Probing the cooling of the Central Compact Object in the Cas A supernova remnant

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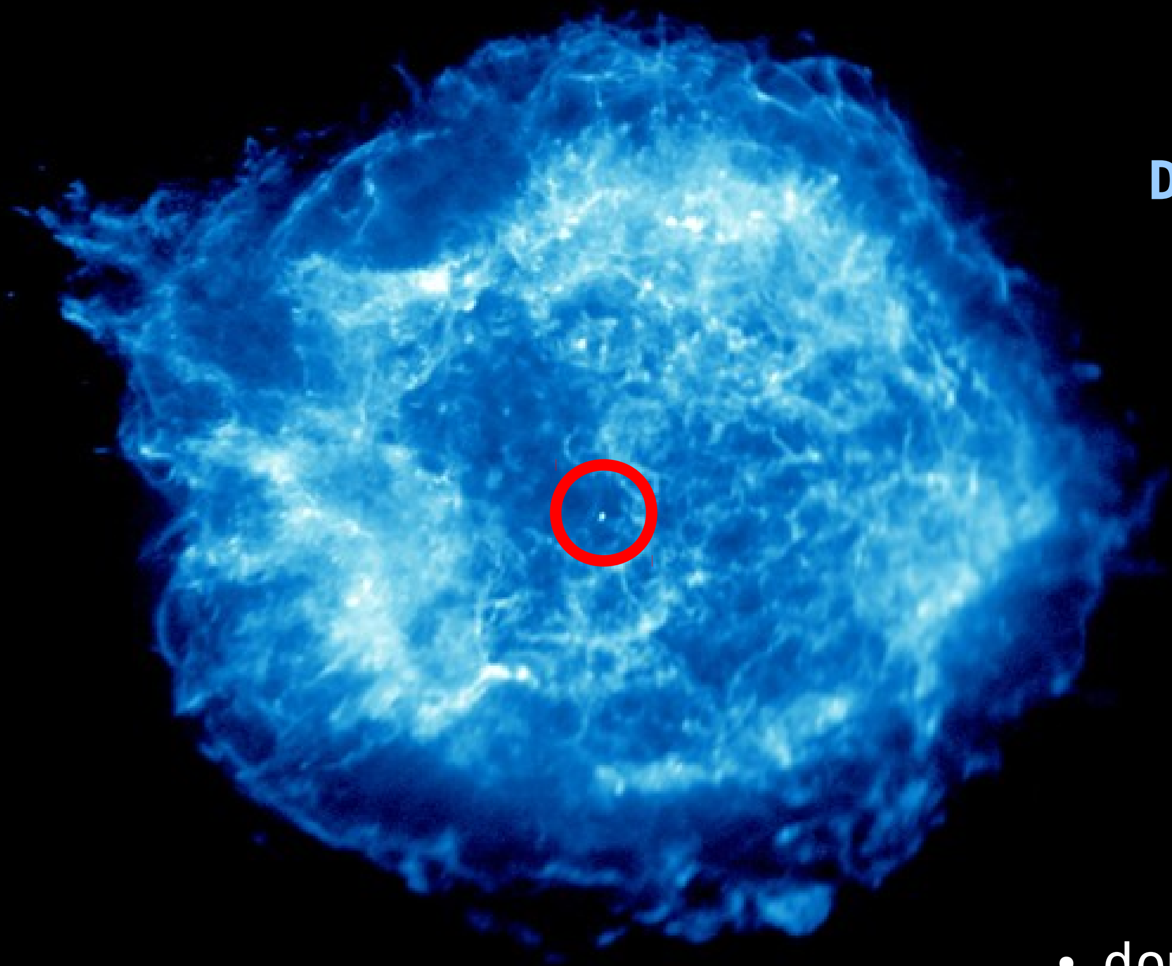
Cassiopeia A SNR and CCO



SNR

Distance: 3.4 (+0.3/-0.1) kpc

Age: ~ 330 years

CCO

no pulsations detected

Pulsed fraction limits:

