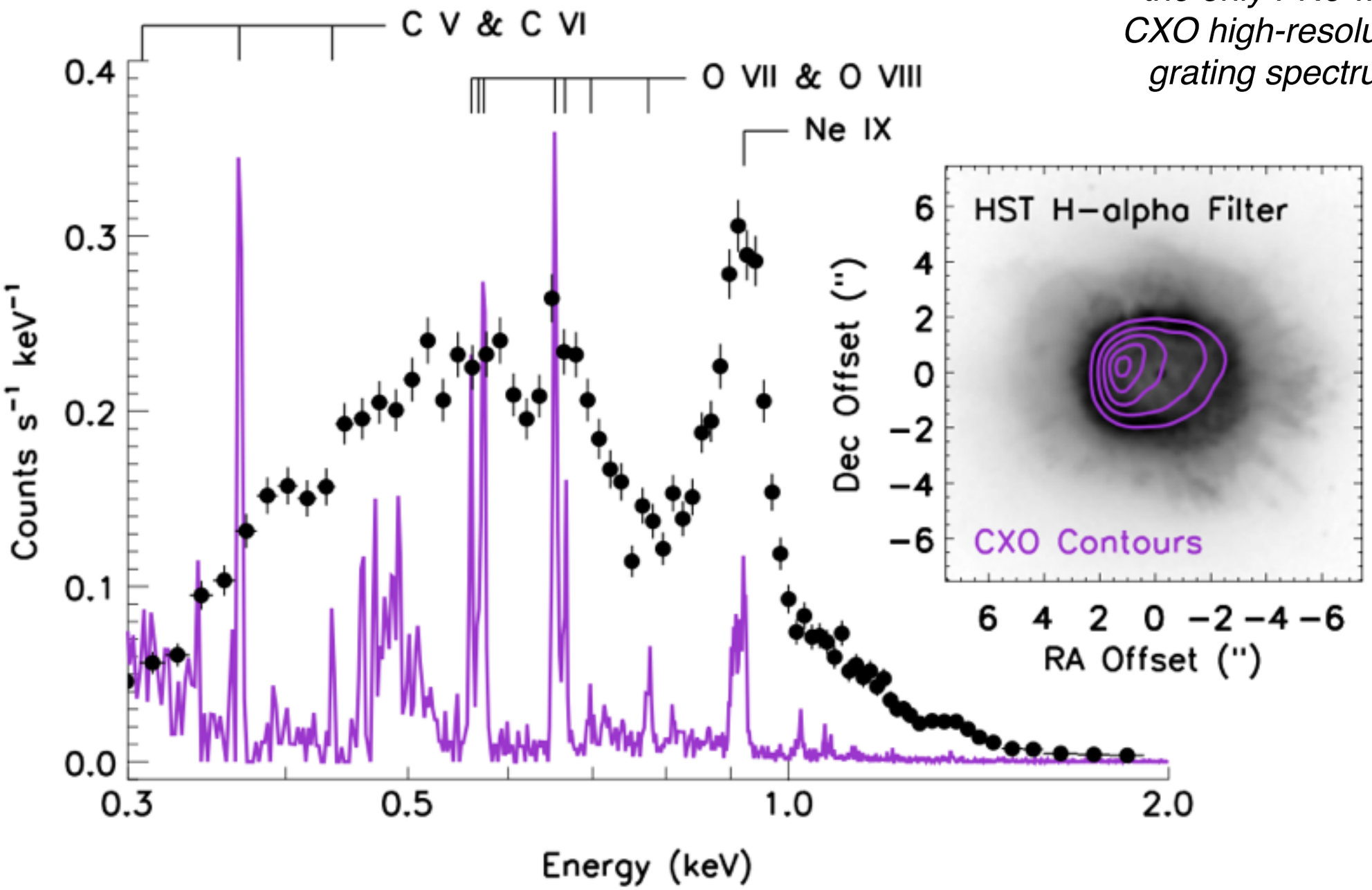
Kastner et al. 2001, Kastner et al. 2002, Maness et al. 2003

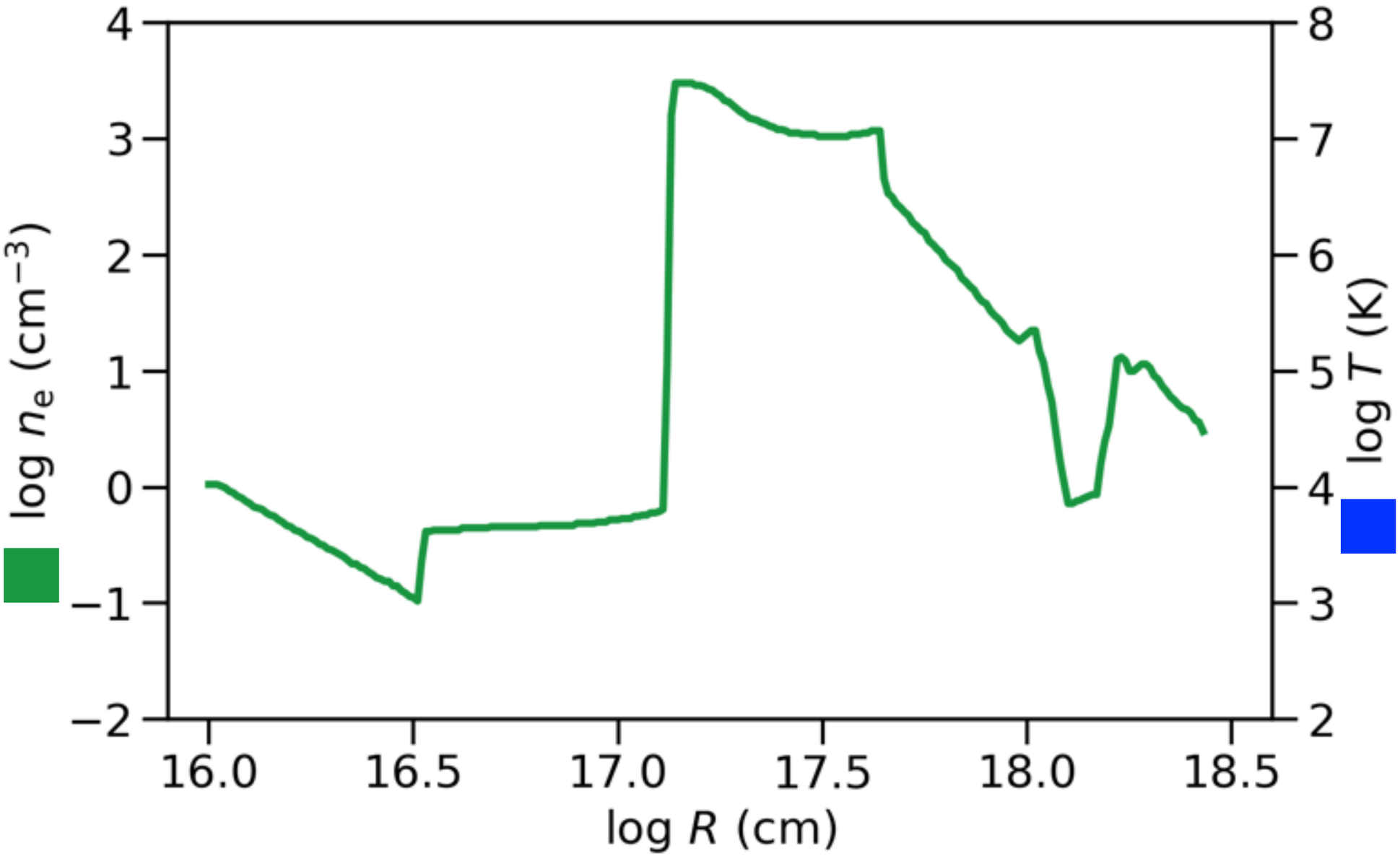


# BD+30 3639

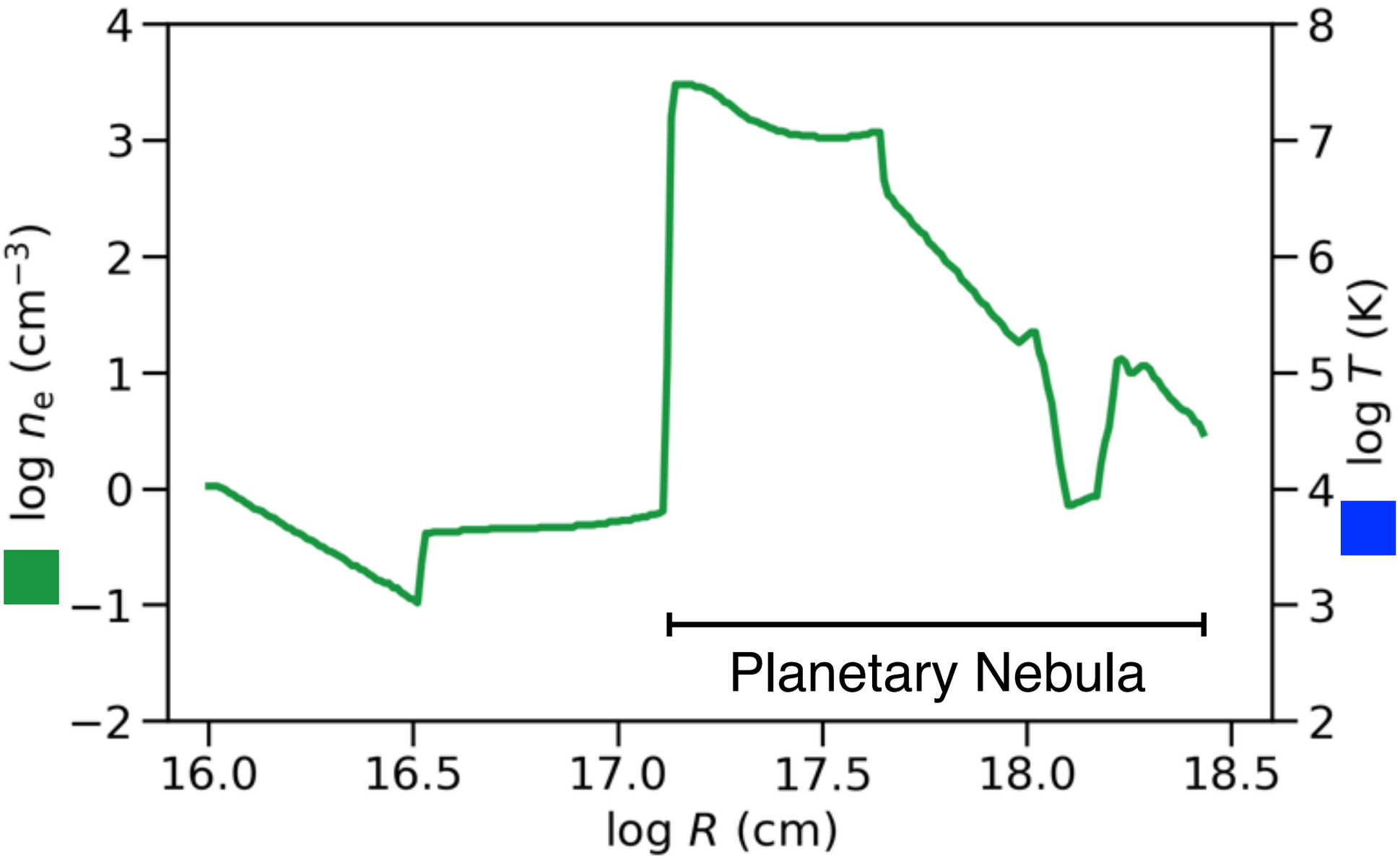
Kastner et al. 2001, Kastner et al. 2002, Maness et al. 2003 , Yu et al. 2009

