X-ray Properties of the Starburst-Driven Outflow in NGC 253

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Multi-Wavelength View of NGC 253

Superwind optical Hα (Westmoquette et al. 2011)

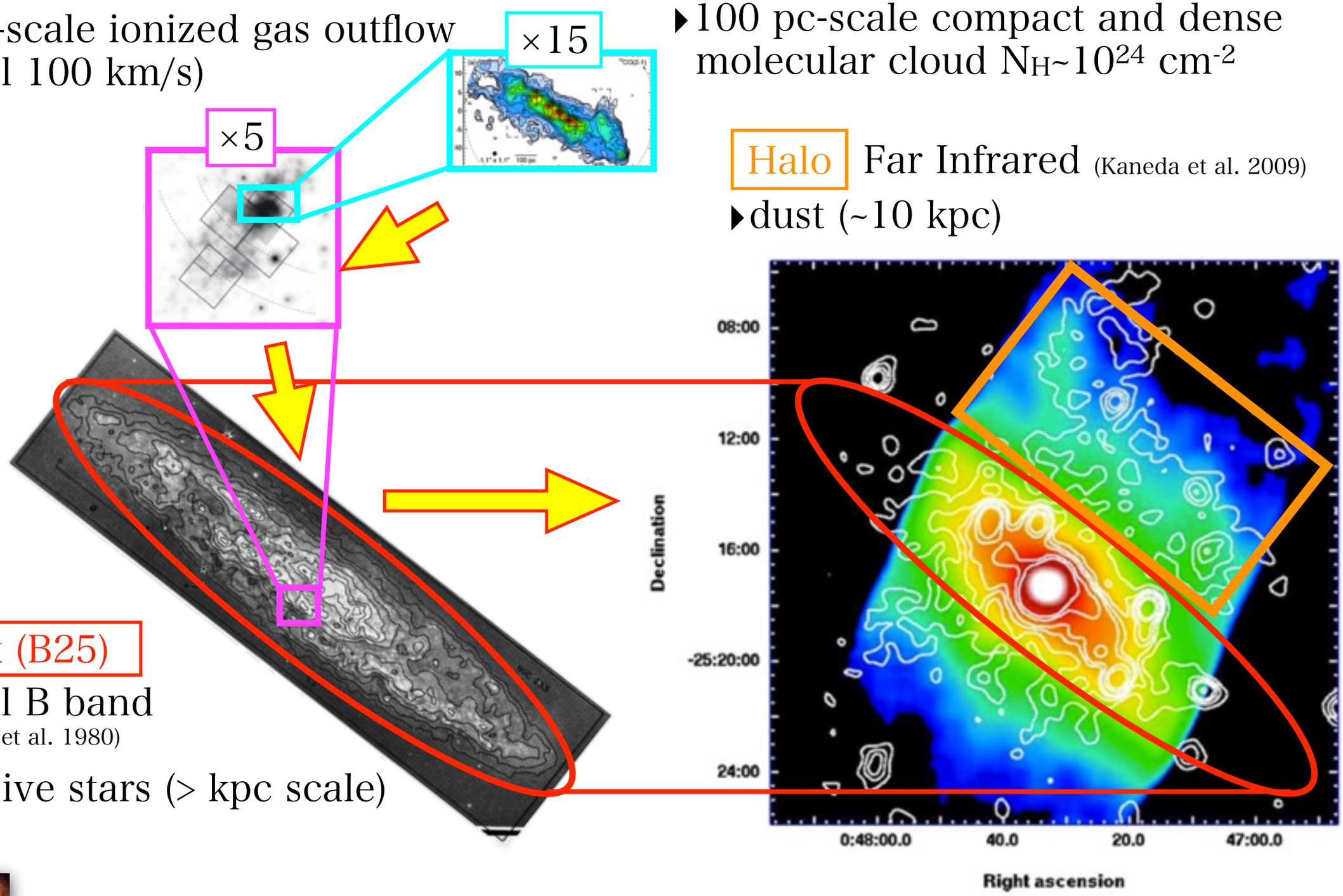
- <1 kpc-scale ionized gas outflow (several 100 km/s)

Nuclear Radio CO (Sakamoto et al. 2011)

- 100 pc-scale compact and dense molecular cloud N_H~10^{24} cm^{-2}

Halo Far Infrared (Kaneda et al. 2009)

- dust (~10 kpc)



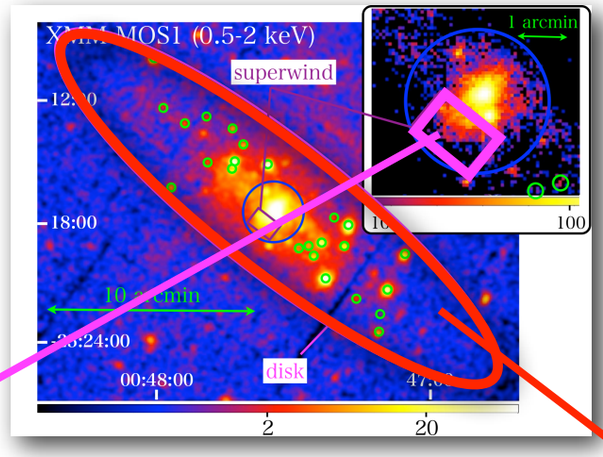
Disk (B25)

optical B band (Pence et al. 1980)