< ~30% for P> 0.3 s

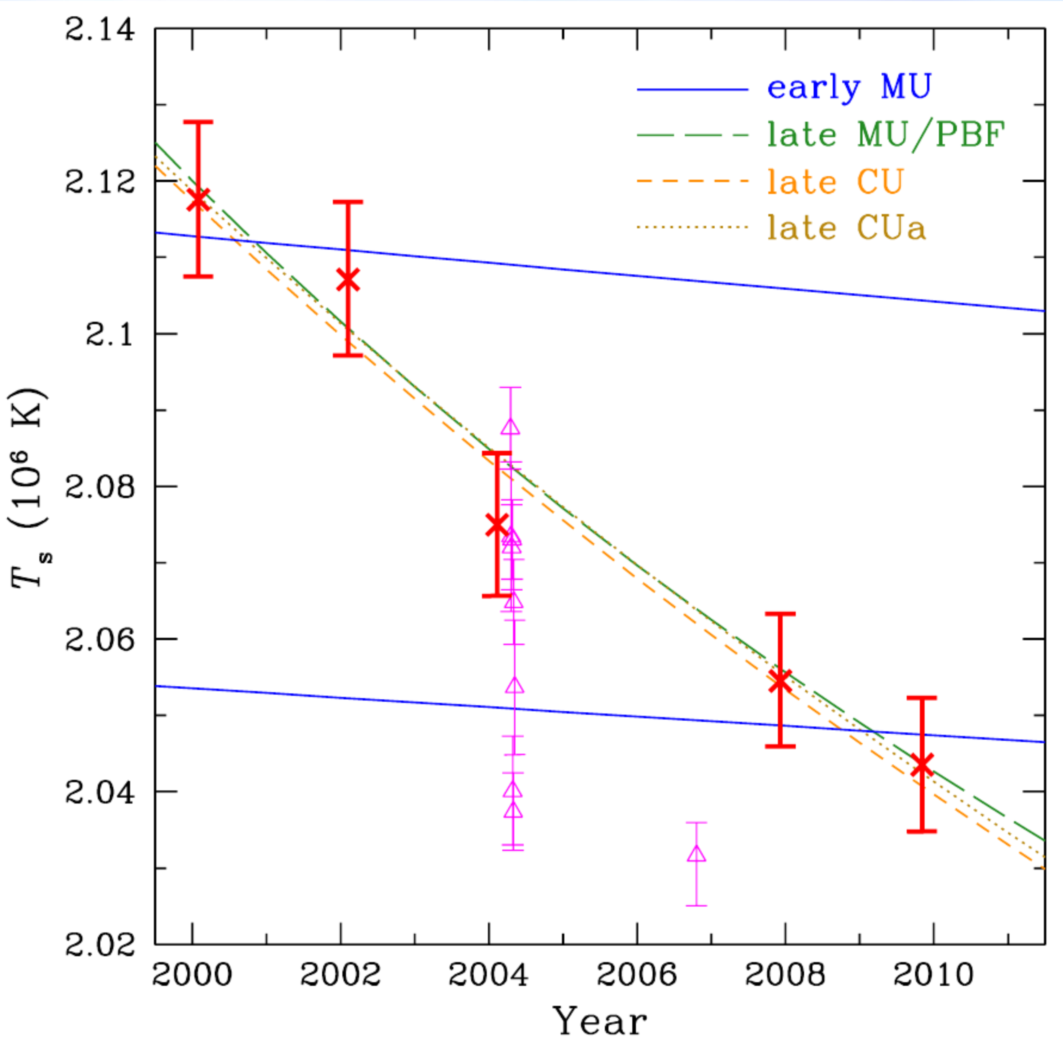
< 16% for P> 0.68 s

Spectrum:

- dominated by thermal emission
- small emission area for H atmosphere or blackbody models
- emission area ~ NS surface area for carbon atmospheres models

Reed et al. 1992, Ashworth 1980, Mereghetti et al. 2002, Pavlov & Luna 2009, Ho & Heinke 2009