*the only PNe with CXO high-resolution grating spectrum*

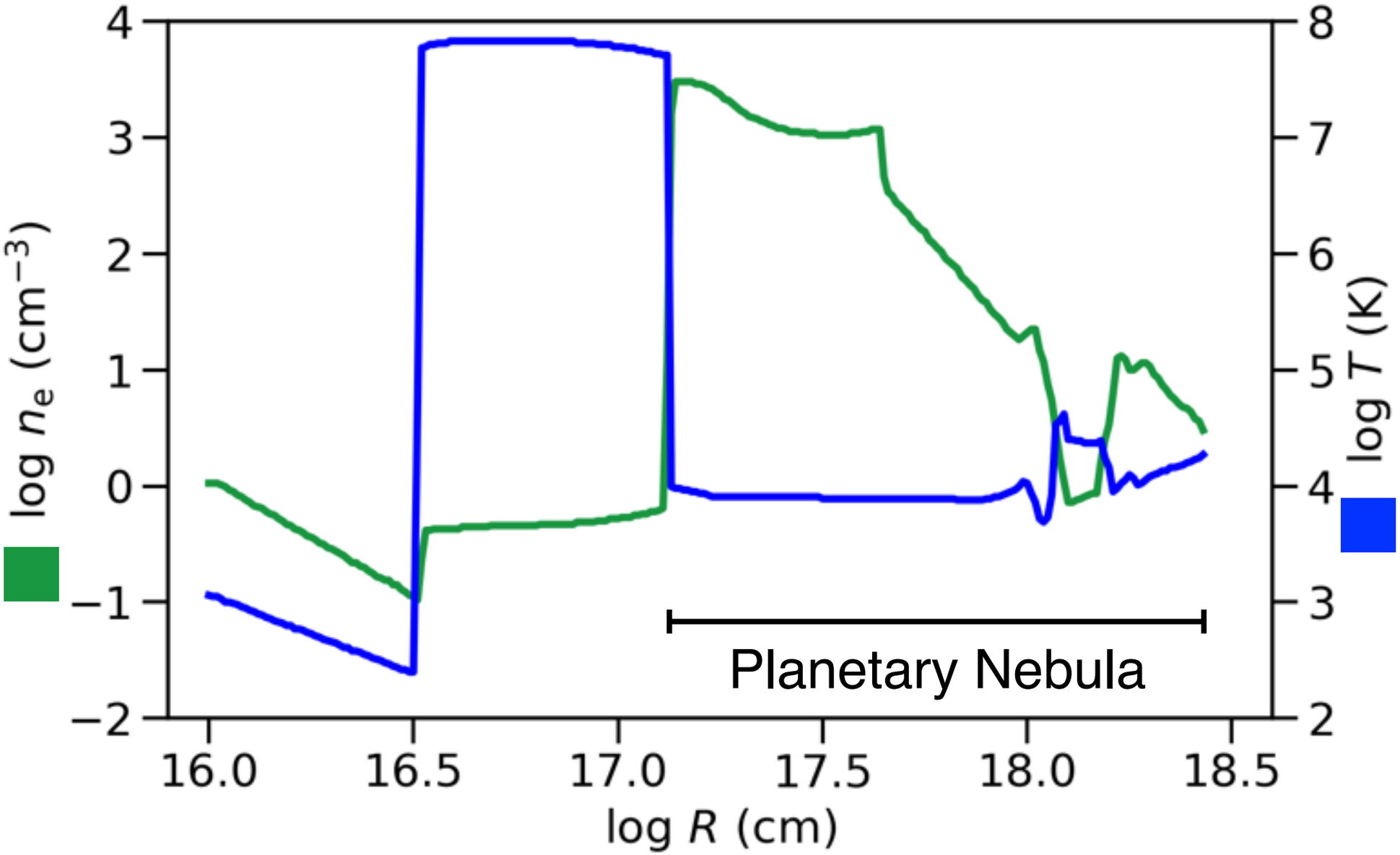




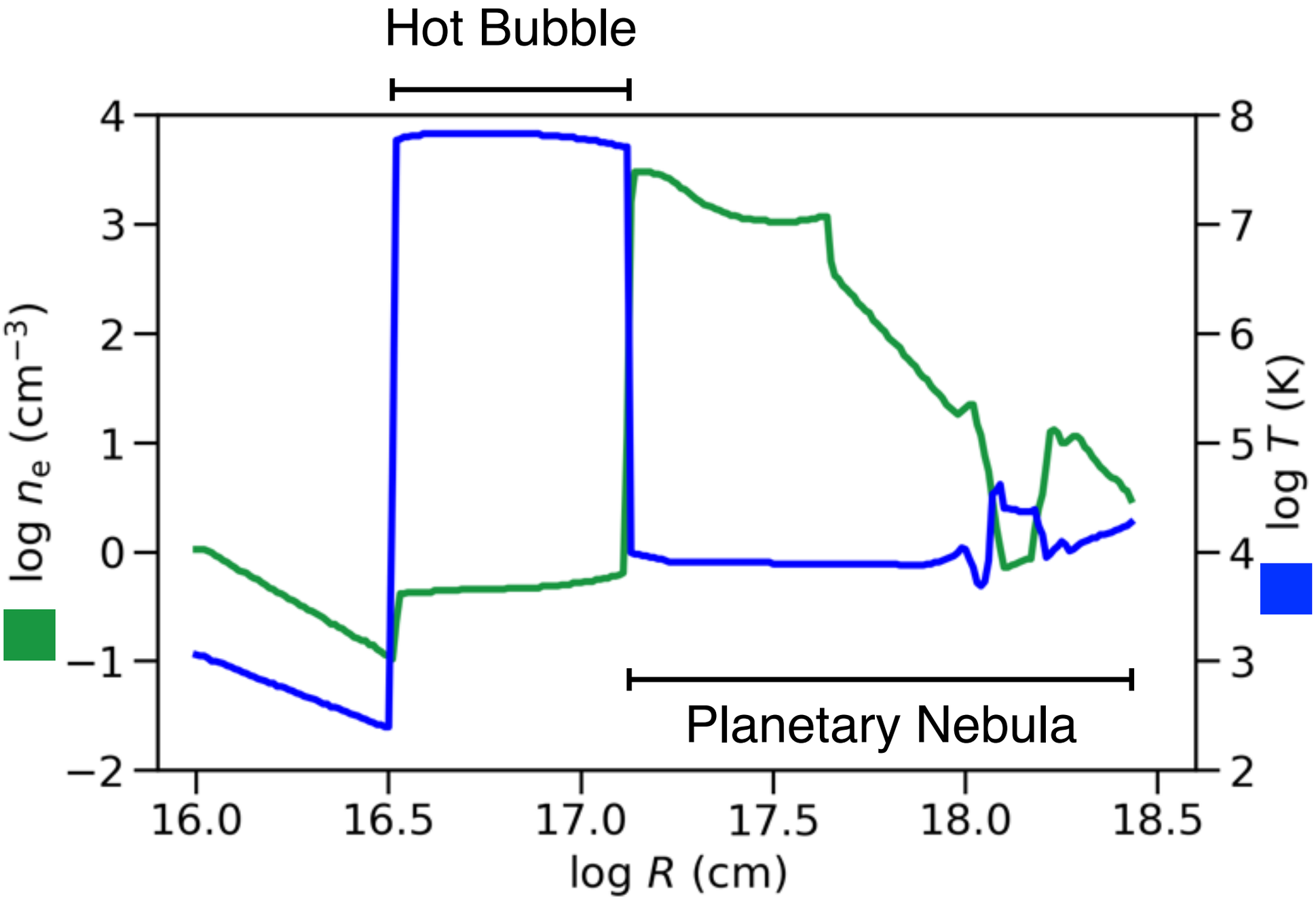

*Radiation Hydrodynamical Models from Steffen et al. (2008)*




*Radiation Hydrodynamical Models from Steffen et al. (2008)*




*Radiation Hydrodynamical Models from Steffen et al. (2008)*

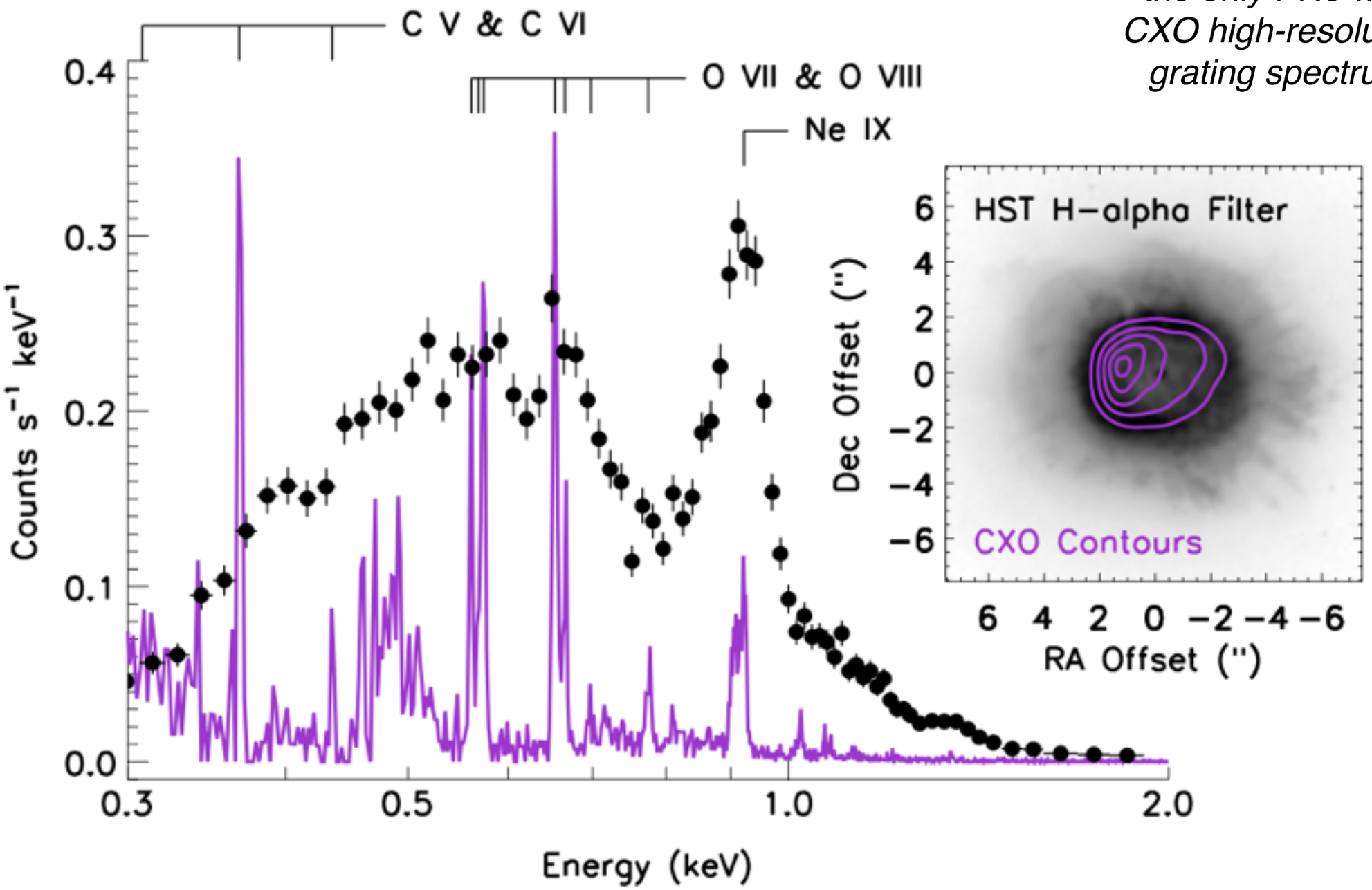


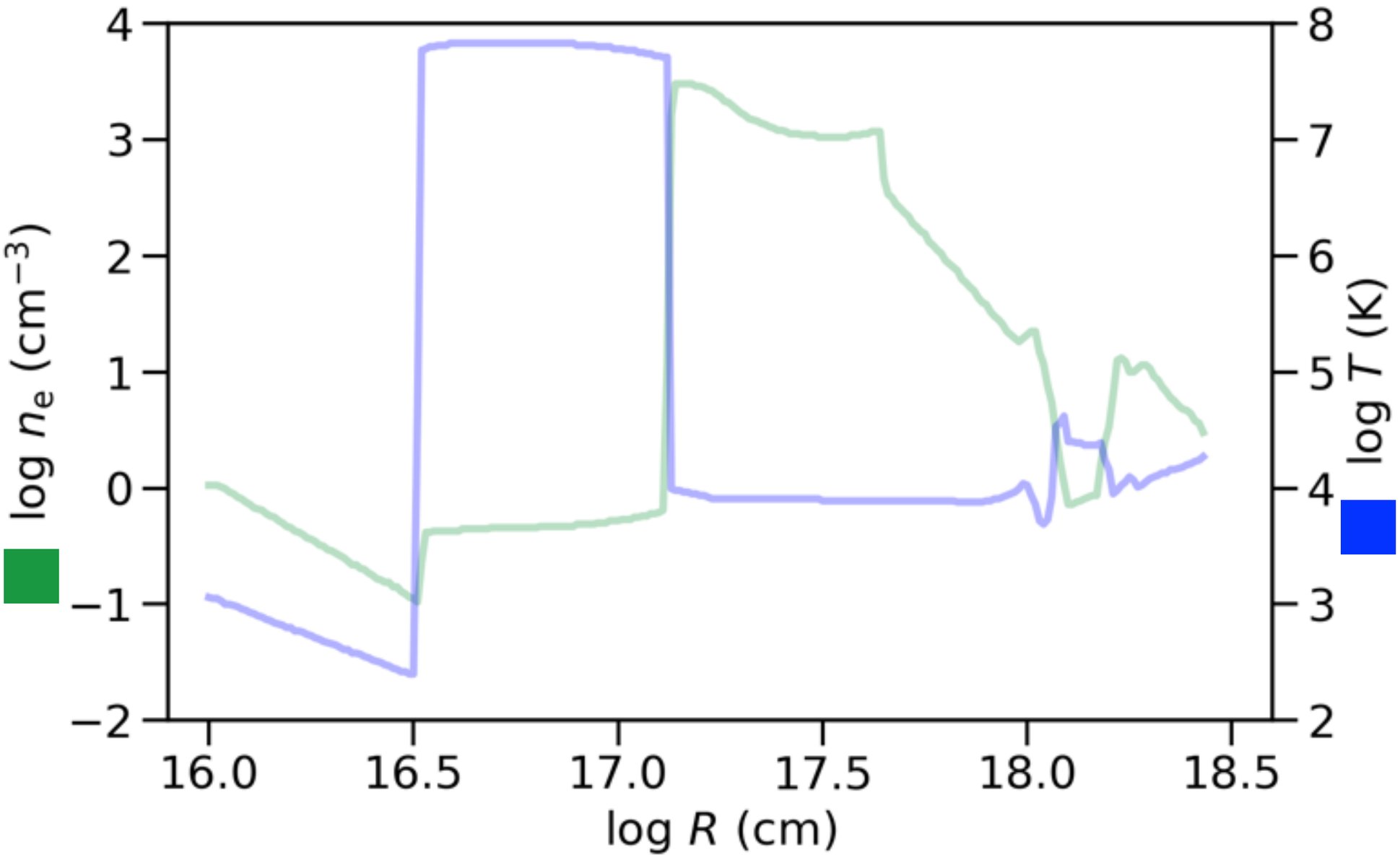

*Radiation Hydrodynamical Models from Steffen et al. (2008)*

# BD+30 3639

Kastner et al. 2001, Kastner et al. 2002, Maness et al. 2003 , Yu et al. 2009

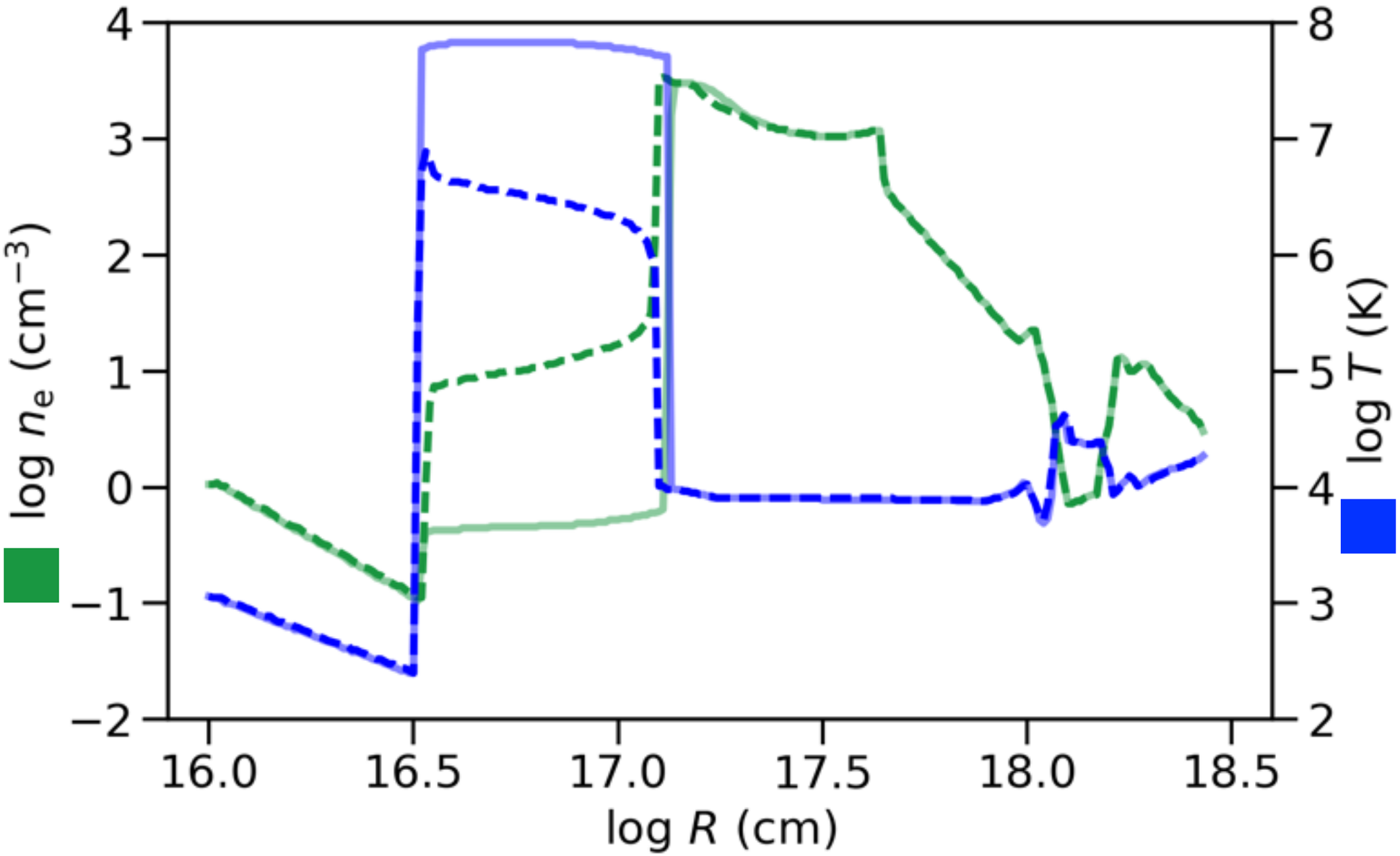
*the only PNe with CXO high-resolution grating spectrum*





