CHEMISTRY IN ACTIVE GALACTIC NUCLEI

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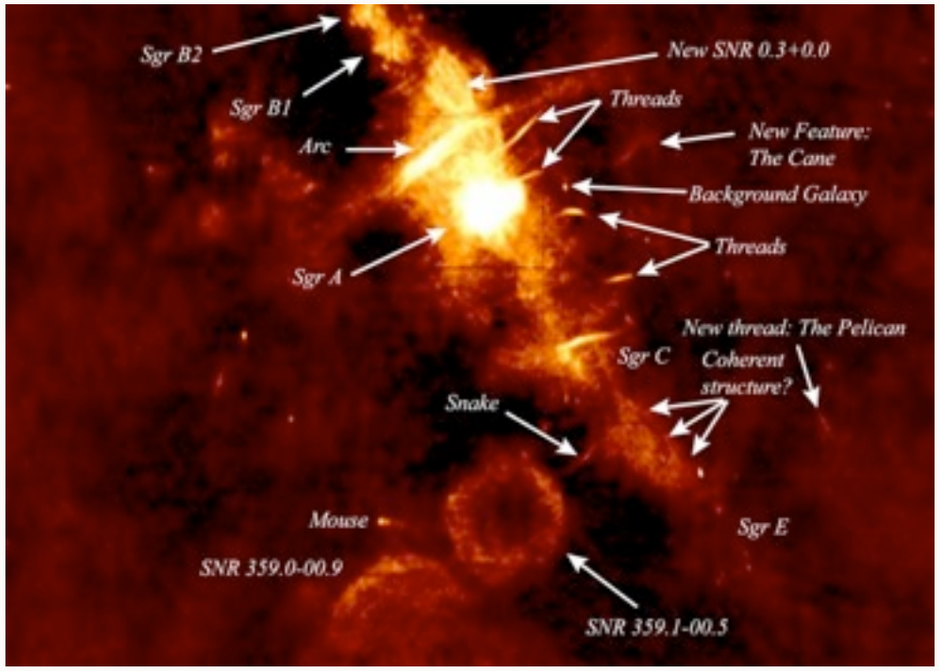
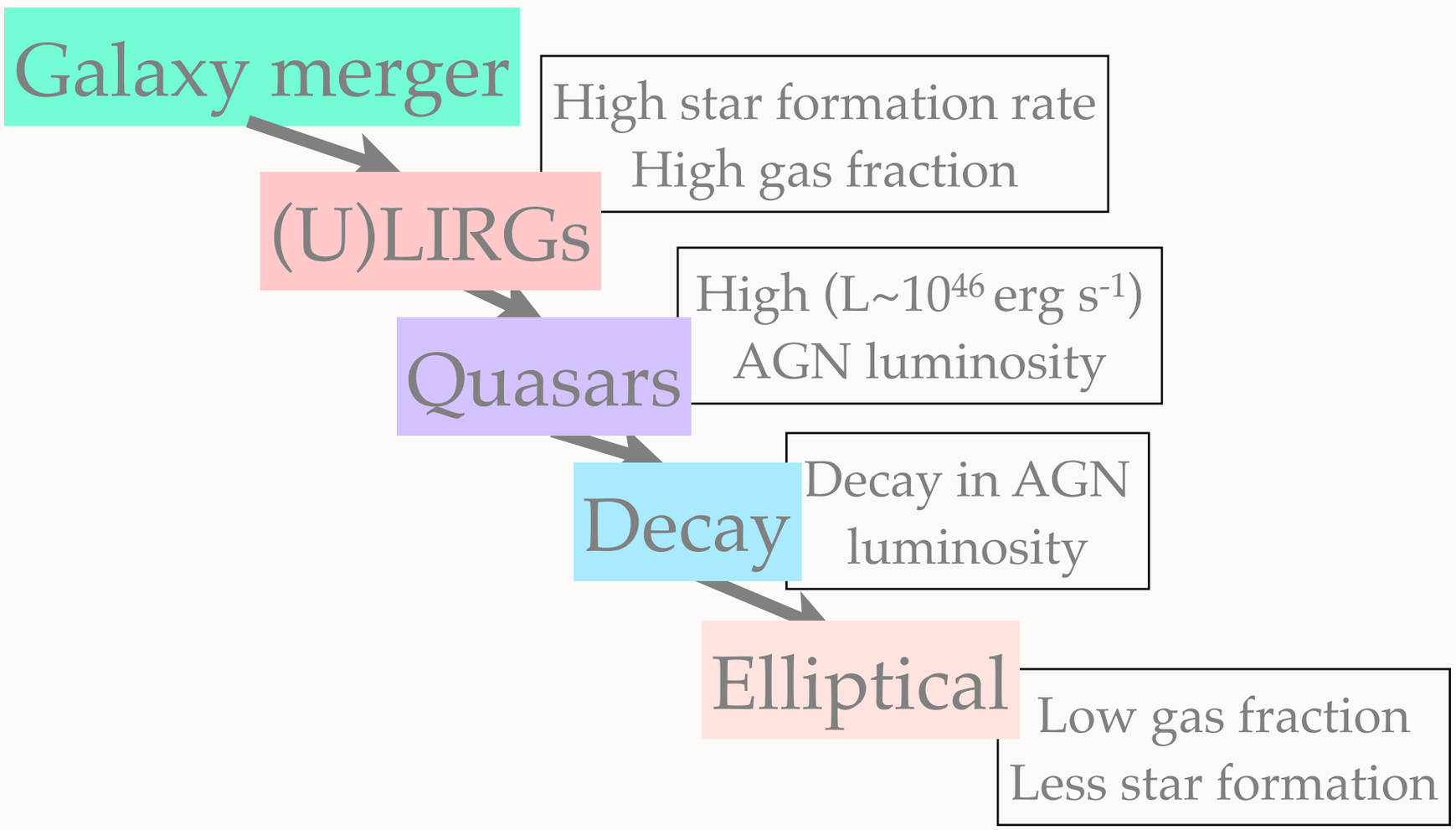
Molecular sources in Milky Way