The temperature decline of the Cas A CCO



Heinke & Ho 2010

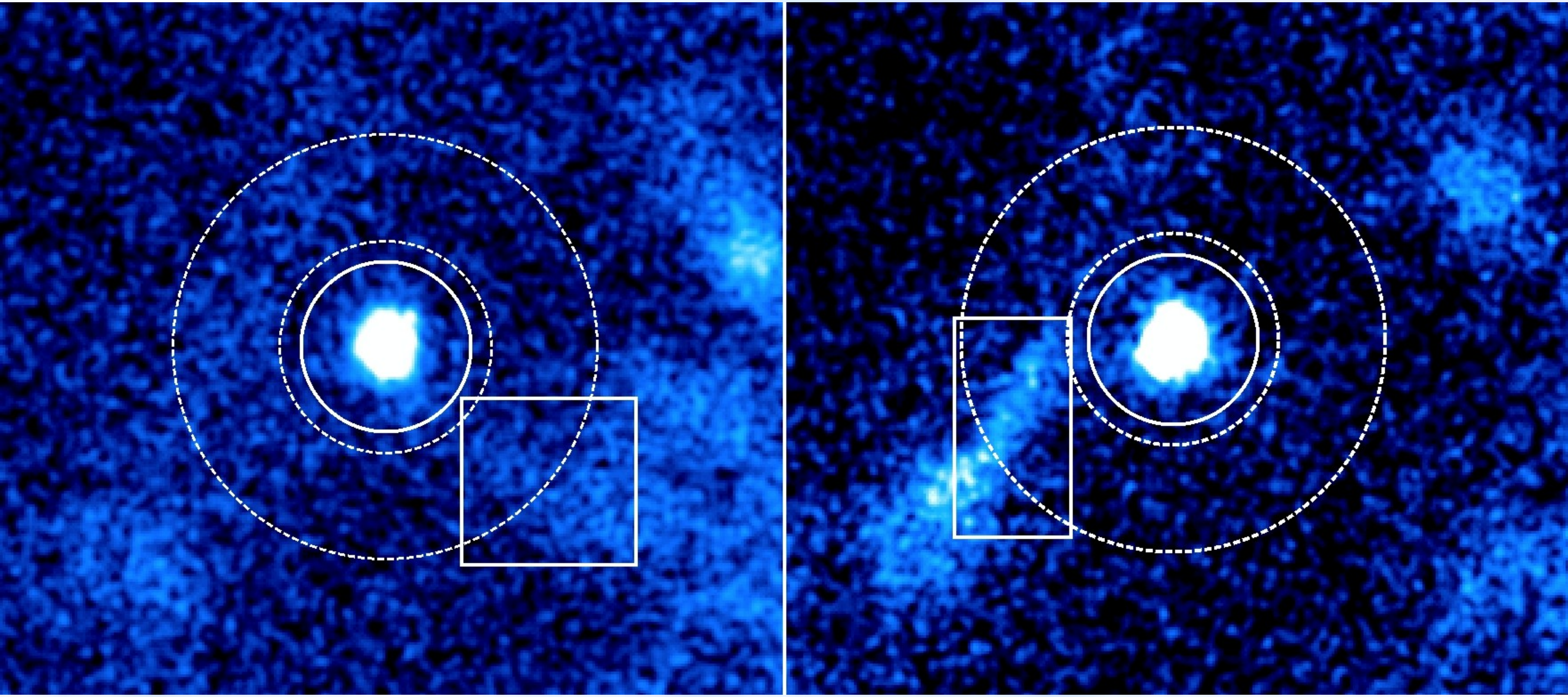
in ~10 years: ΔT = 4% (5.4σ)
ΔFlux = 21%

➡ first direct evidence for superfluidity in neutron star core
(e.g., Page et al. 2011, Shternin et al. 2011)