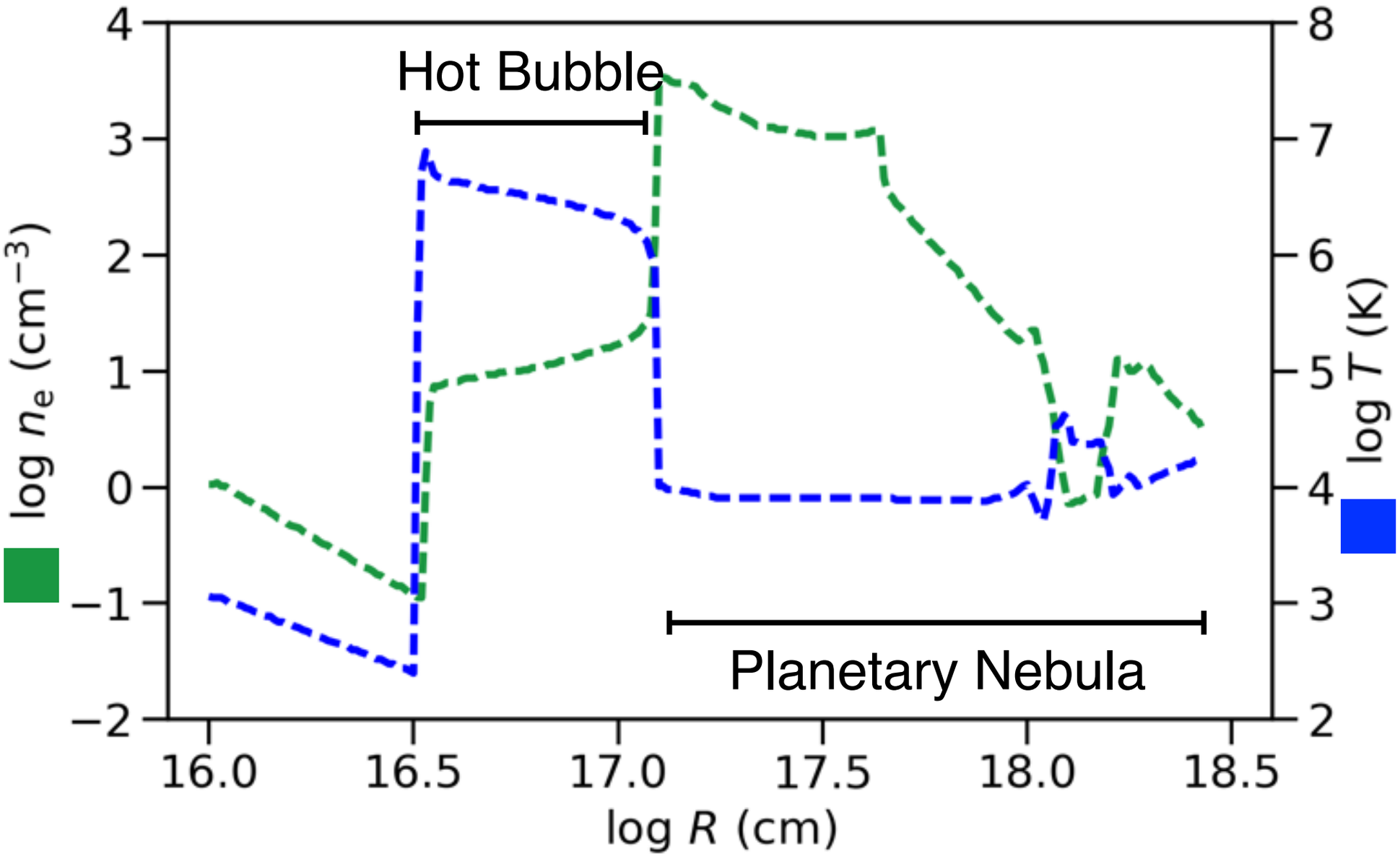

*Radiation Hydrodynamical Models from Steffen et al. (2008)*

# HEAT CONDUCTION




*Radiation Hydrodynamical Models from Steffen et al. (2008)*

# HEAT CONDUCTION

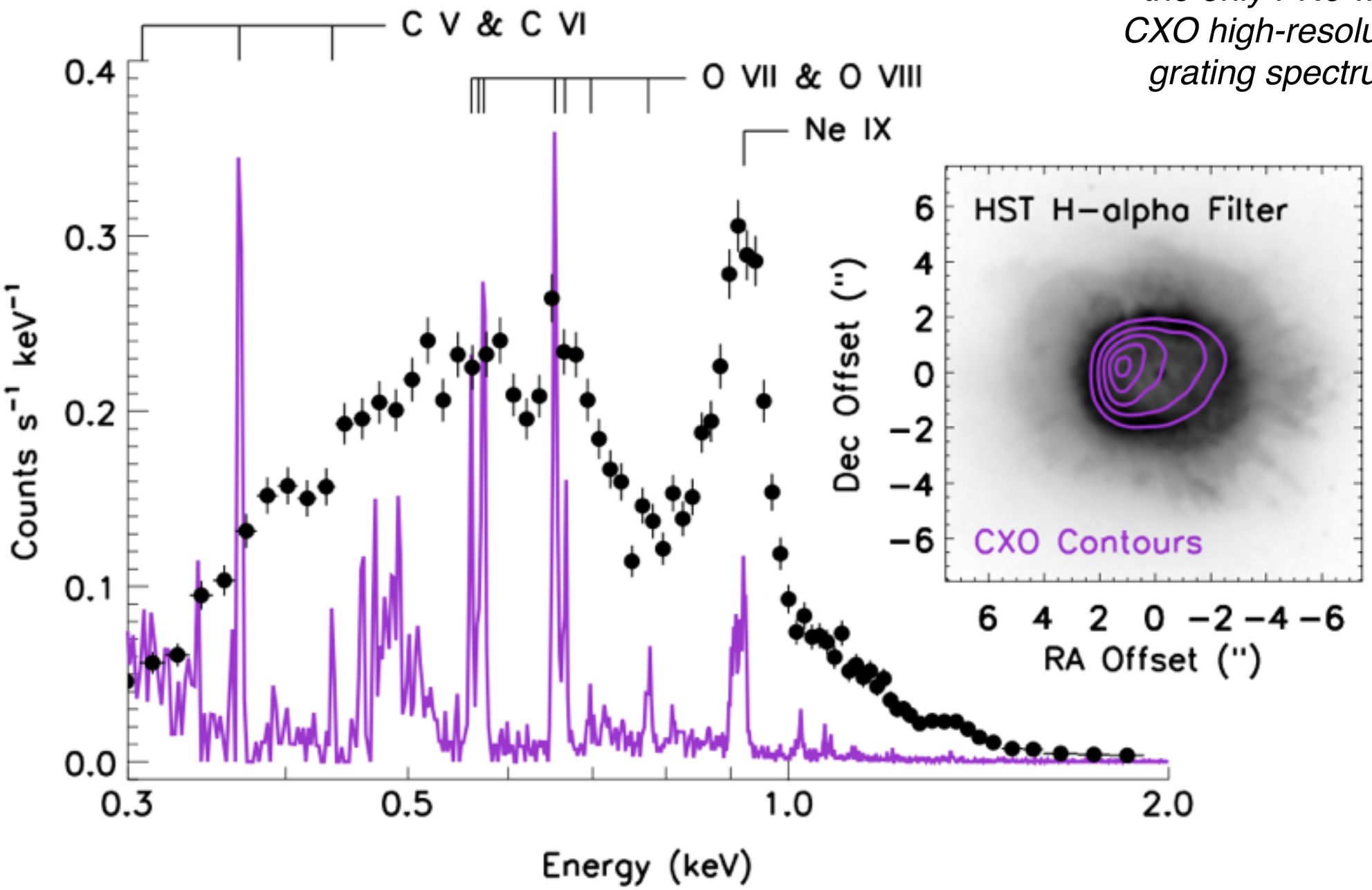



*Radiation Hydrodynamical Models from Steffen et al. (2008)*

# BD+30 3639

Kastner et al. 2001, Kastner et al. 2002, Maness et al. 2003 , Yu et al. 2009

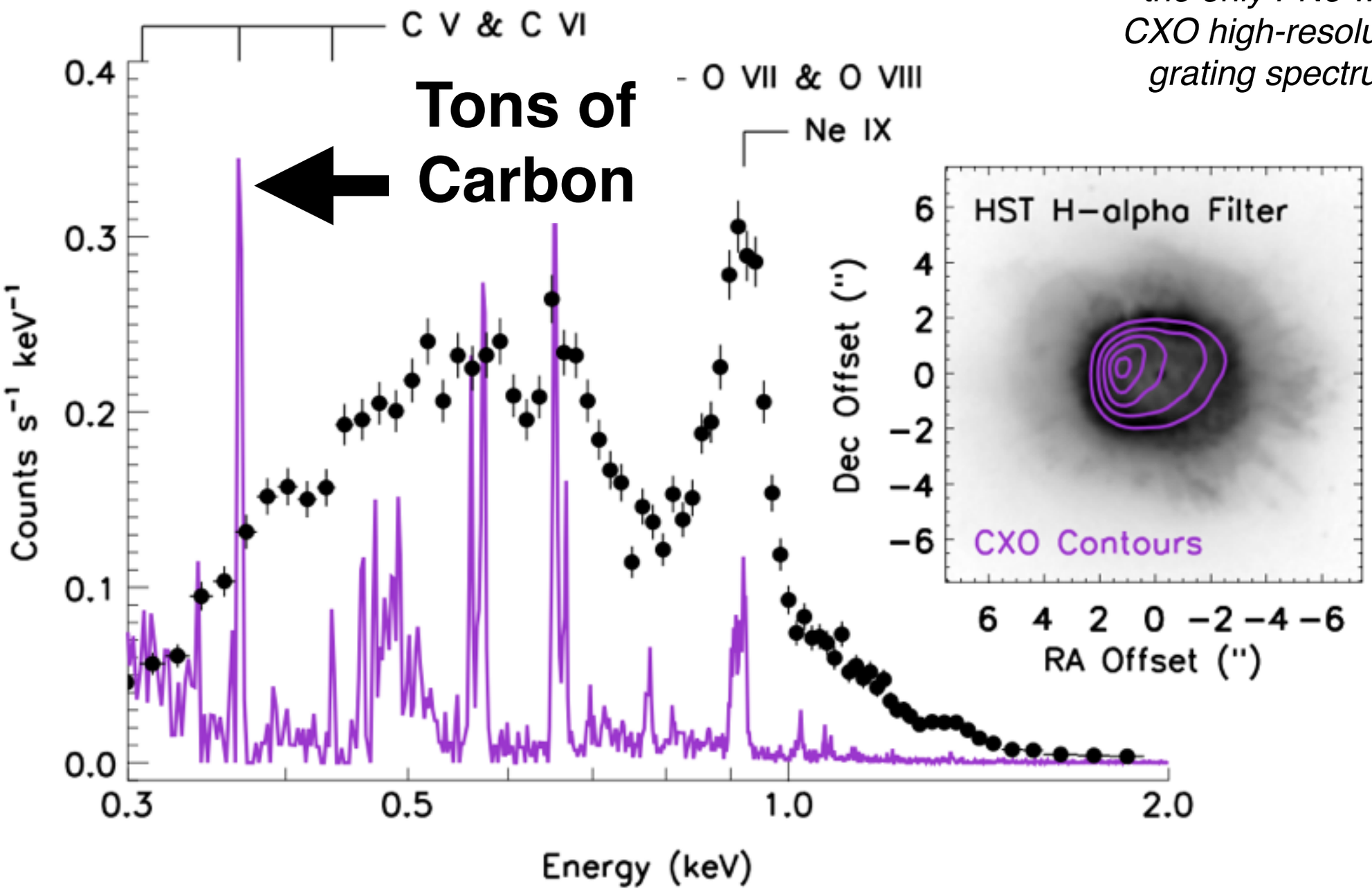
*the only PNe with CXO high-resolution grating spectrum*



# BD+30 3639

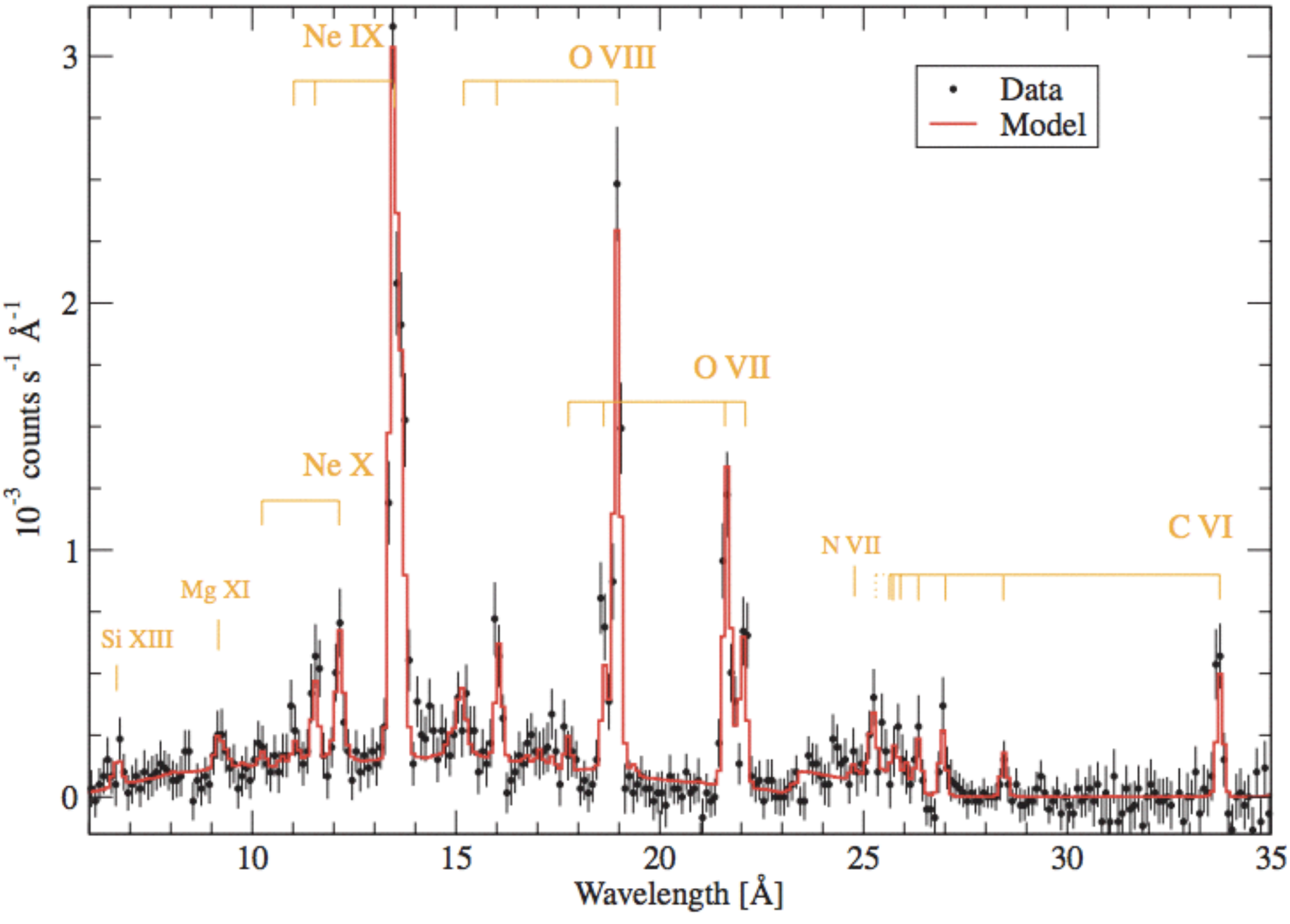
Kastner et al. 2001, Kastner et al. 2002, Maness et al. 2003 , Yu et al. 2009