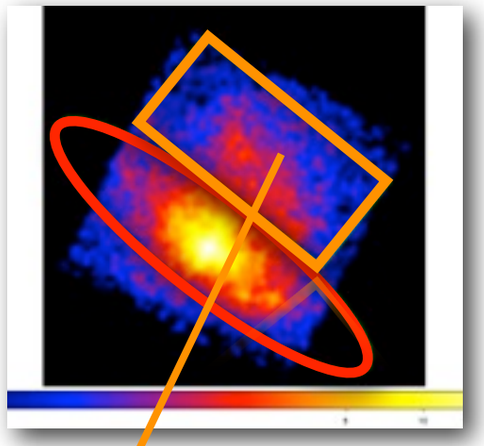
- massive stars (> kpc scale)

Spectral Fitting

XMM (0.5-2.0 keV)



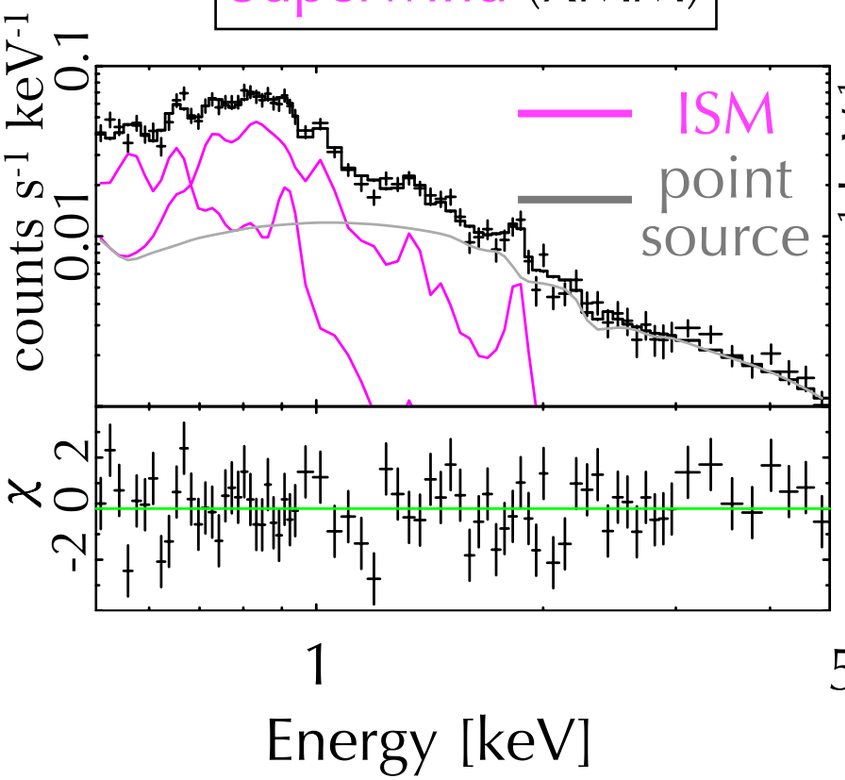
Suzaku (0.5-2.0 keV)