- Galactic Center
  - Higher density (<n>~$10^2 cm^{-2}$)
  - Higher cosmic-ray ionization rate (x100 higher than other parts)
  - Complex molecules observed in Sgr B2



Galaxy evolution

- Stages in galaxy evolution (Hopkins et al. 2008)

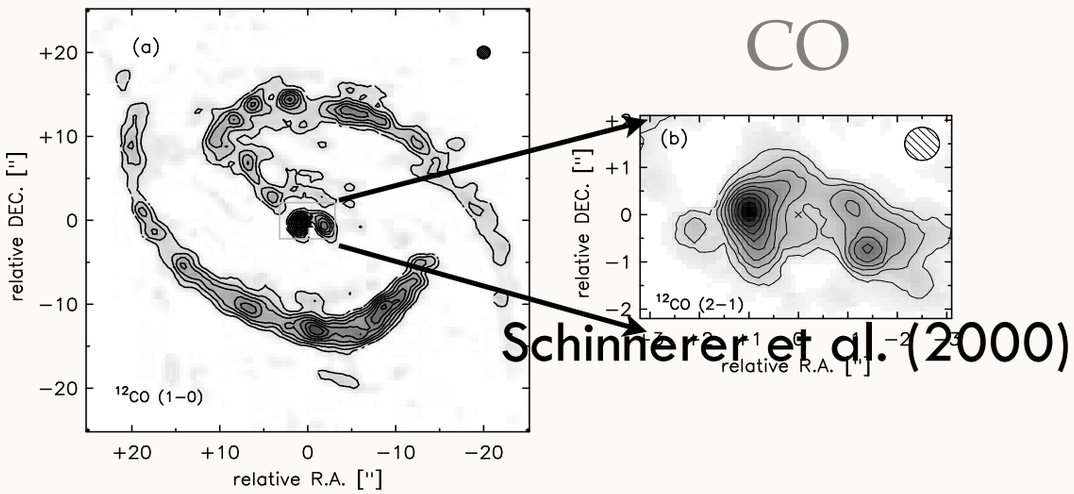


- LLAGN can be caused without mergers.