*the only PNe with CXO high-resolution grating spectrum*



# BD+30 3639

Kastner et al. 2001, Kastner et al. 2002, Maness et al. 2003 , Yu et al. 2009




CXO LETG/ACIS
High-res Spectrum

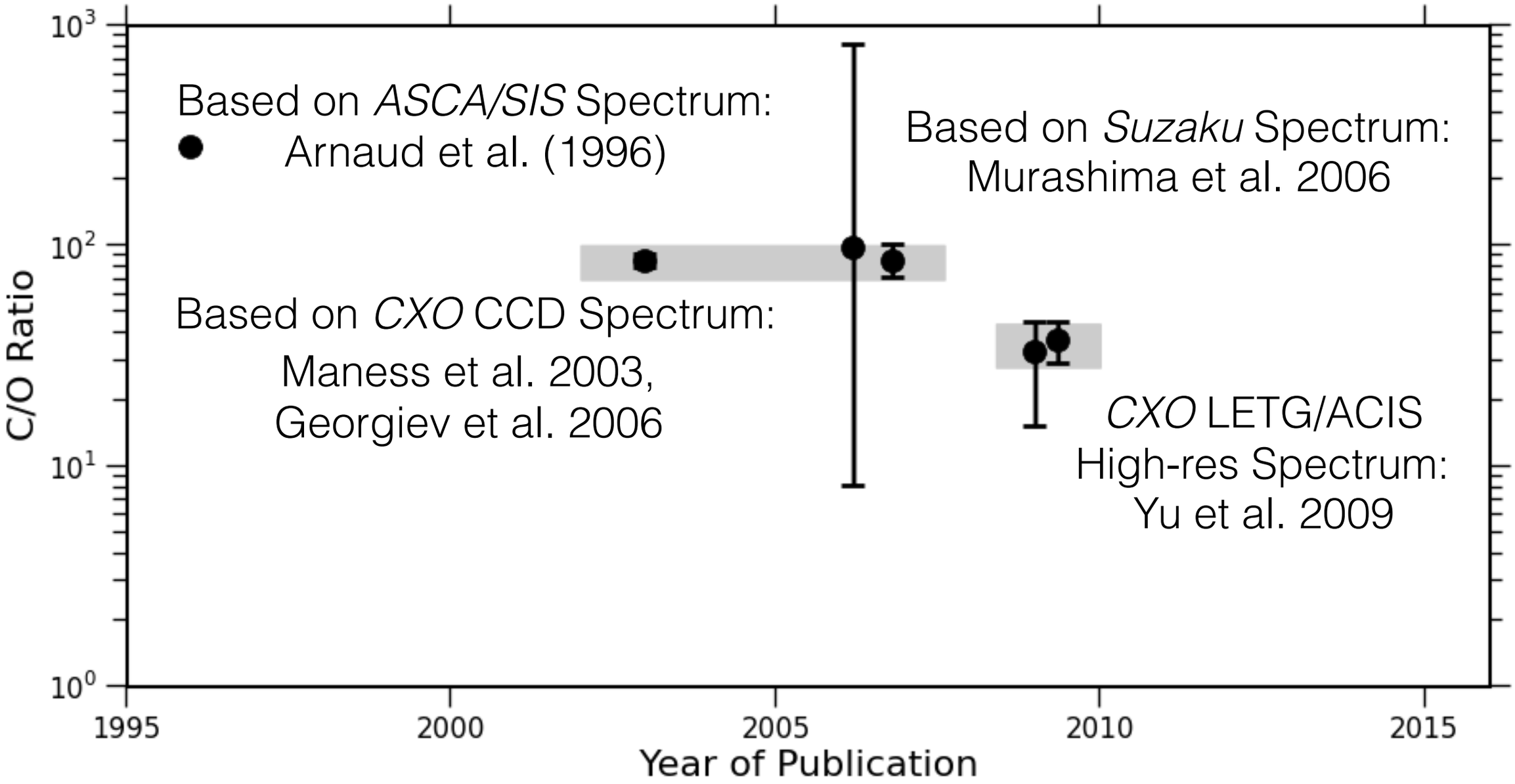
**C/O ~ 30**

*near solar O*
*enhanced C*
*depleted Fe*

(Yu et al. 2009)

# BD+30 3639

Kastner et al. 2001, Kastner et al. 2002, Maness et al. 2003 , Yu et al. 2009



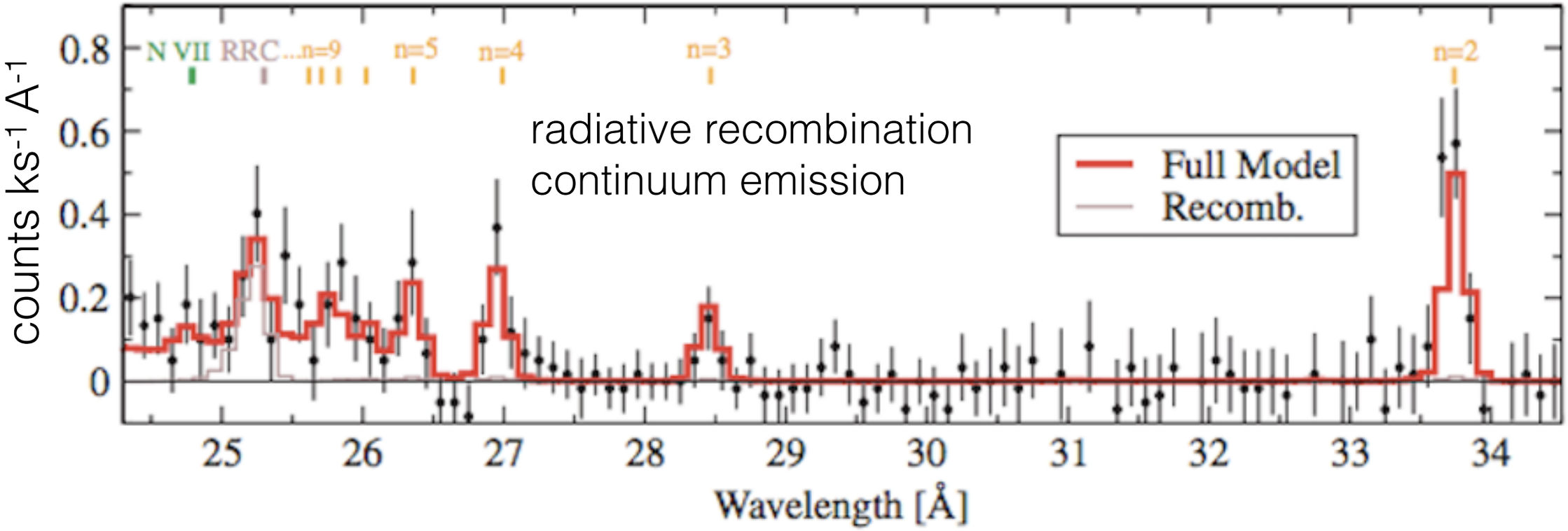
# BD+30 3639

Kastner et al. 2001, Kastner et al. 2002, Maness et al. 2003 , Yu et al. 2009

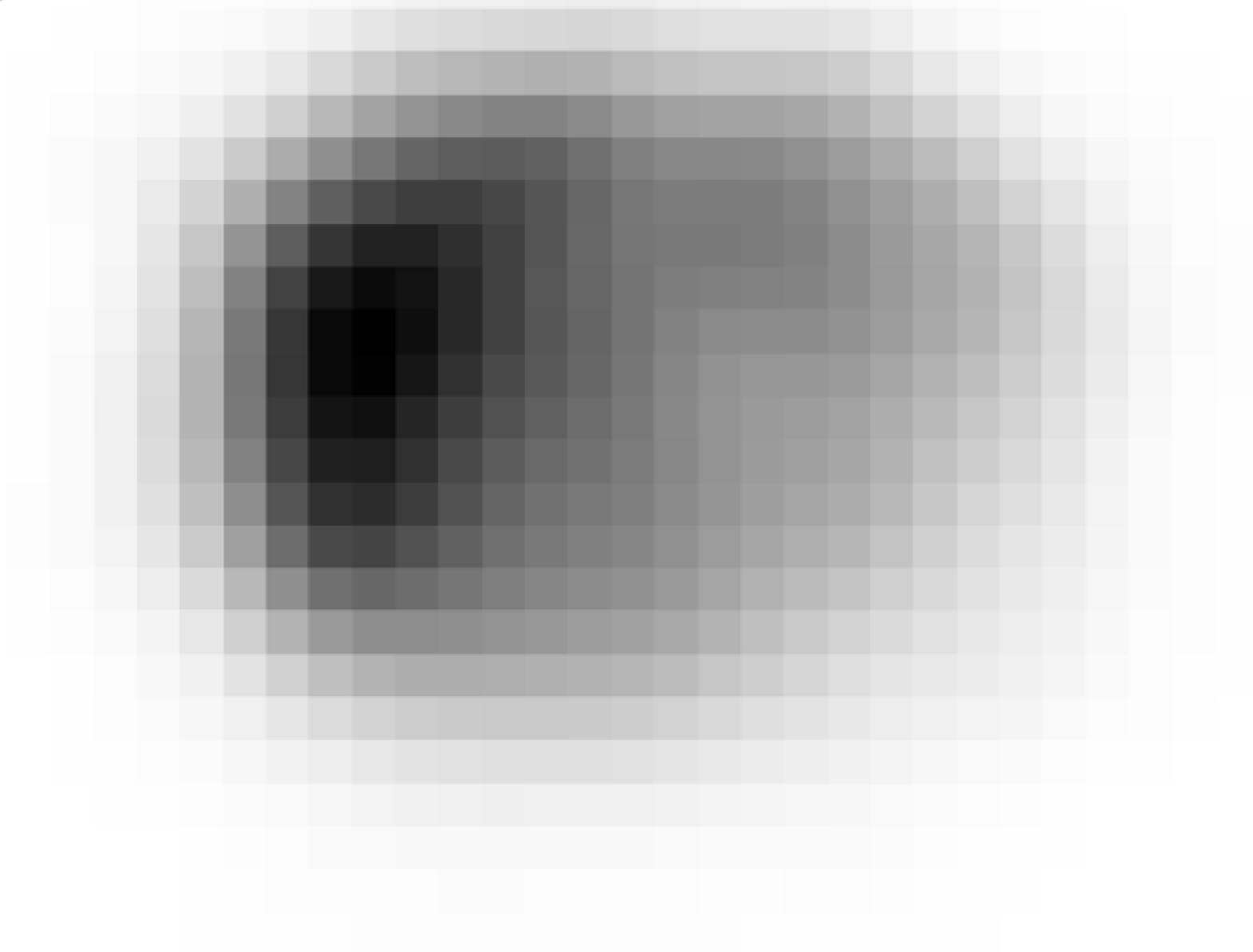
**Nordon et al. 2009**

*Tons of Carbon*

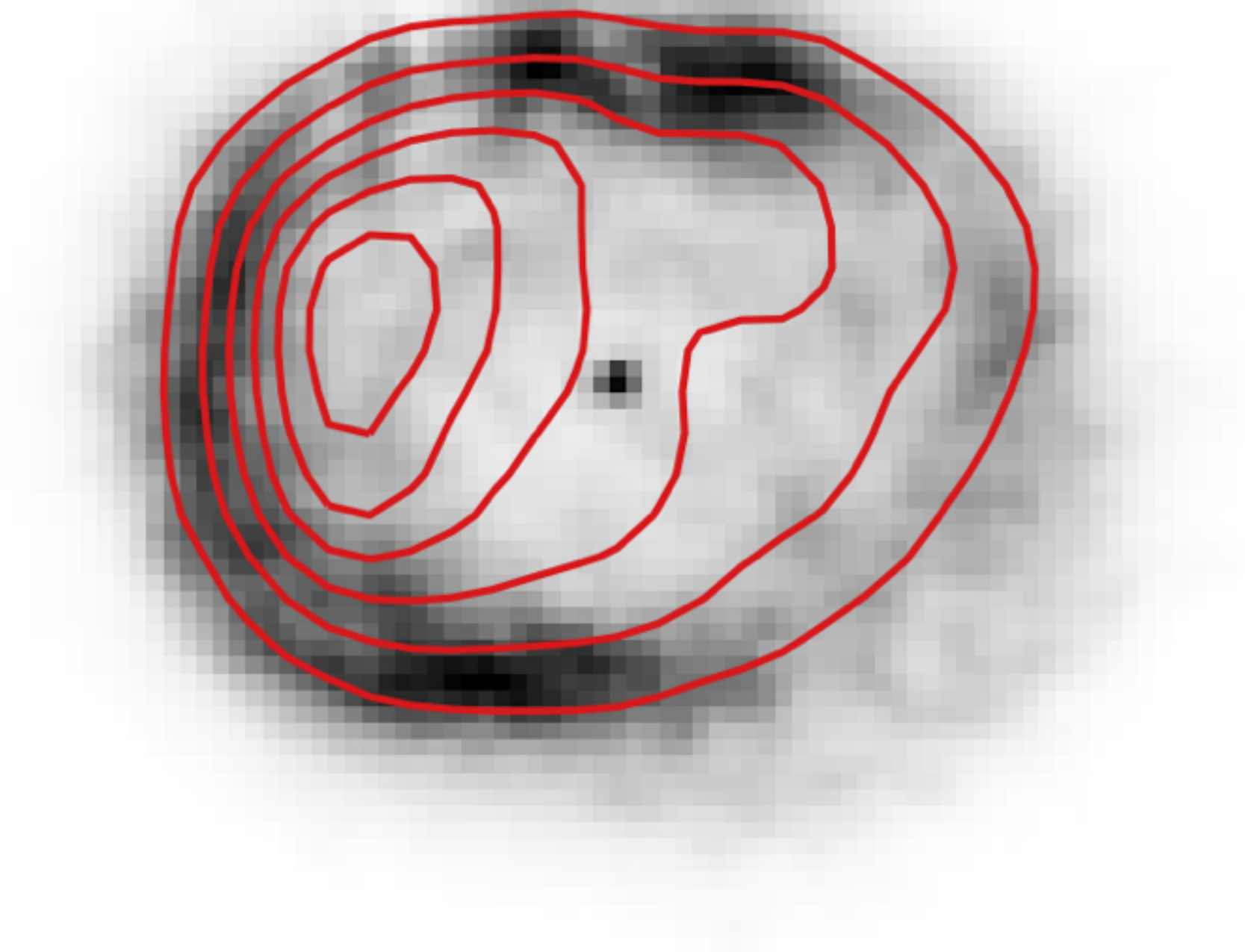
**bare CVII ions crossing CD recombining with cooler nebular plasma**