❗ data is subject to the pile-up effect (~ 20 %)
➡ possible spectral distortions

Dedicated CCO observations

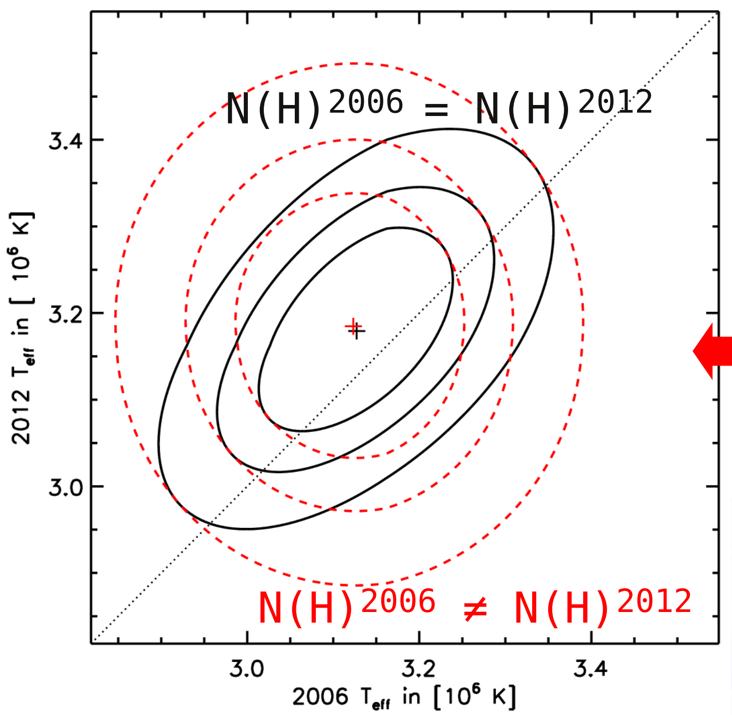
October 2006 (61.7 ks) **May 2012** (63.4 ks)



ACIS-S3 sub-array mode (frame time 0.34s pile-up < 2%)

Spectra: binned with SNR>10; Energy range: 0.3 – 5.0 keV

Atmosphere Models

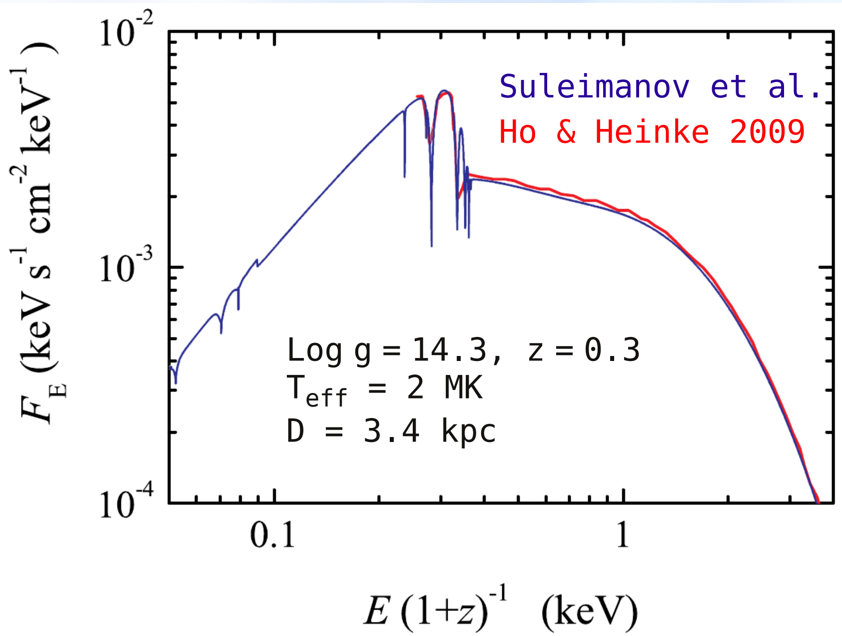


Hydrogen atmosphere (NSA, $B<10^{10}$G)

e.g., Pavlov & Luna 2009

No significant temperature change

Emission Area: ~10% of NS surface



Carbon atmosphere models

Suleimanov et al.
(in preparation)