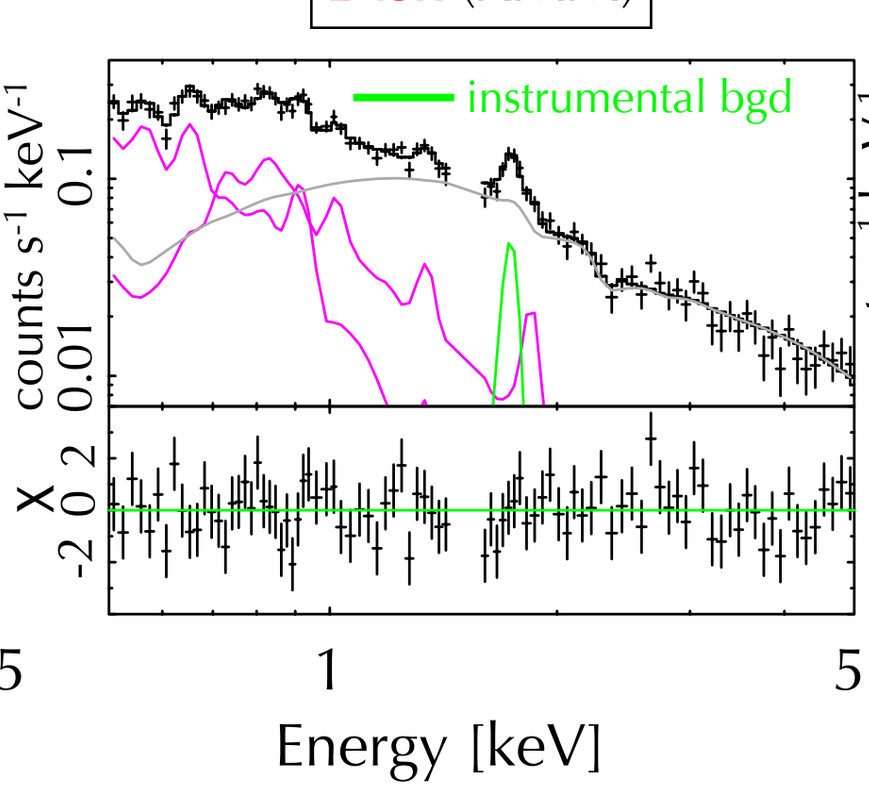


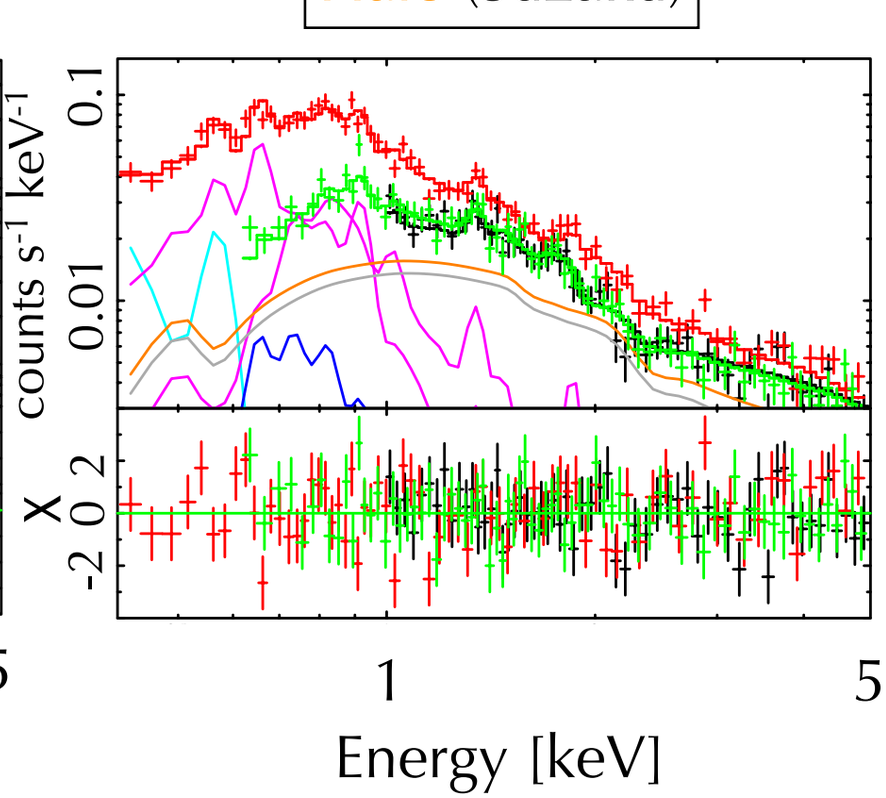
Superwind (XMM)

Disk (XMM)

Halo (Suzaku)