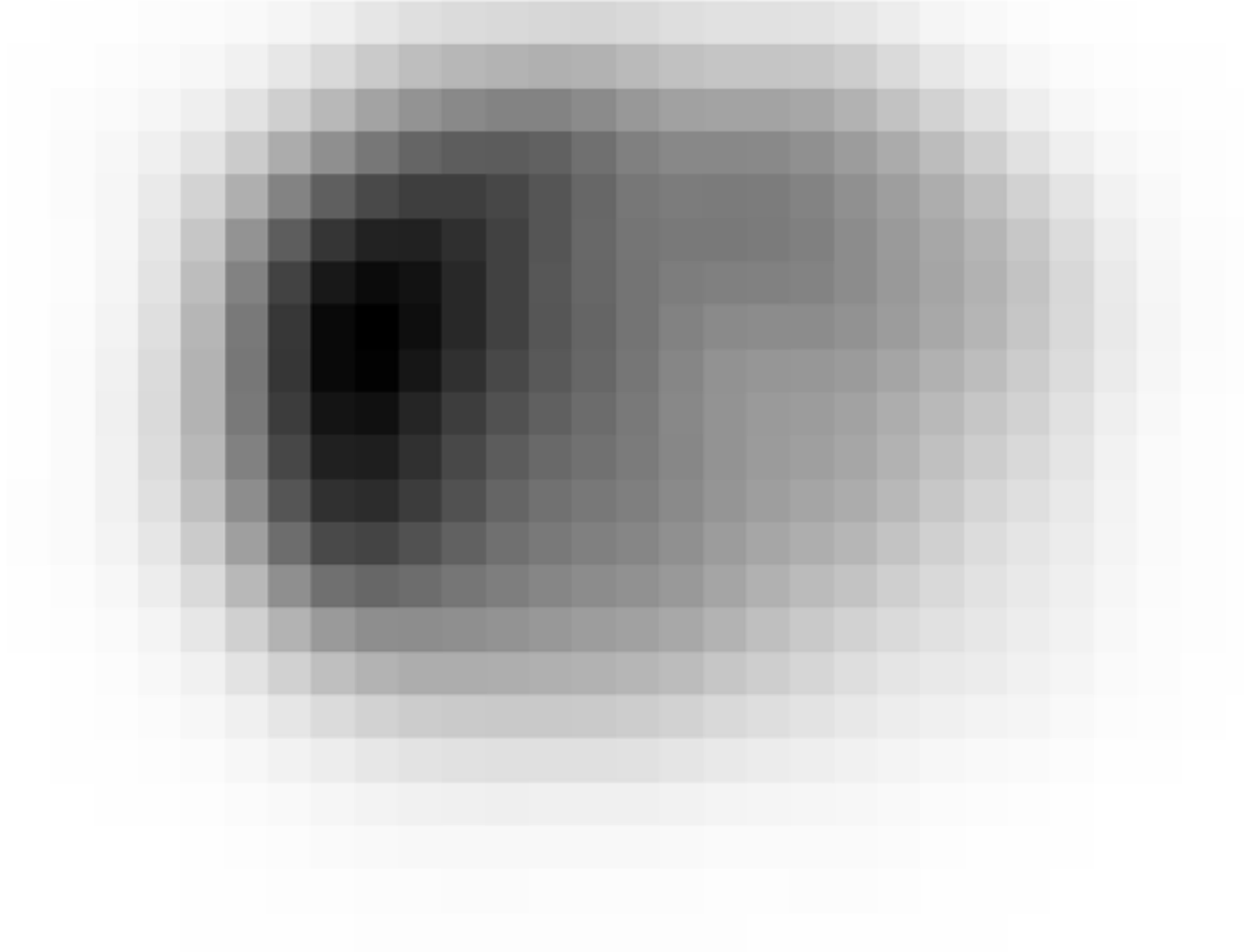
**100 ks**
**CXO**
**ACIS-S**



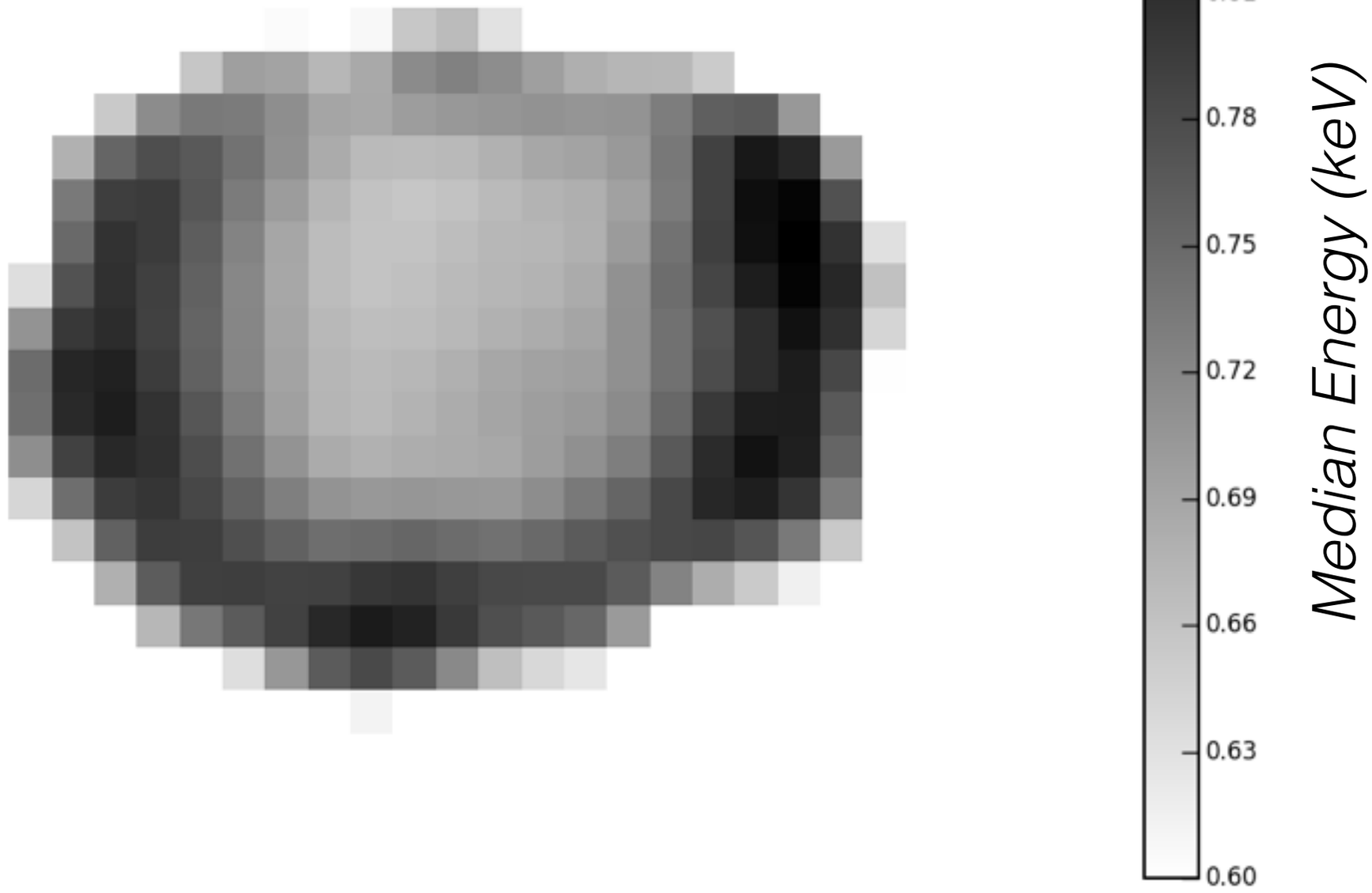
*Chandra X-ray Image*



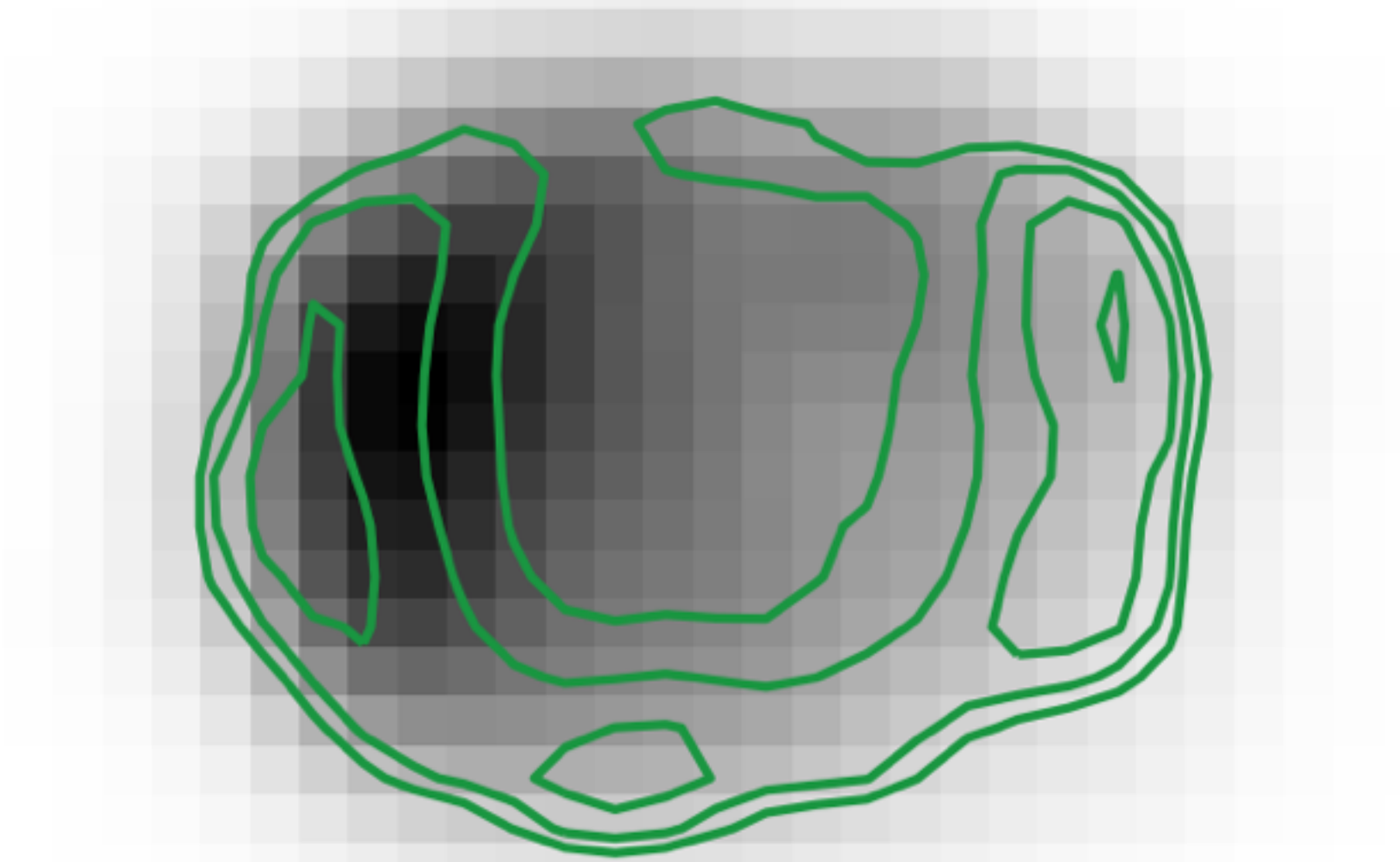
*X-ray Contours on H-alpha Image*



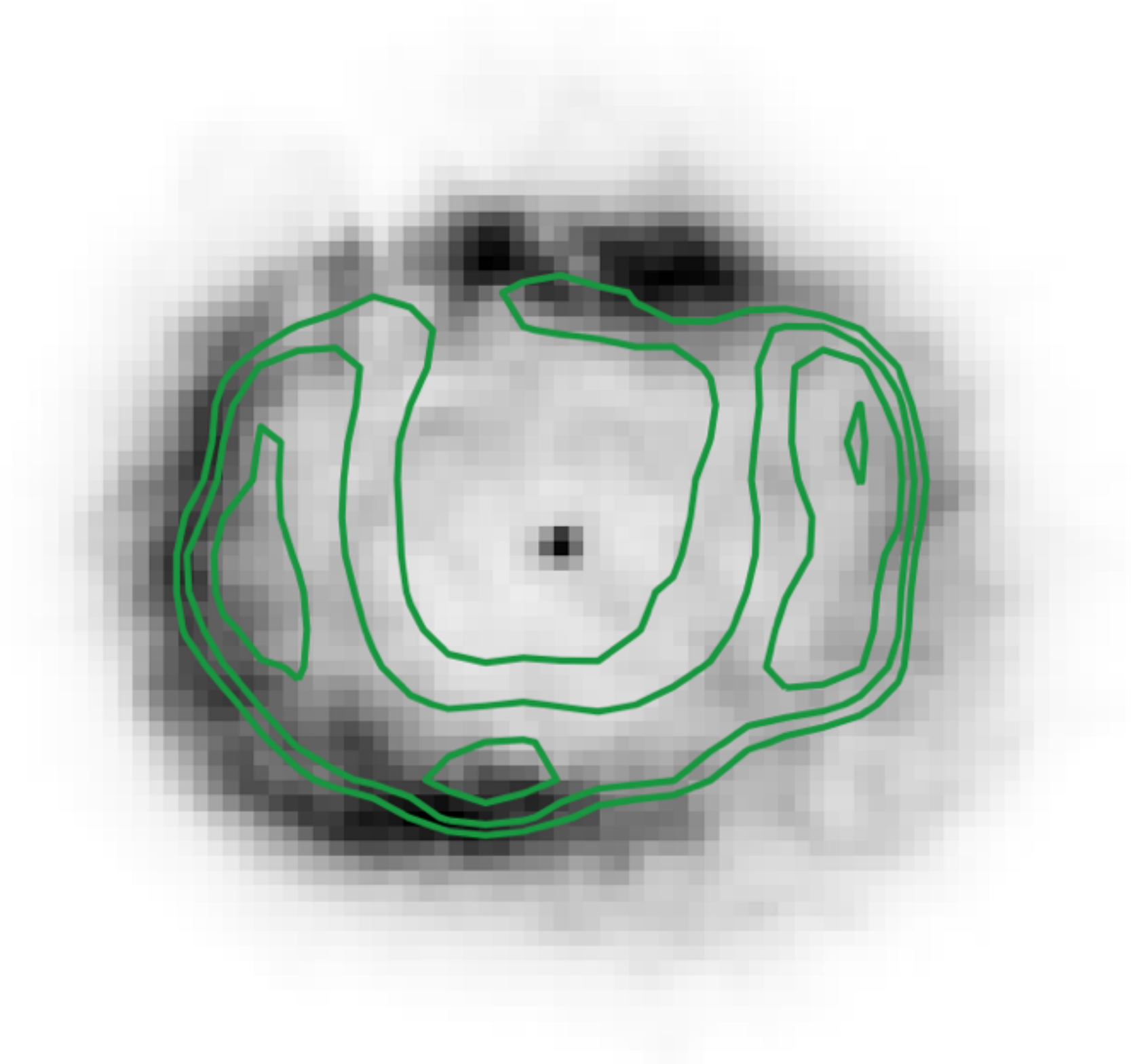
*Chandra X-ray Image*



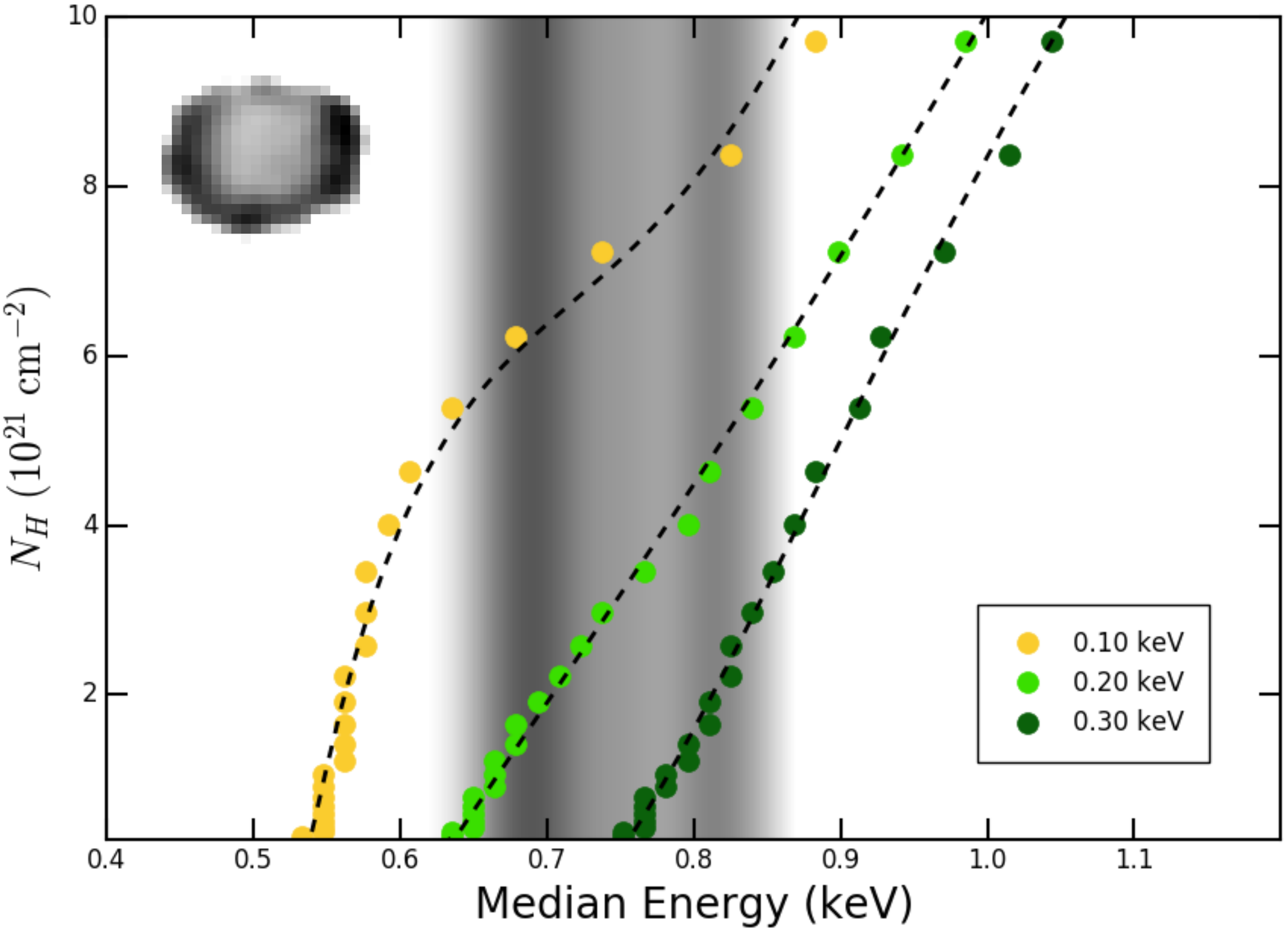

Median Energy Image