Fit results for 2006 data consistent with those by Ho & Heinke 2009

Important spectral model parameters

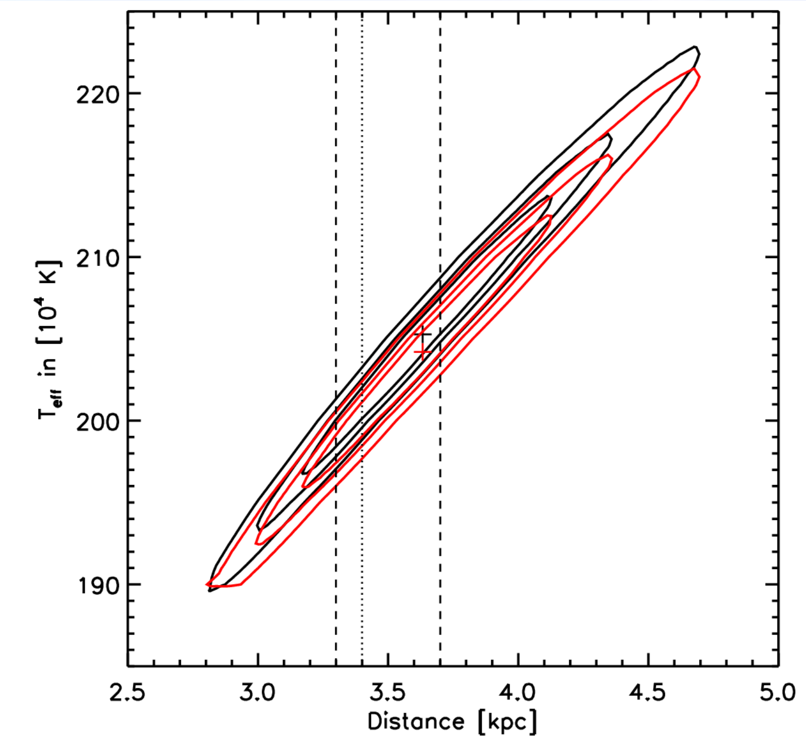
N(H) in the Interstellar Absorption
Is it the same in all epochs ?
(effect on T and ΔT → next slide)

Distance in Normalization
What is the effect of
the distance uncertainty ?

(effect on ΔT → next slide)