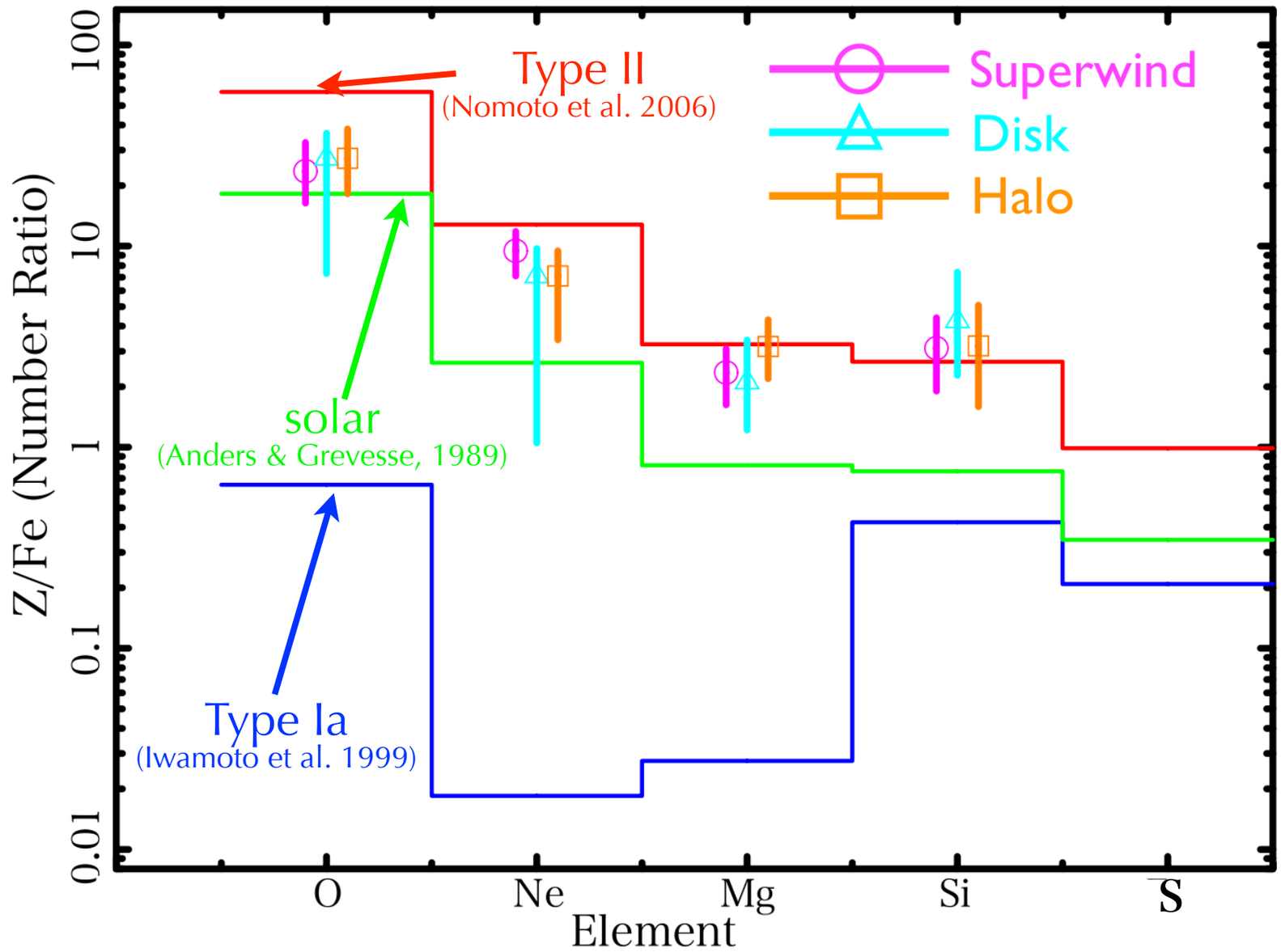


- 2 T (~0.2 keV, ~0.6 keV)

➡extract abundance patterns to examine the origin of hot gas

Abundance Patterns in NGC 253

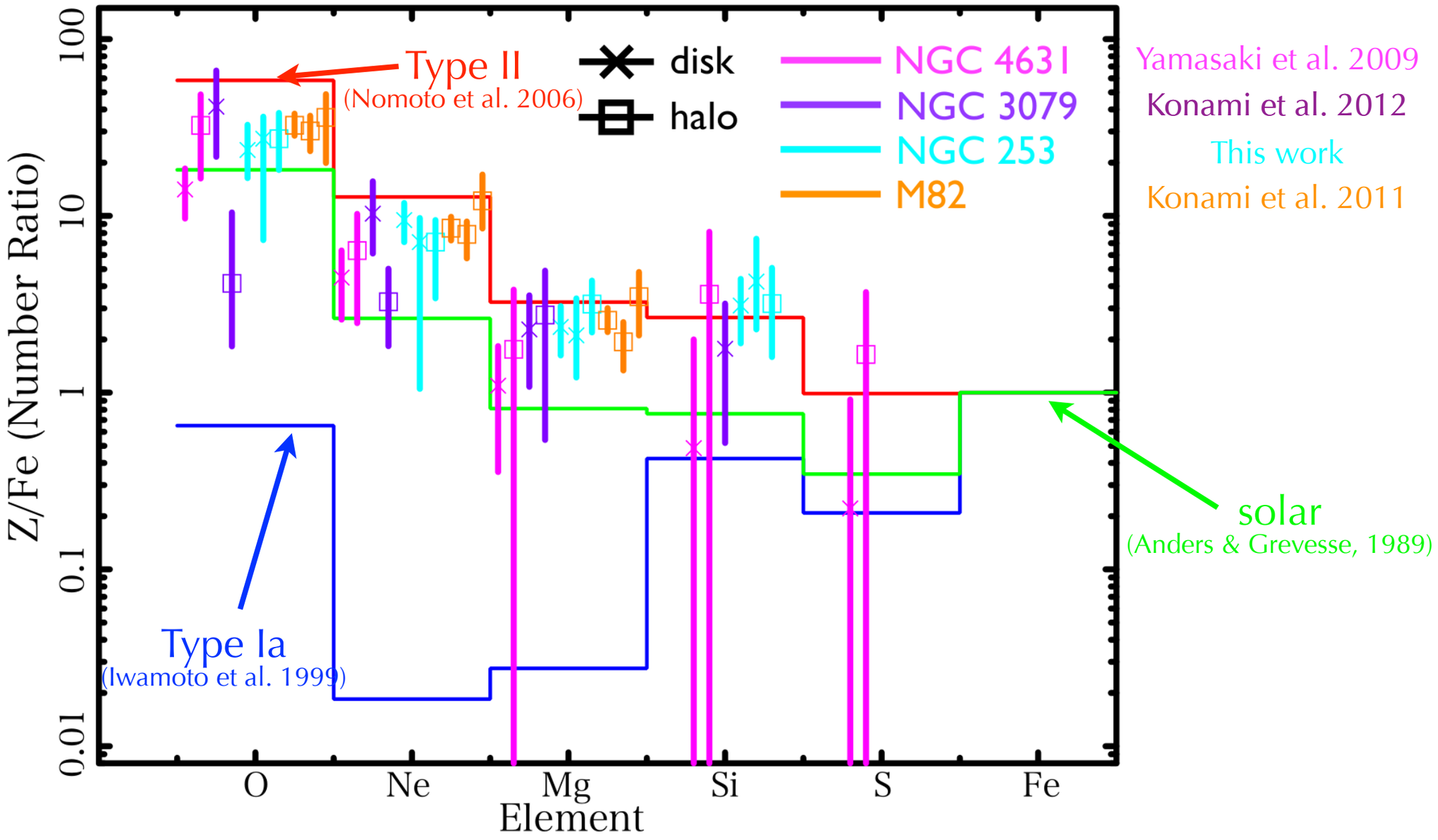
Mitsuishi et al. PASJ submitted



- the same abundance patterns
  - the same origin
- heavily contaminated by Type II
  - starburst origin