Molecular Observations

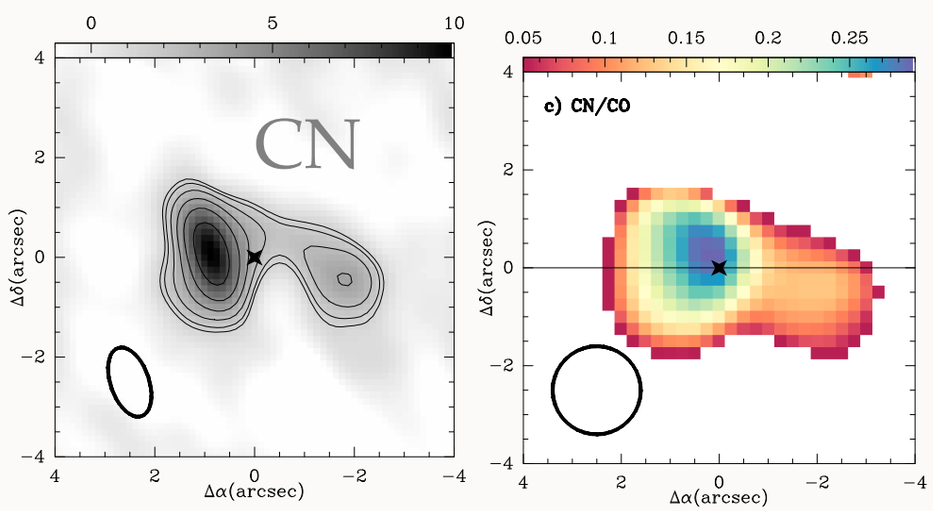
- Spatial distributions

CO

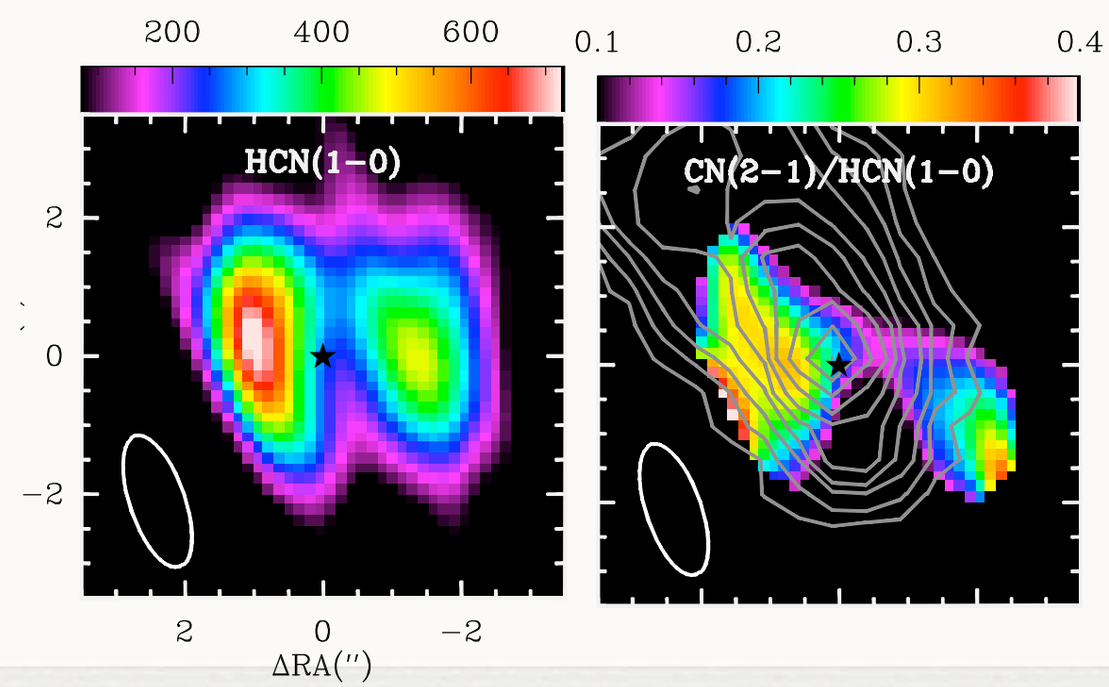


Schinnerer et al. (2000)

Garcia-Burillo et al. (2010)



HCN Garcia-Burillo et al. (2008)