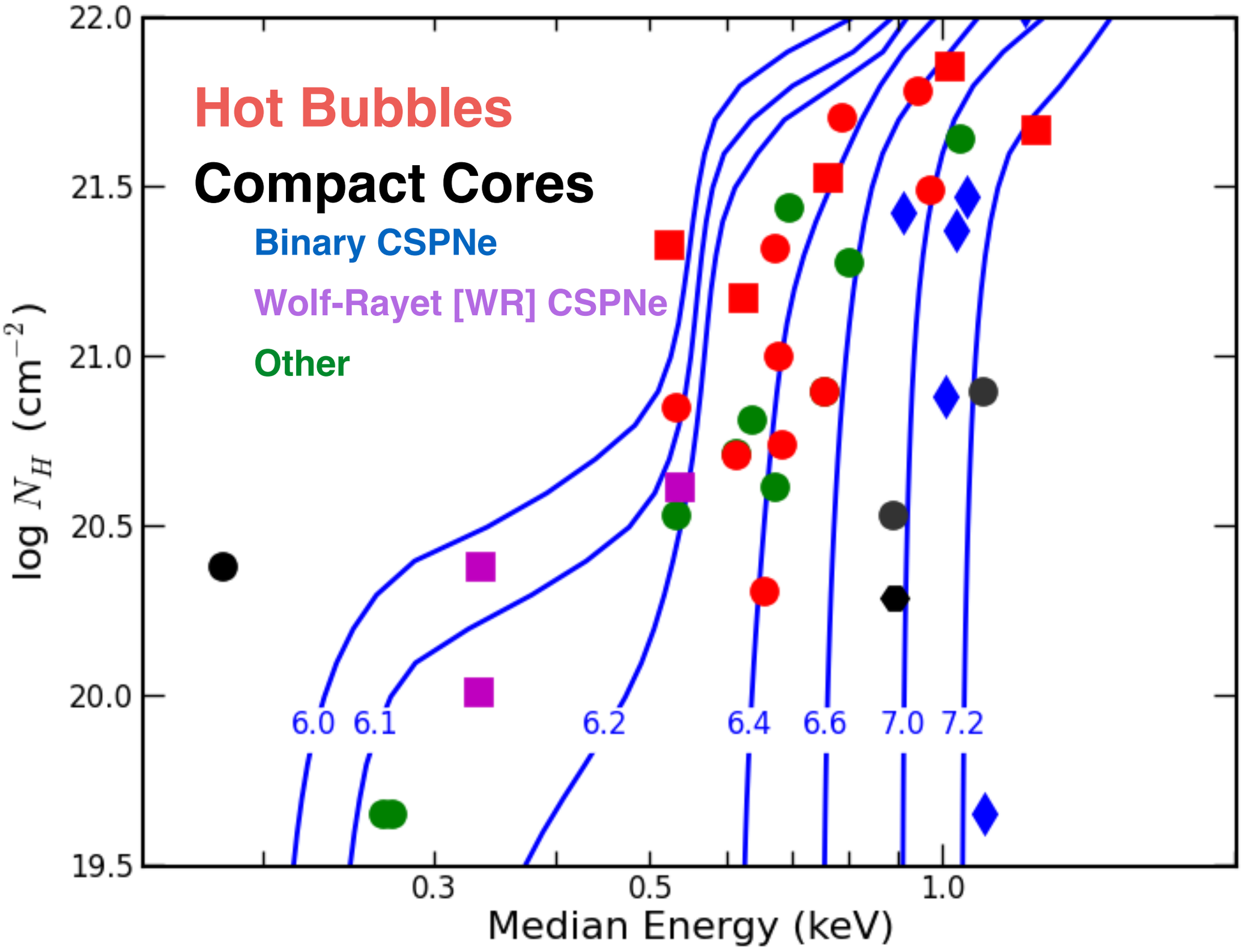
*Median Energy Contours on X-ray Image*



*Median Energy Contours on H-alpha Image*

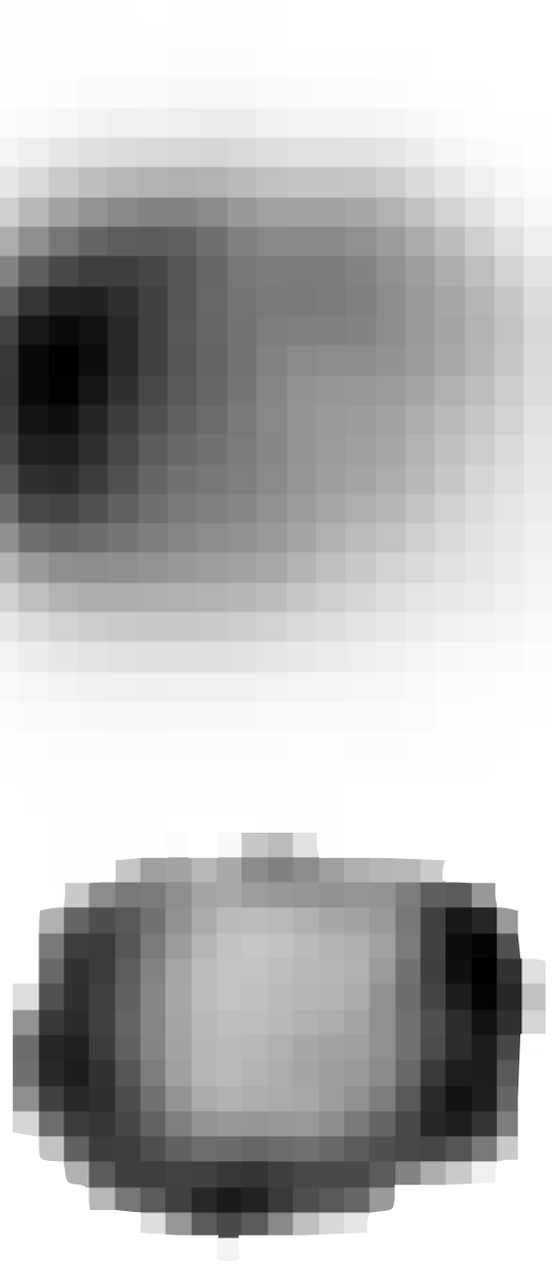



*MEKAL Plasma Models in the $N_H$–Median Energy Plane*

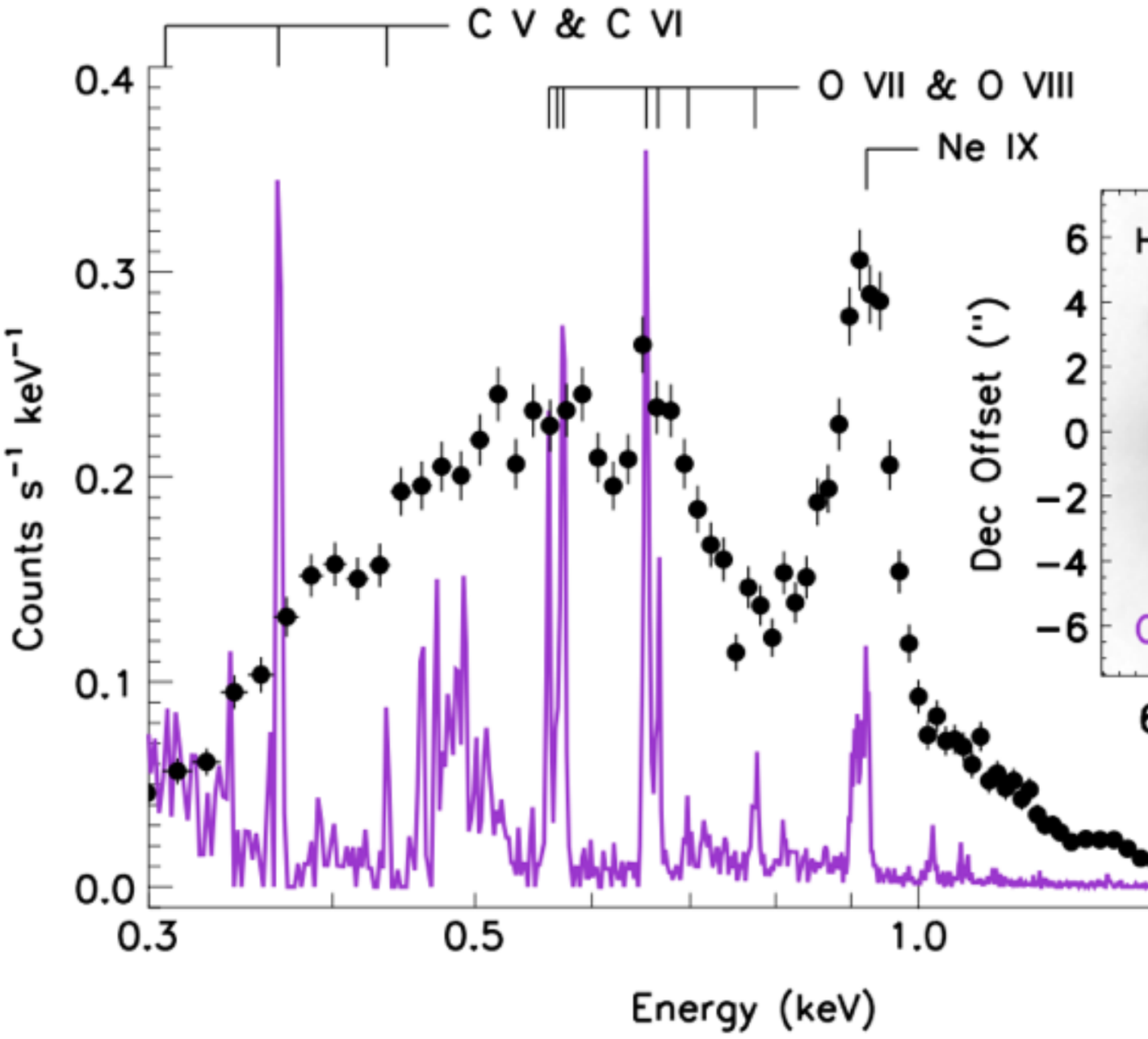



Kastner et al. 2012, Freeman et al. 2014,
Montez et al. 2016, Montez et al. 2017 [in prep]