effect on T : →

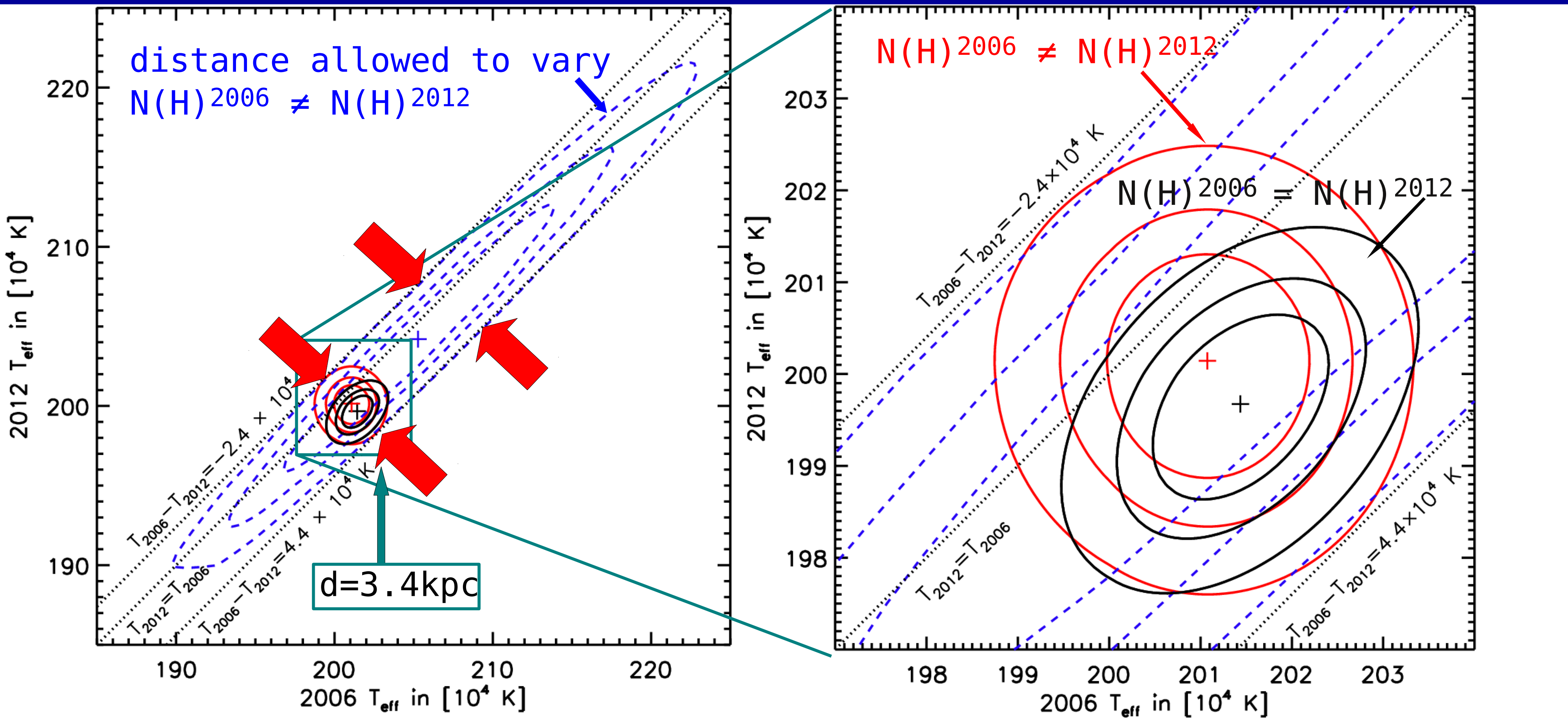
a large temperature uncertainty



Additional influence on spectral fit results:

Effects due to the ACIS contamination model
uncertainties in the used calibration

Dependencies of the uncertainty of ΔT



fit d ➡ $\Delta T = -1.1 \pm 1.9\ 10^4$K (0.5% of T^{2006})

All errors: 90% confidence level

$\Delta T = -0.9 \pm 1.8\ 10^4$K (0.5% of T^{2006}) ⬅ $N(H)^{2006} \neq N(H)^{2012}$

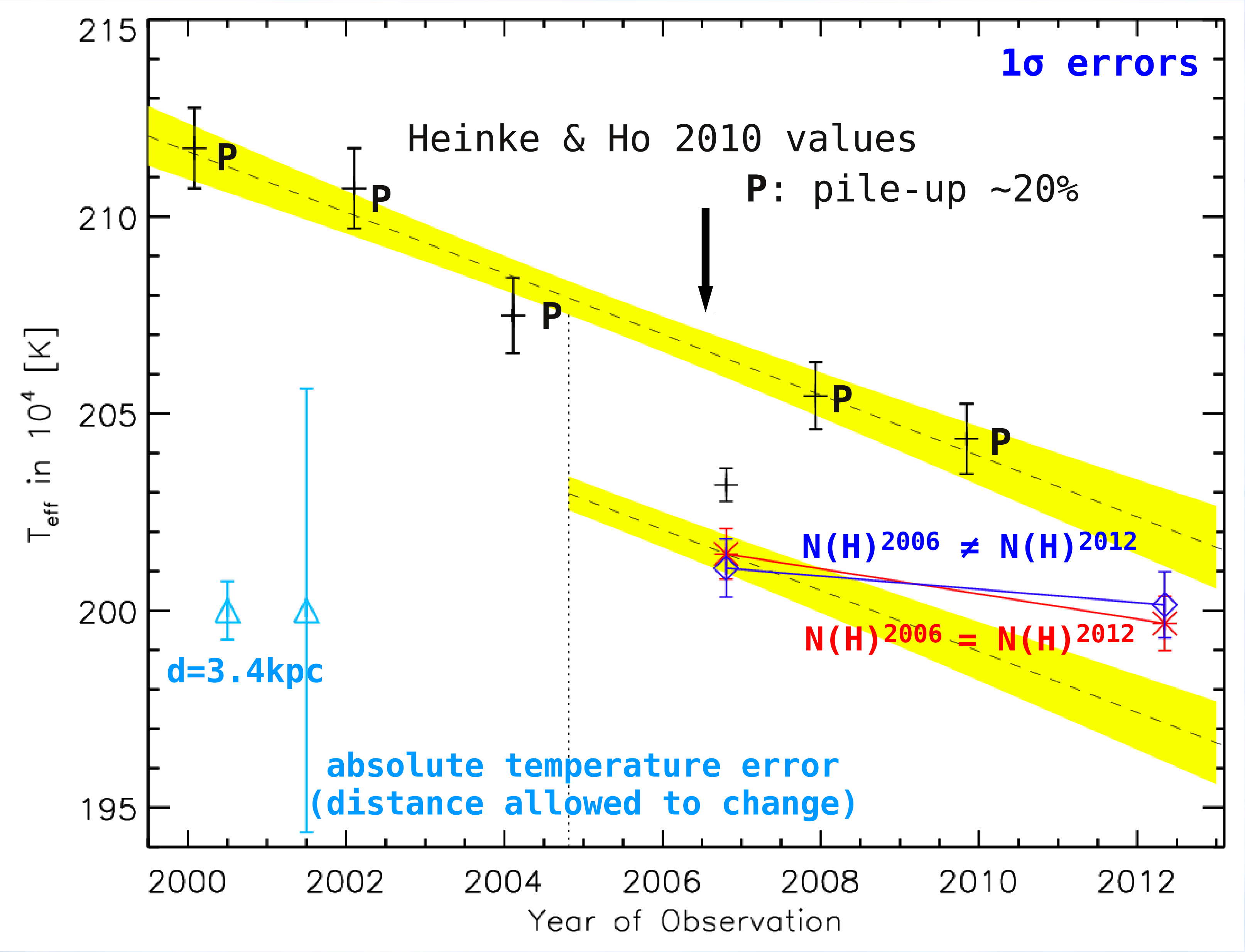
$\Delta T = -1.8 \pm 1.2\ 10^4$K (0.9% of T^{2006}) ⬅ $N(H)^{2006} = N(H)^{2012}$