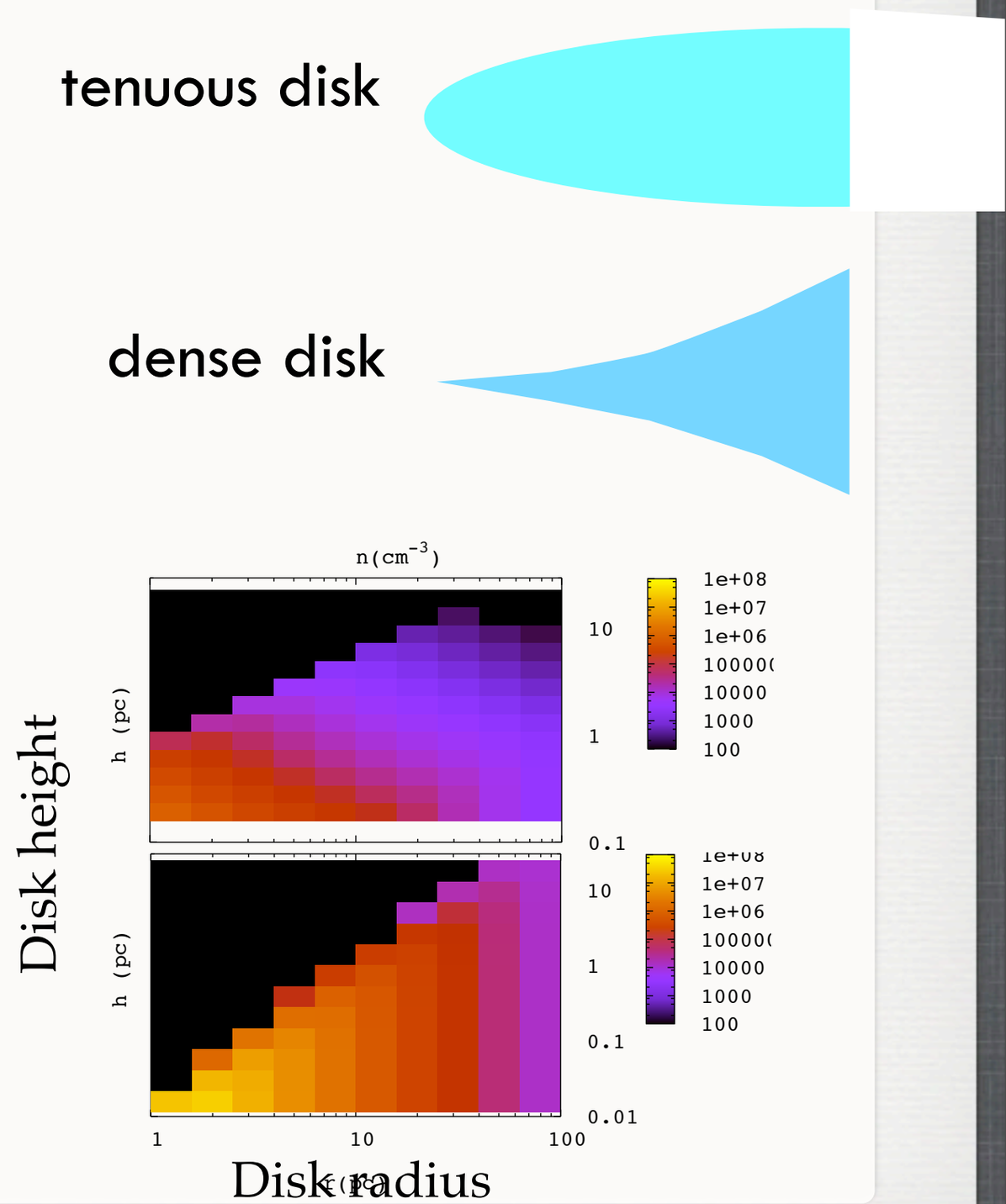
Molecular Observations

- Molecular abundances

	NGC1068(CND)	TMC-1
HCN	1×10^{-7}	2×10^{-8}
CN	$(0.2\text{-}1.3)\times10^{-7}$	5×10^{-9}
HCO^{+}	$(0.6\text{-}13)\times10^{-8}$	8×10^{-9}
CS	1×10^{-8}	4×10^{-9}