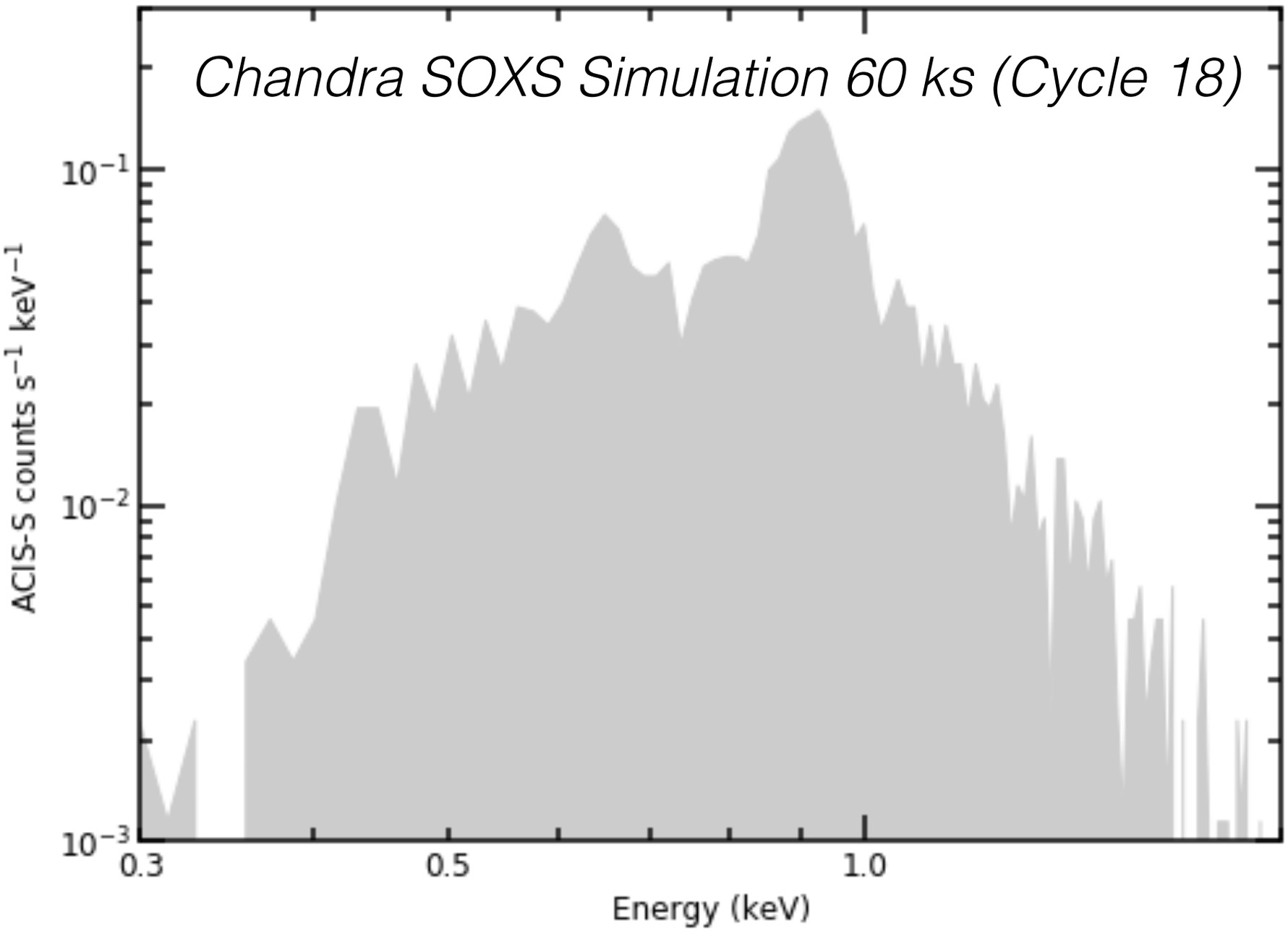
# 100 ks CXO ACIS-S



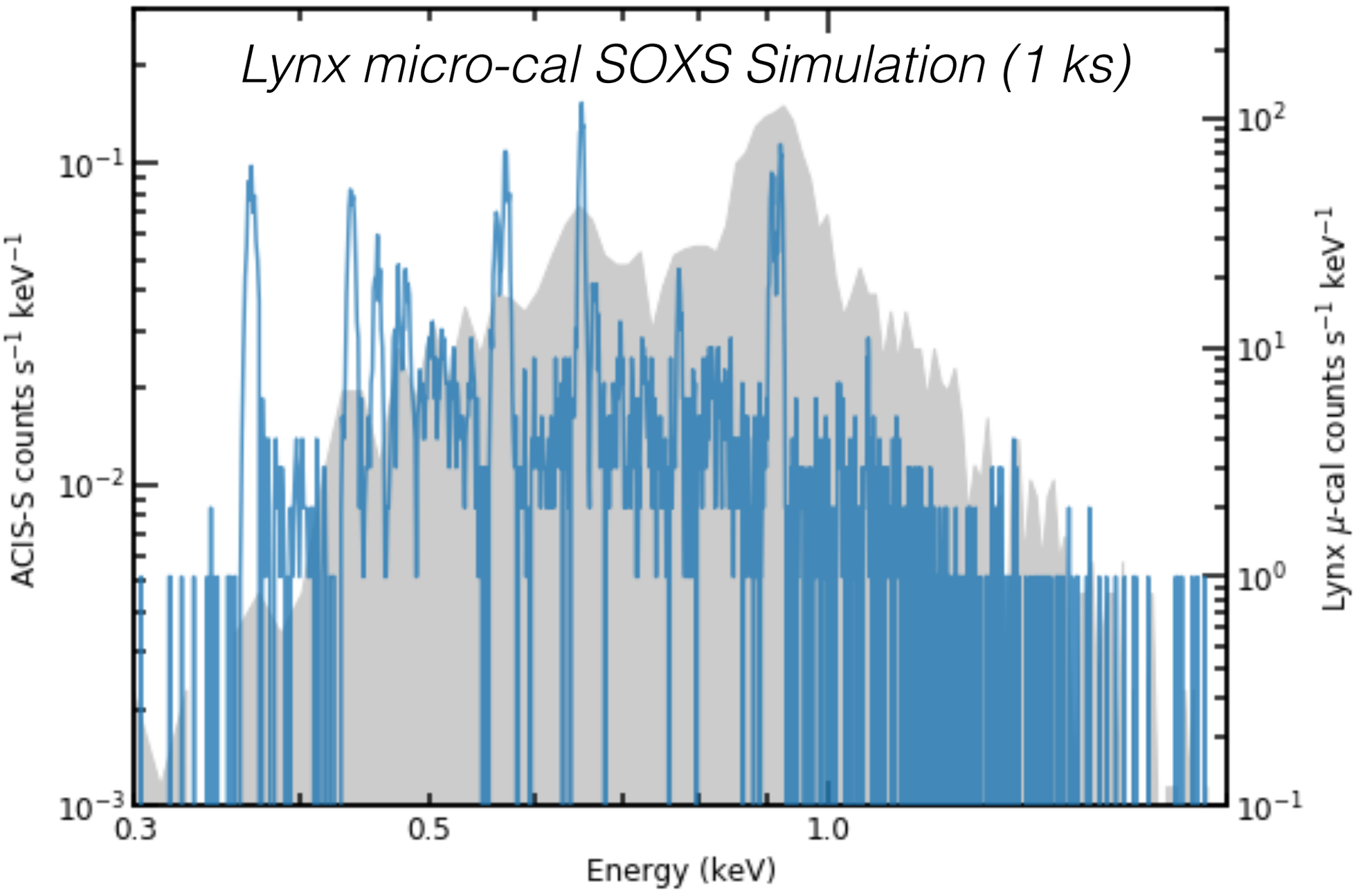
# 300 ks CXO LETG



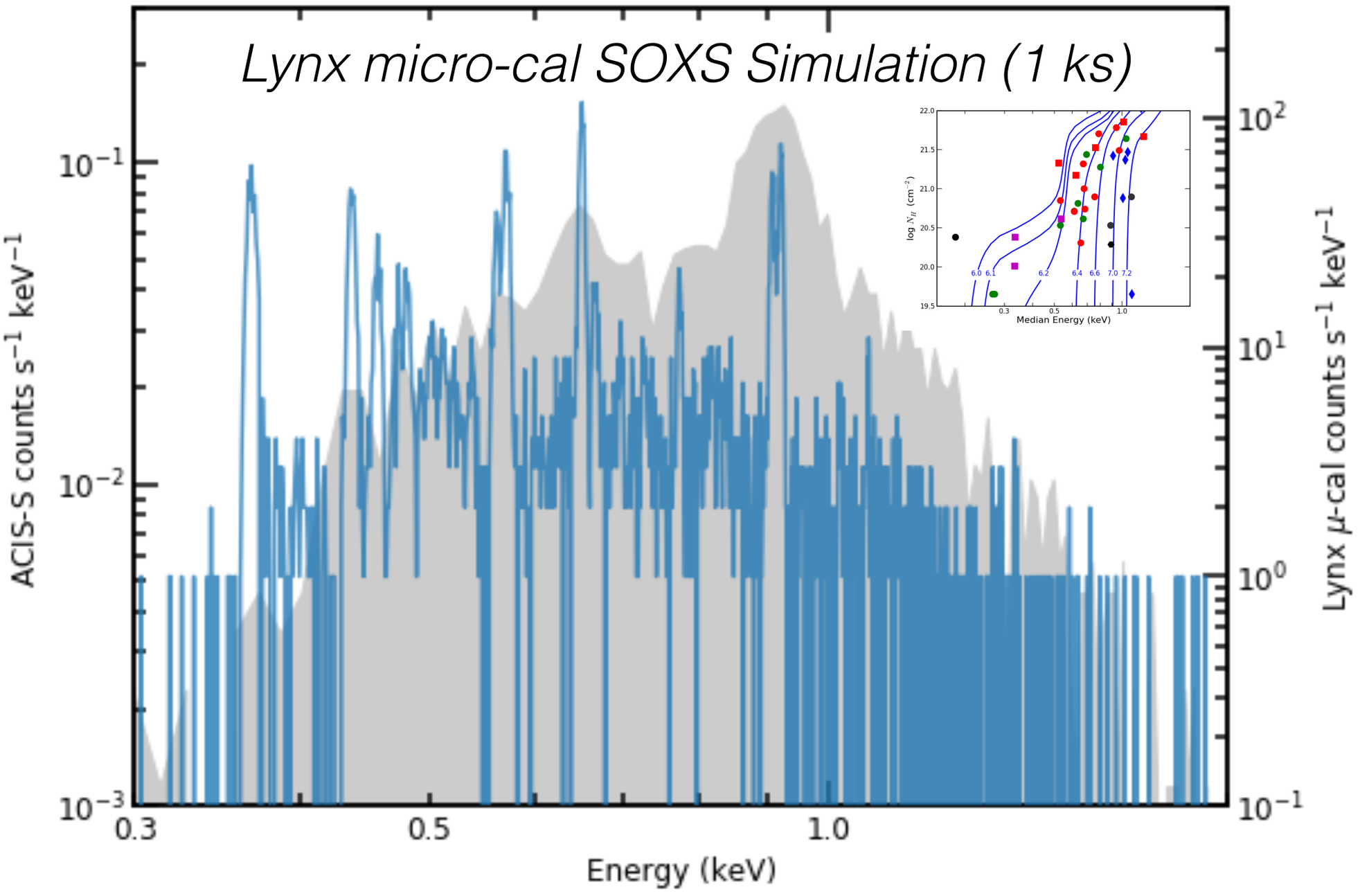
# TO LYNX


Chandra SOXS Simulation 60 ks (Cycle 18)
$10^{-1}$
$10^{-2}$
$10^{-3}$
ACIS-S counts $s^{-1}$ $keV^{-1}$
0.3
0.5
1.0
Energy (keV)

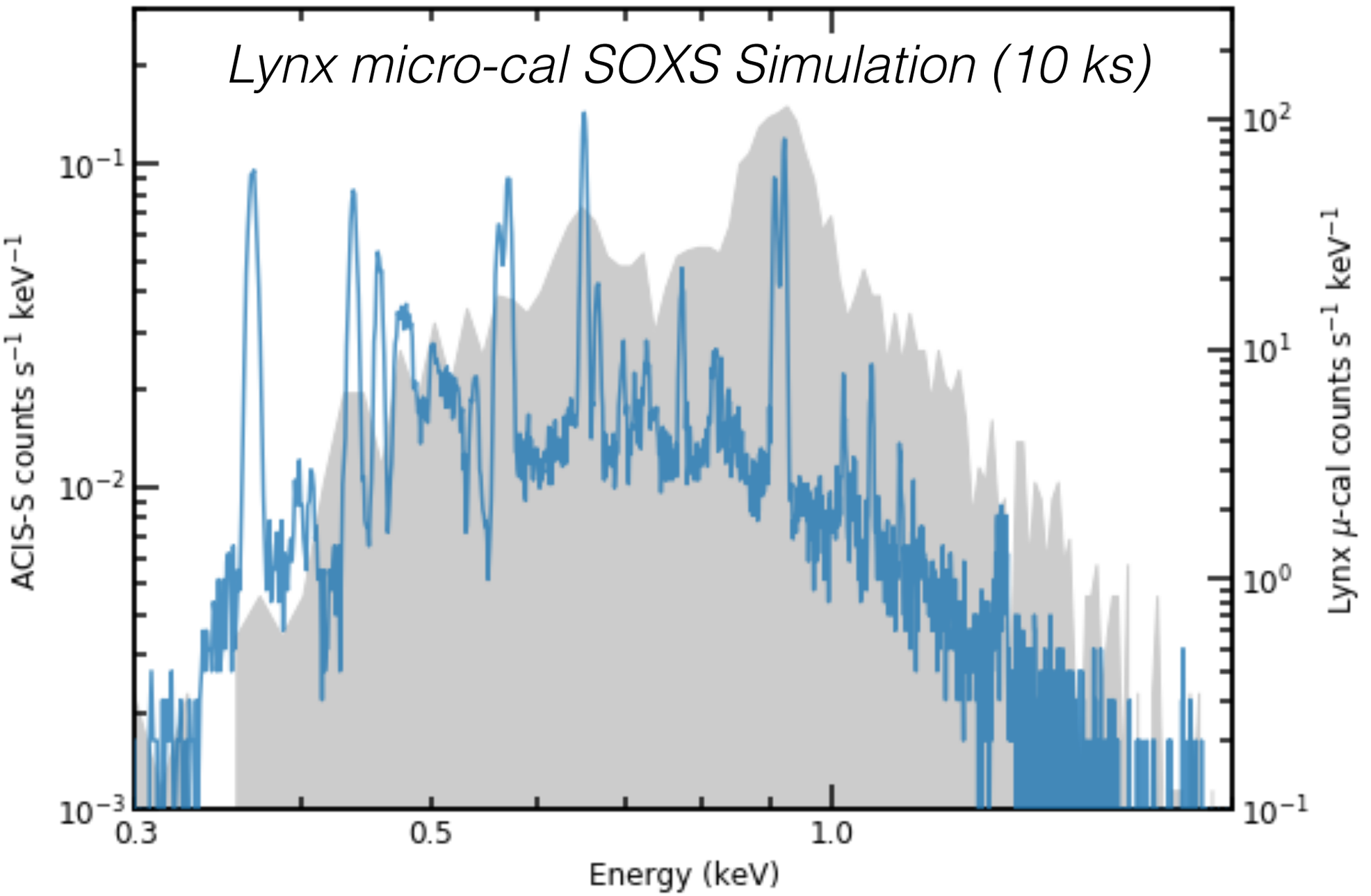
# TO LYNX


Lynx micro-cal SOXS Simulation (1 ks)
ACIS-S counts s$^{-1}$ keV$^{-1}$
Lynx $\mu$-cal counts s$^{-1}$ keV$^{-1}$
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{2}$
$10^{1}$
$10^{0}$
$10^{-1}$
0.3
0.5
1.0
Energy (keV)