Abundance Patterns in Starburst Galaxies

Mitsuishi et al. PASJ submitted

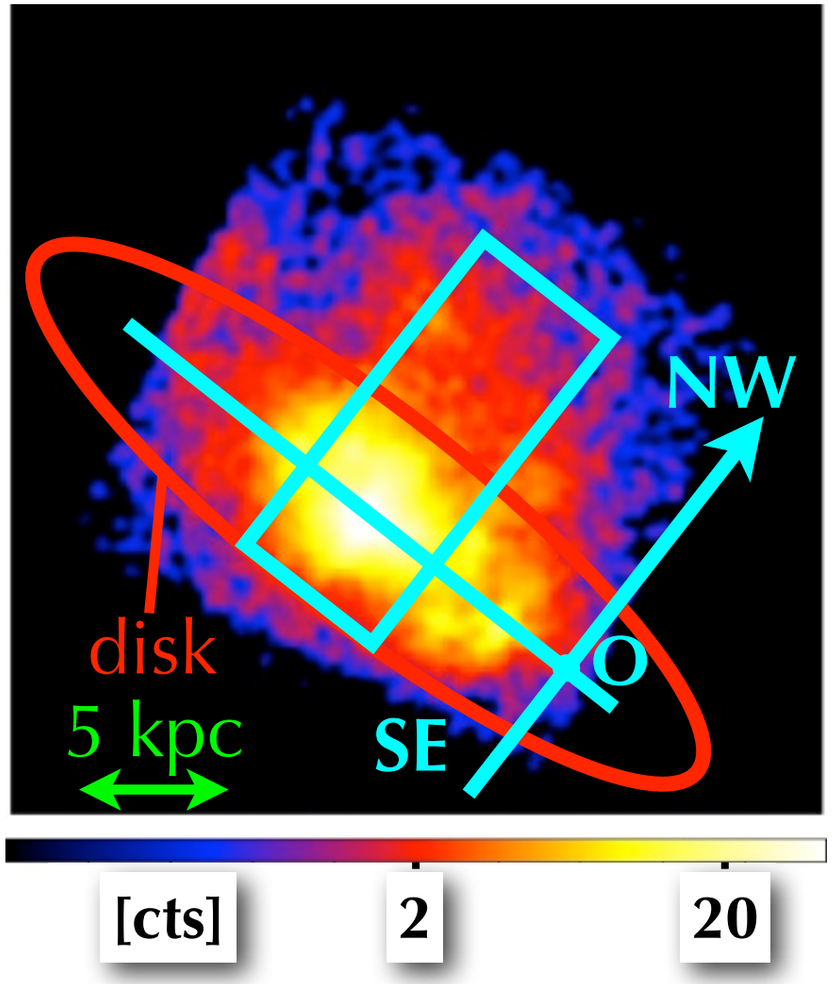


- the similar abundance patterns
  - ▸universal mechanism ??

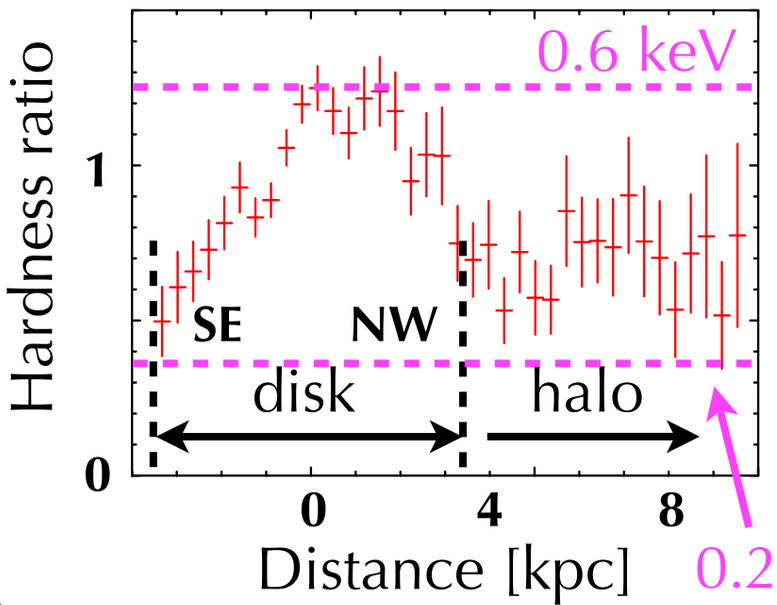
Hardness ratio and Surface brightness of ISM