Uncertainty of ΔTemperature is similar if distance fixed or not

Uncertainty of ΔTemperature is different if N(H) is tied or not

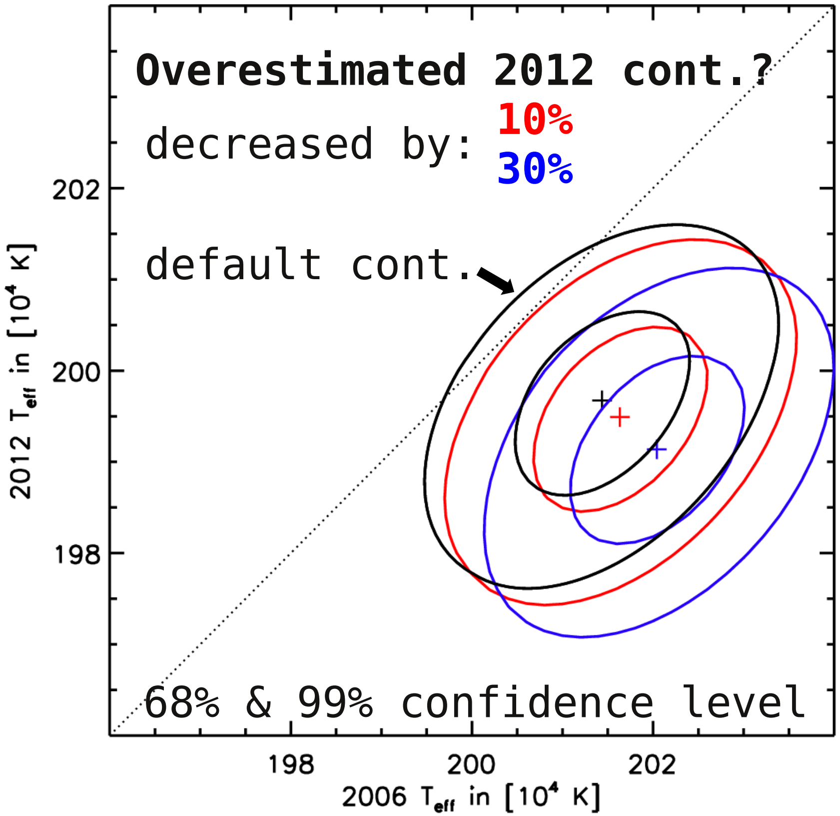
If different: $N(H)^{2006} = 2.25 \pm 0.06\ 10^{22}\ cm^{-2}$, $N(H)^{2012} = 2.30 \pm 0.07\ 10^{22}\ cm^{-2}$ (d=3.4kpc)