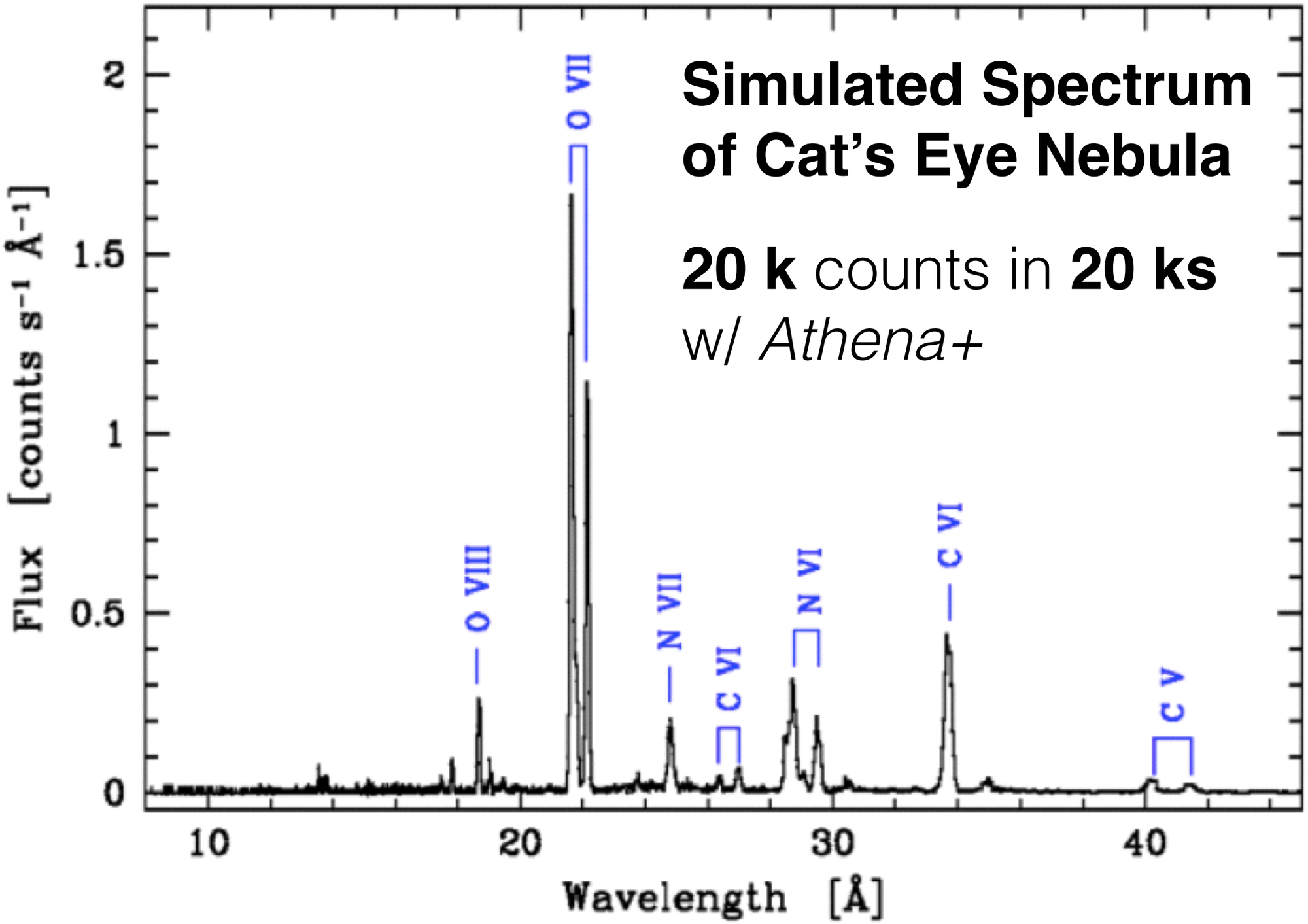
# TO LYNX


Lynx micro-cal SOXS Simulation (1 ks)
ACIS-S counts s$^{-1}$ keV$^{-1}$
Lynx $\mu$-cal counts s$^{-1}$ keV$^{-1}$
Energy (keV)
log $N_H$ (cm$^{-2}$)
Median Energy (keV)
6.0 6.1 6.2 6.4 6.6 7.0 7.2

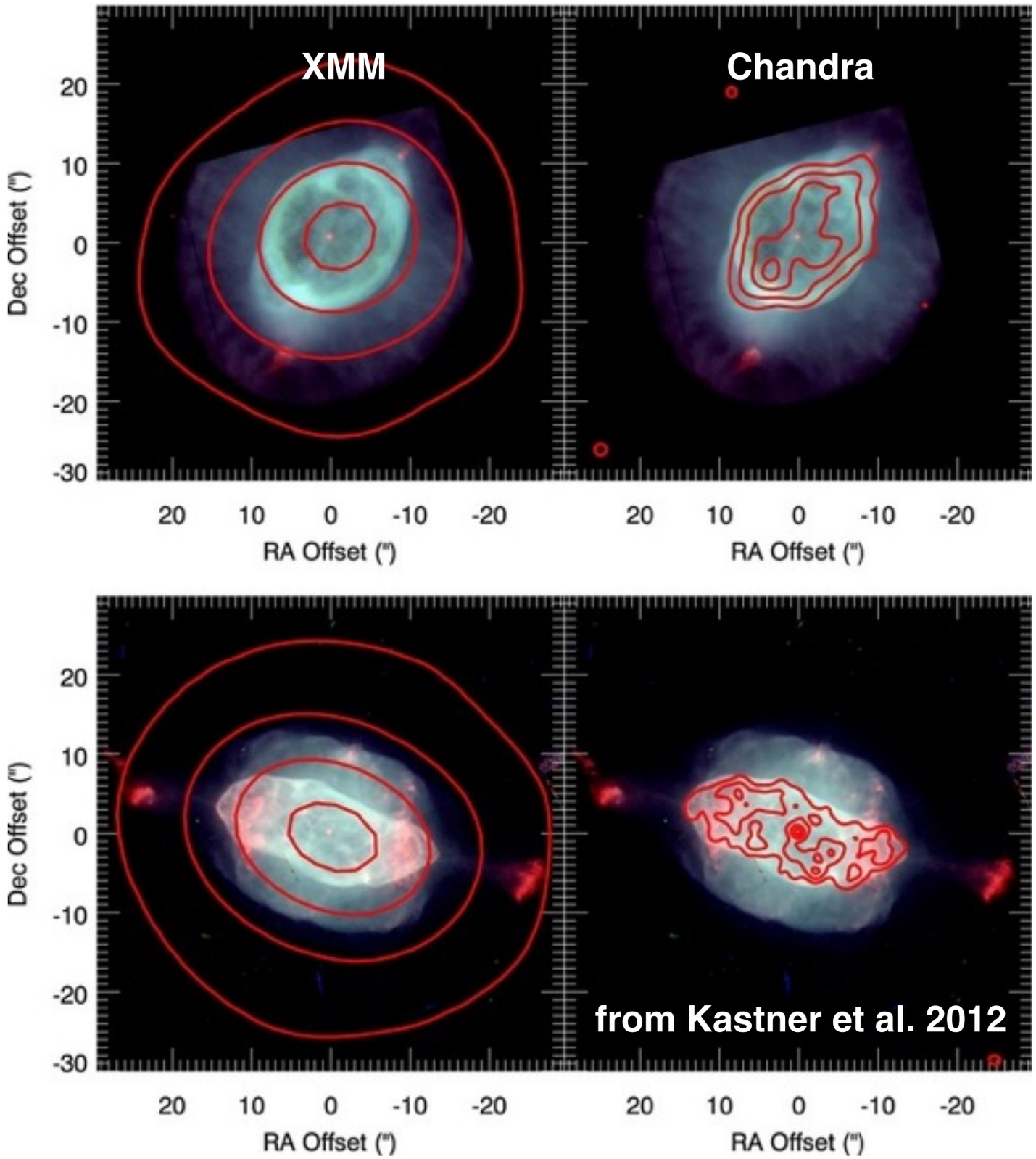
# TO LYNX


Lynx micro-cal SOXS Simulation (10 ks)
ACIS-S counts s$^{-1}$ keV$^{-1}$
Lynx $\mu$-cal counts s$^{-1}$ keV$^{-1}$
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{2}$
$10^{1}$
$10^{0}$
$10^{-1}$
0.3
0.5
1.0
Energy (keV)

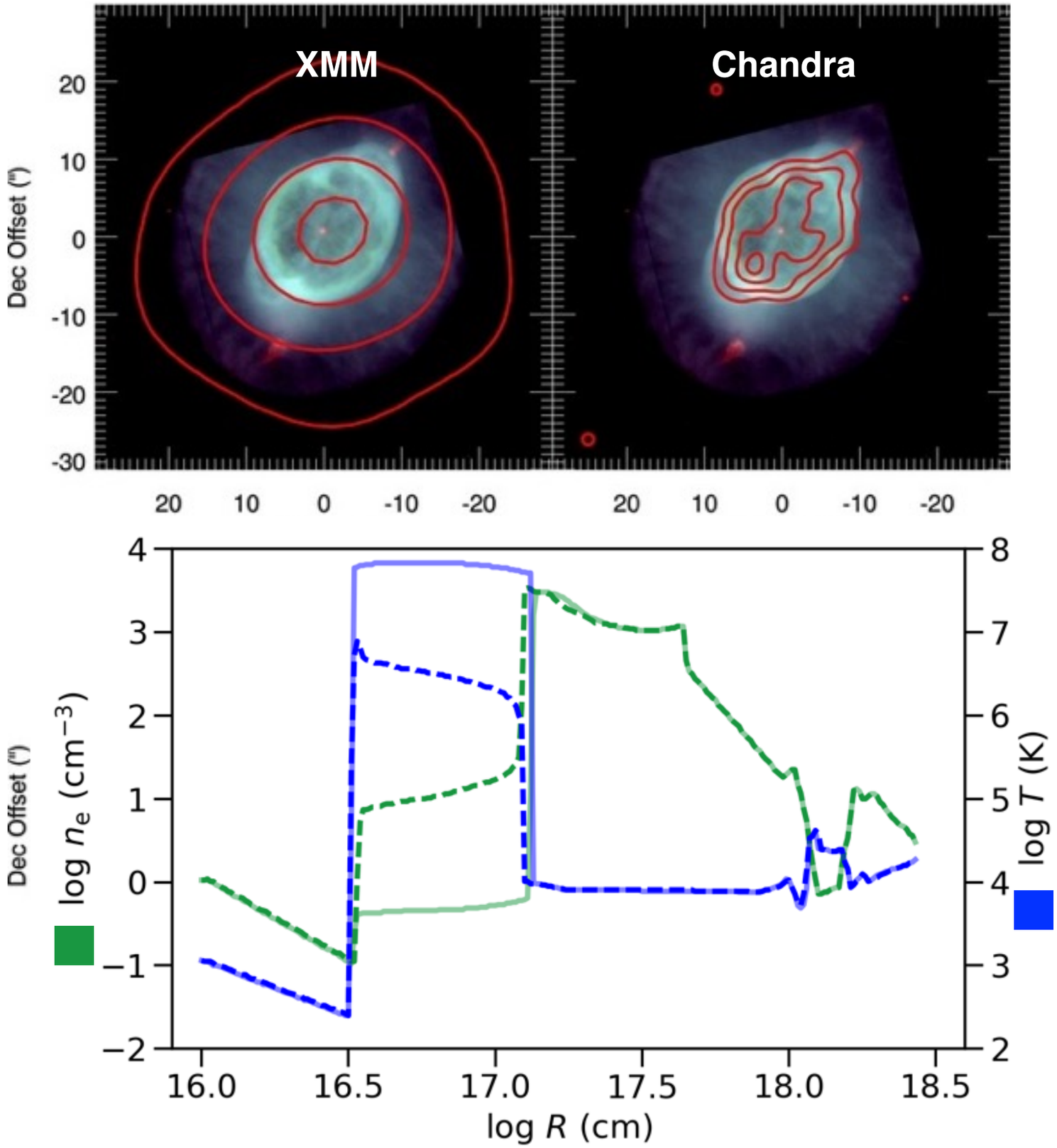
# YEAH, NICE SPECTRUM WITH ATHENA+

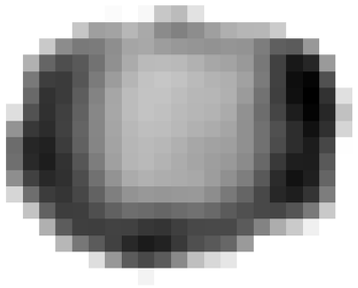


# BUT SPATIAL RESOLUTION MATTERS



# BUT SPATIAL RESOLUTION MATTERS



# CONCLUSIONS FROM CHANPLANS TO LYNX

Planetary nebulae serve as astrophysical probes of:

- plasma and radiation processes
- test of stellar evolutionary models

X-ray observations can provide insight to:

- the shocks that form PNe (the elusive fast wind mechanism)
- heat conduction physics in a variety of chemical environments
- heat conduction suppression by magnetic fields
- post-common envelope binary star evolution

**PEAK CHANPLANS**

# CONCLUSIONS FROM CHANPLANS TO LYNX

Planetary nebulae serve as astrophysical probes of:

- plasma and radiation processes
- test of stellar evolutionary models

X-ray observations can provide insight to:

**LYNX+**
- the shocks that form PNe (the elusive fast wind mechanism)

**LYNX**
- heat conduction physics in a variety of chemical environments

**LYNX**
- heat conduction suppression by magnetic fields

**LYNX+**
- post-common envelope binary star evolution

**PEAK CHANPLANS**