Mitsuishi et al. PASJ submitted

0.5-2 keV

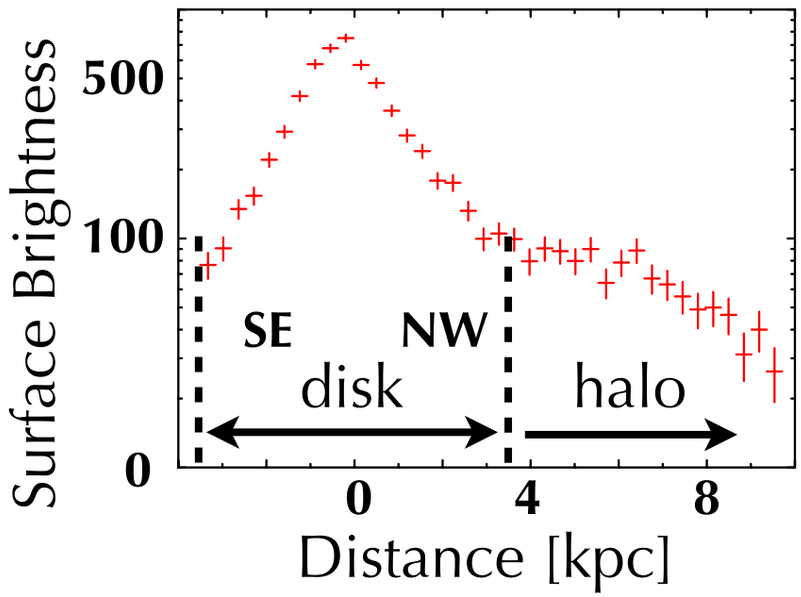


Hardness ratio (0.8-1.0 keV/0.4-0.8 keV)



- different trend
  - hard in disk
  - flat in halo
- reflect spectral shape
  - temperature profile

Surface brightness (0.4-0.8 keV)



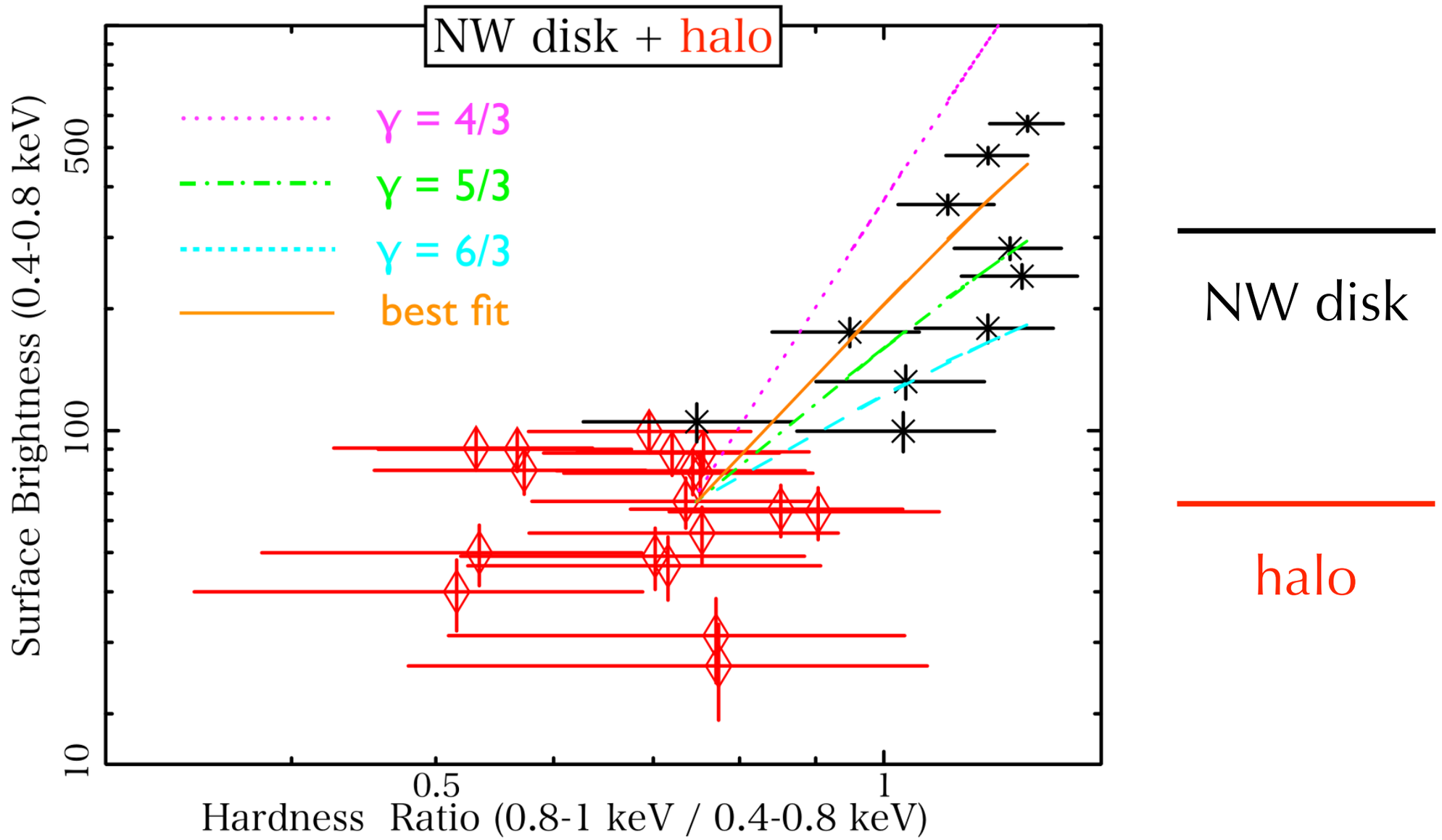
- different trend
  - sharp in disk
  - relatively shallow in halo
- $SB = \int \Lambda \times n_H \times n_e \, dV$
  - density profile