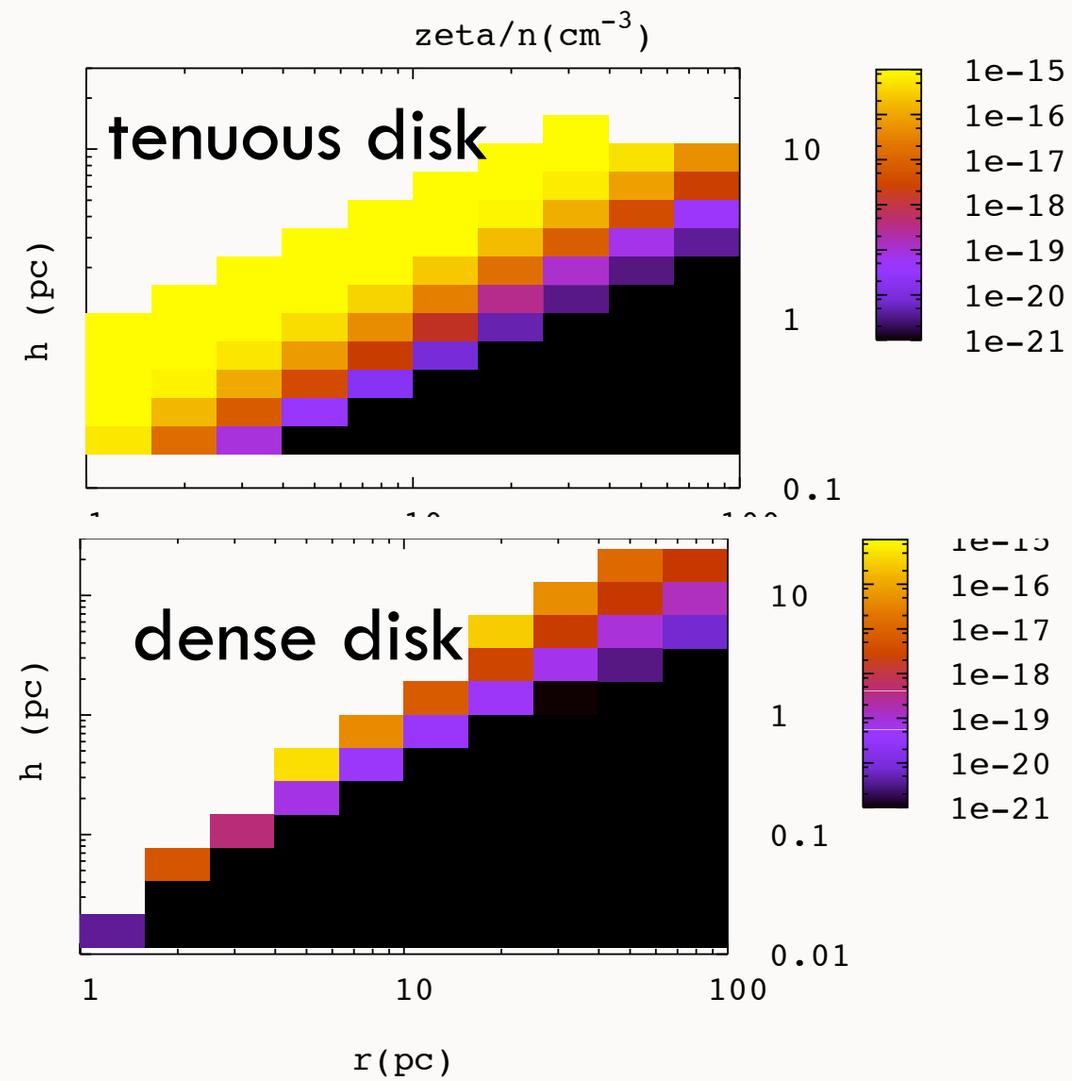
Disk density

- "Dense disk":Thompson et al. (2005): disk is supported by the radiation-pressure on dust
  - Toomre-stable disk Q~1
  - $\varrho_{mid} \sim \Omega^2/(\pi G Q)$; $\Omega=(GM_{BH}/r^3+2\sigma/r^2)^{-1/2}$
- "Tenuous disk":
  - Q=5
  - Thick scale height h/r~0.5