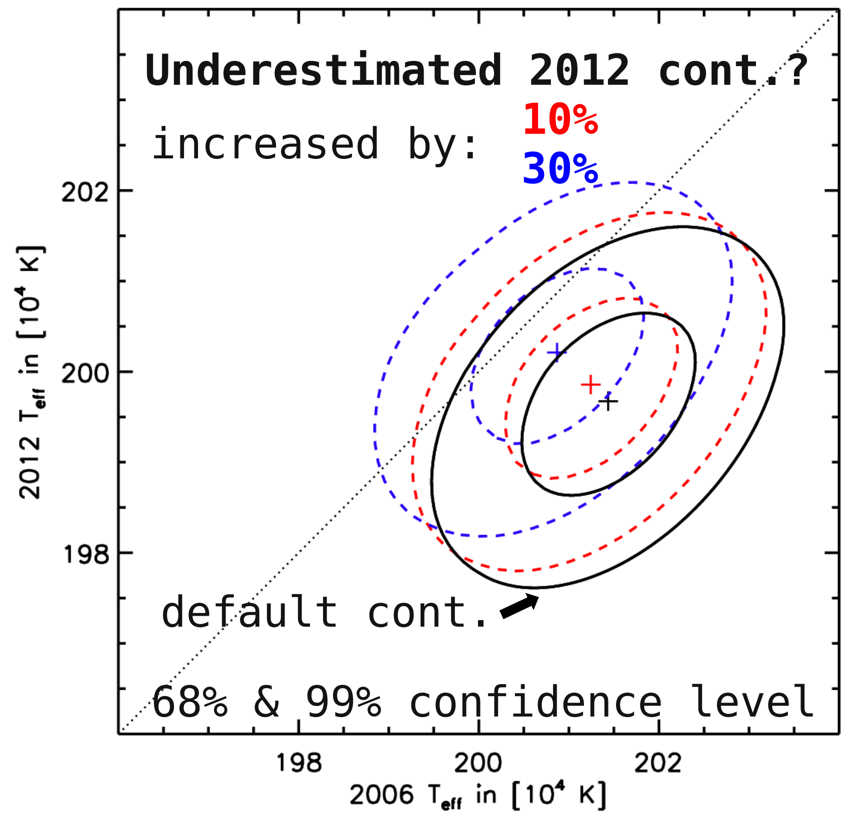
Check a simple picture: linear decline



The influence of the ACIS contamination

Contamination buildup changed in 2012 (likely accelerated)
Uncertainty in calibration of the contamination model ~10% at 0.67 keV





Absorbed Fluxes
[10^{-13} erg cm^{2} s^{-1}]

$N(H)^{2006} \neq N(H)^{2012}$

	2006	2012
2012 Cont. +10% :	7.34 (±0.18)	7.04 (±0.18)
Default 2012 cont. :	7.34 (±0.18)	6.99 (±0.18)
2012 Cont. -10% :	7.34 (±0.18)	6.94 (±0.18)

Plots for: Distance fixed at 3.4 kpc, $N(H)^{2006} = N(H)^{2012}$

Conclusions

No significant temperature change between 2006 and 2012
(carbon atmospheres, hydrogen atmospheres)

Allowing N(H) to change between epochs results in less significance of any temperature difference

Absolute temperature uncertainty much larger than the uncertainty of temperature difference

Indication of slight flux decrease (~4% in 6 years)
(however, just not significant at 90% confidence)

Good knowledge of calibration uncertainties important
(contamination, piled-up data in Heinke & Ho 2010)

more questions ? → posselt @ psu.edu