Gas Dynamics in NGC 253

Mitsuishi et al. PASJ submitted

polytropic relation between density and temperature

$$PV^{\gamma} = \text{const} \rightarrow T\rho^{1-\gamma} = \text{const}$$



Gas Dynamics in NGC 253

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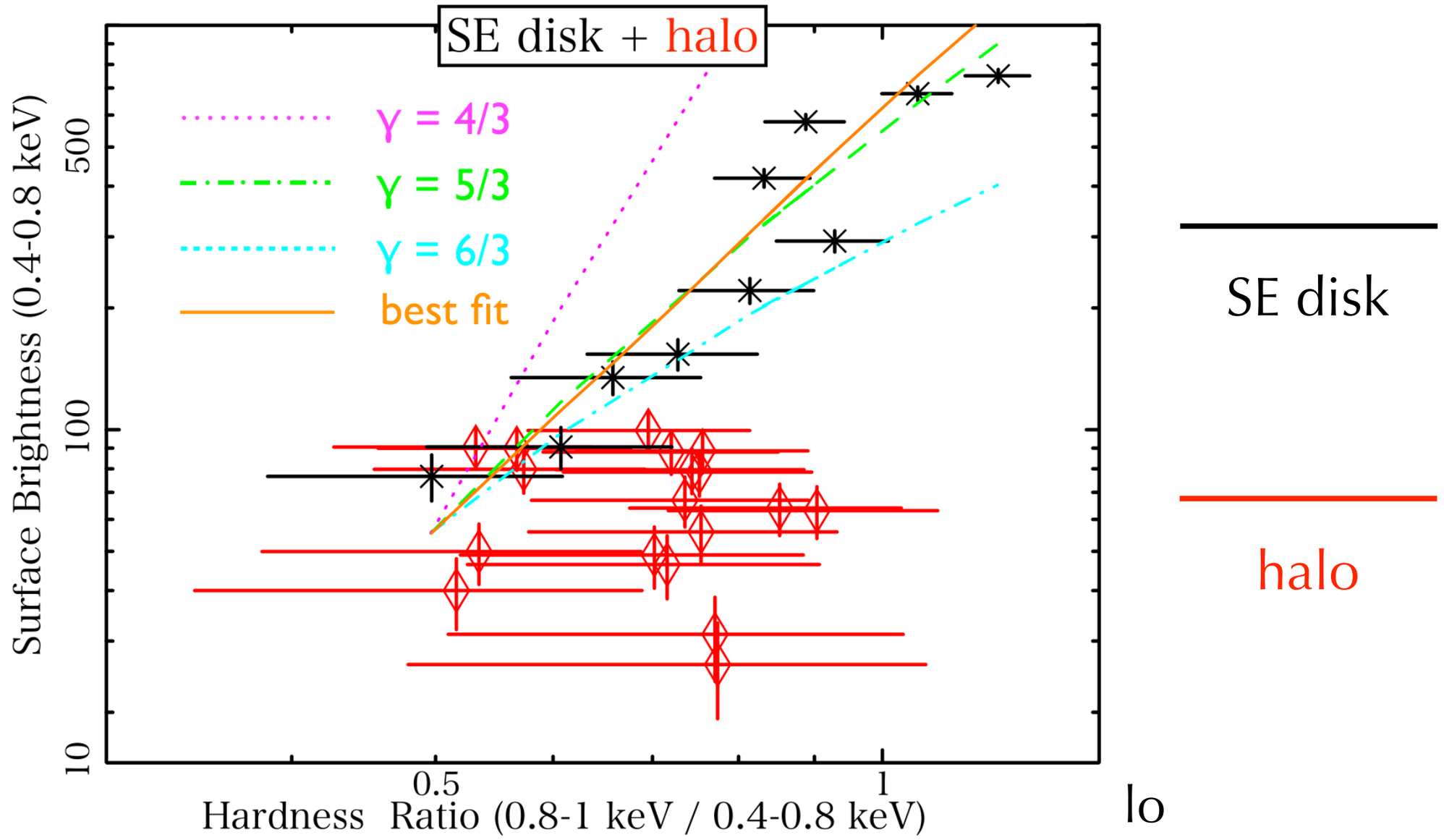


lo

- different dynamics
  - adiabatic expansion in the disk
  - free expansion in the halo

Possibility of the Outflow toward the Intergalactic Space

Mitsuishi et al. PASJ submitted

Motivation:

- free expansion in the halo
- flat temperature in the halo
  - no effective cooling process
    - needs a certain level of velocity

➡velocity constraint

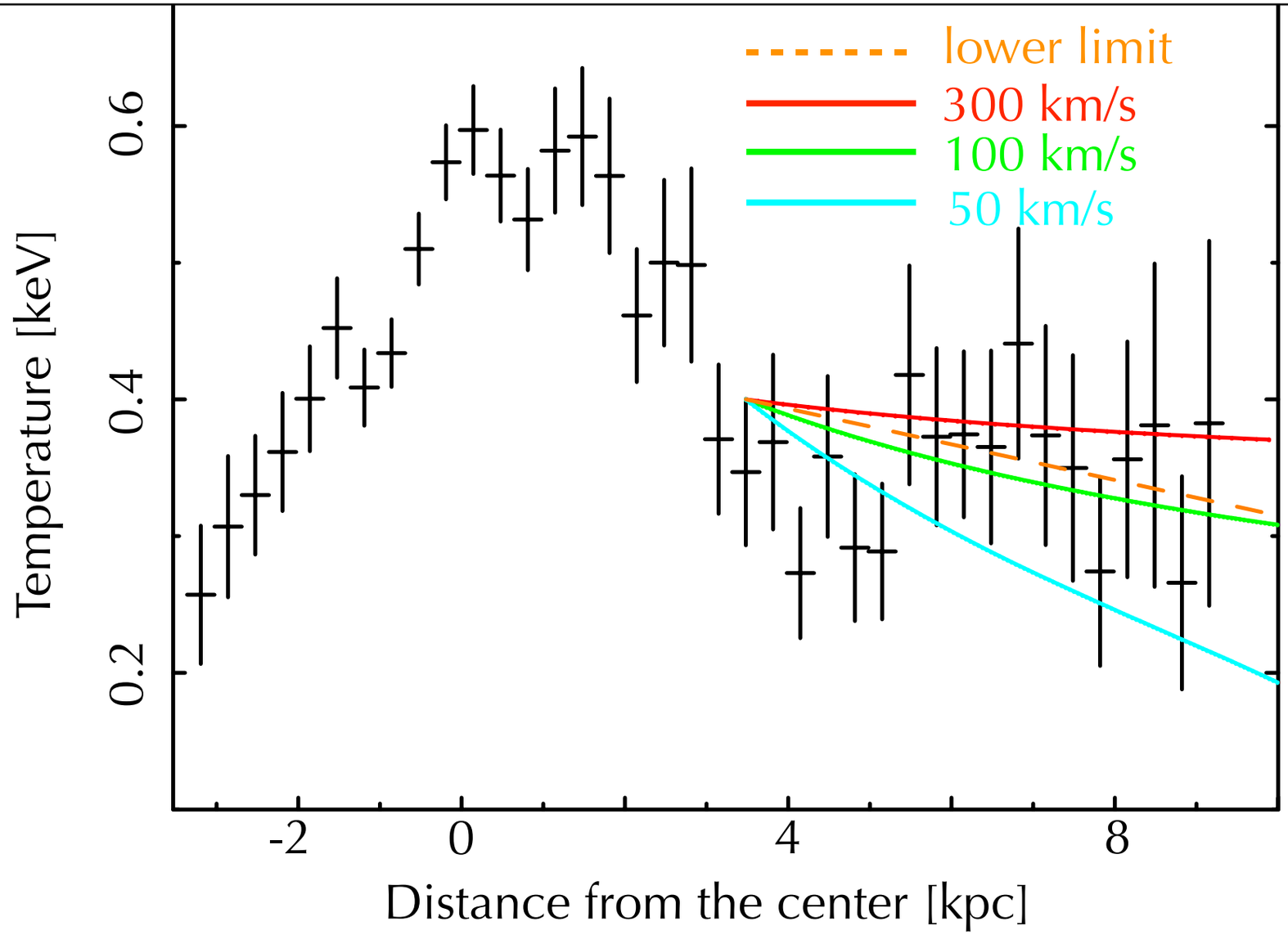
Assumptions:

(1) hot gas in the halo moves along with the minor axis with constant V_{bulk}
(2) only radiative cooling as a cooling process
(3) adopt density profile obtained from the surface brightness

Constraint on the velocity of the outflow in the halo

Mitsuishi et al. PASJ submitted

Comparison of the expected and the observed temperature distribution



- $V_{bulk} > 100$ km/s

▶ $V_{bulk} + V_{thermal} > V_{escape}$ (~220 km/s)

Summary

X-ray observations for NGC 253 to verify the starburst-driven outflow scenario

- nuclear region (=most intense starburst region)
  - hard X-ray originates from starburst activity
    - several 1000 type-II supernovae
      - ➡supply from the central starburst activity (Mitsuishi et al. 2011 ApJL)

- outer regions (superwind, disk and halo)
  - same abundance patterns
  - type-II contaminated abundance patterns
    - same origin as the inner region
      - same mechanism in starburst galaxies ?
  - constraint gas dynamics in the disk and the halo
    - different behavior of SB and HR
      - adiabatic expansion in the disk
      - free expansion in the halo (Mitsuishi et al. PASJ submitted)