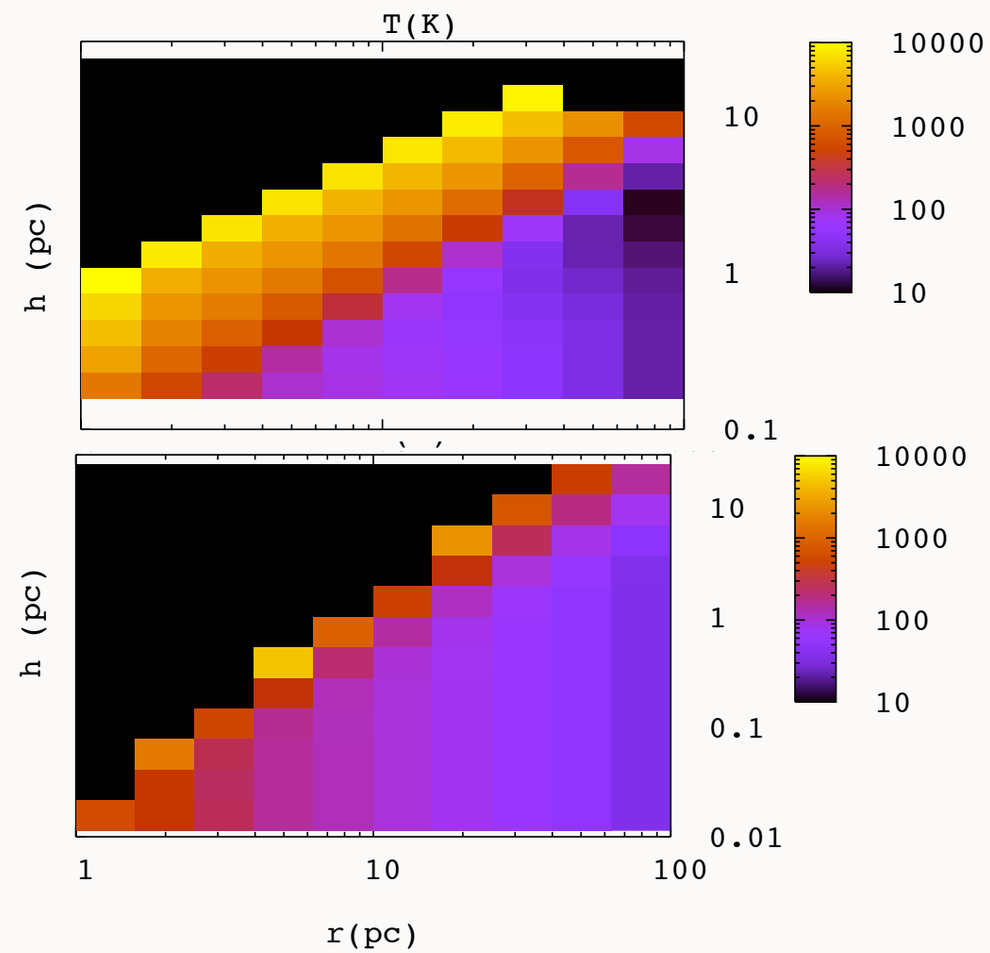
Ionization from X-rays

- X-ray from the central core
- $L_X \sim 6\times10^{43}$ erg s^{-1}
- Enhancement of CN, HCN, HCO^+ at steady-state as ζ/n increases (Lepp and Dalgarno, 1996).
- OH^+ and H_2O^+ are enhanced at higher ζ/n.



Temperature

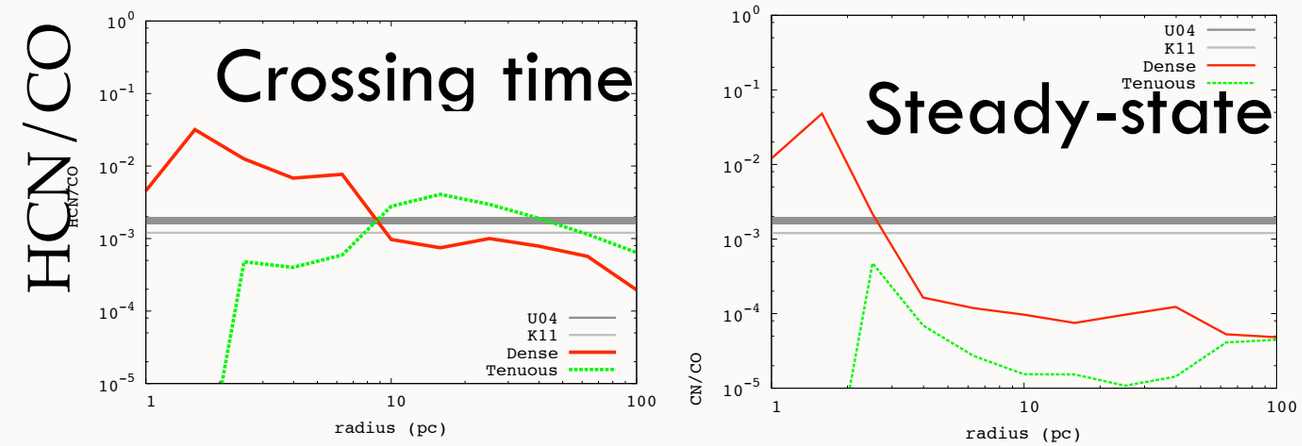
- $T_{dust} = T_{BB}$=750 K $(r/pc)^{-1/2}$
- Gas heating
  - X-ray heating
  - Gas-dust collision
- Gas cooling
  - Approximation of line cooling (Goldsmith et al. 2001)

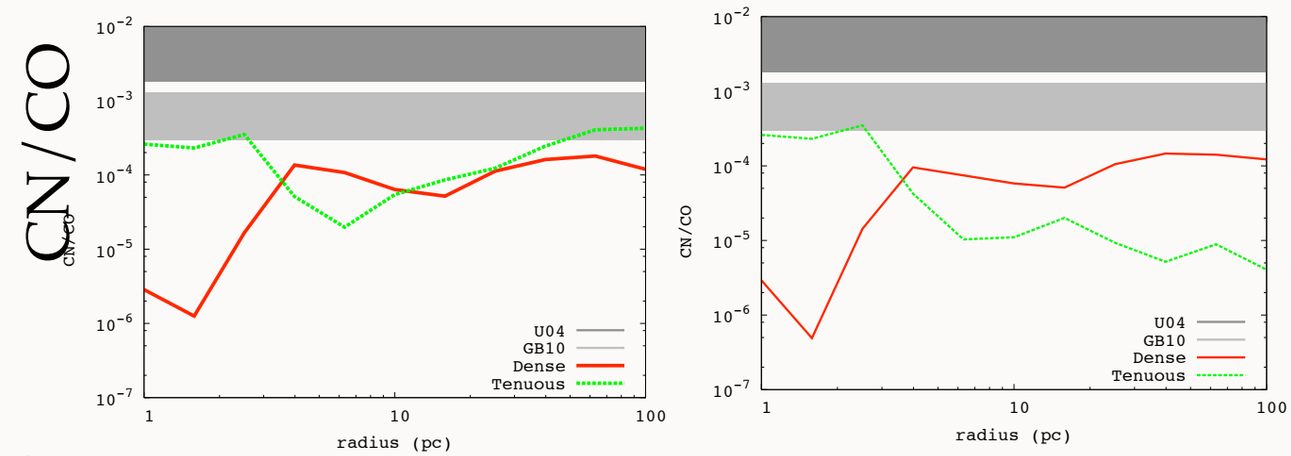


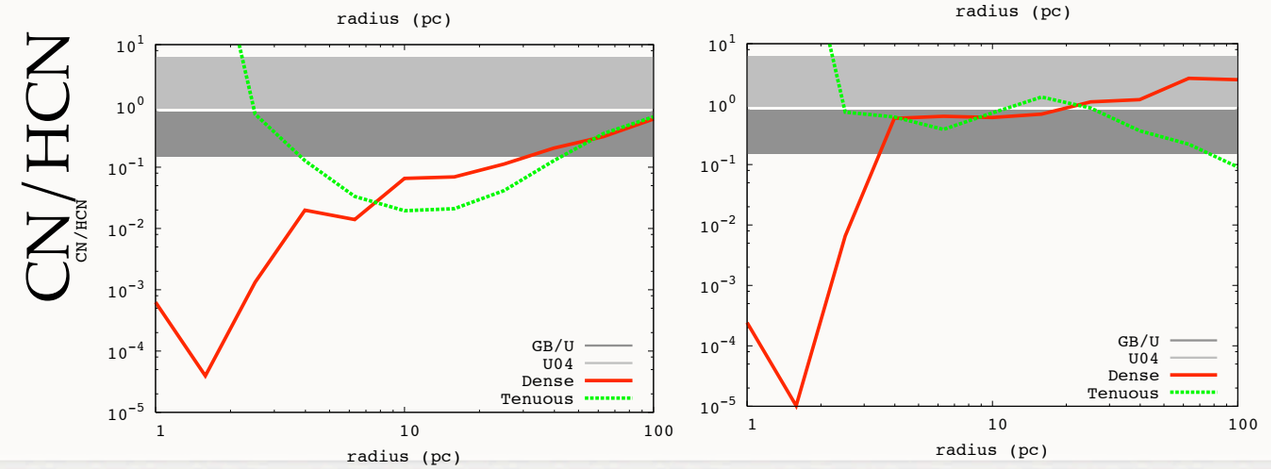
HCN and CN

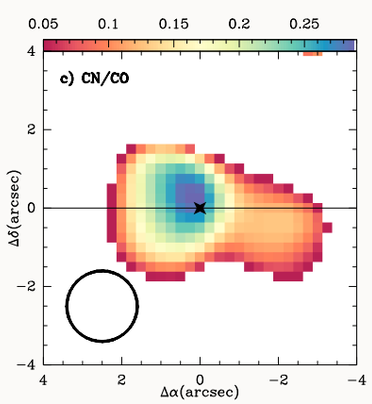
- HCN abundances can be enhanced due to the high temperature.
- Abundances at the crossing time match the observation better for CN and HCN.

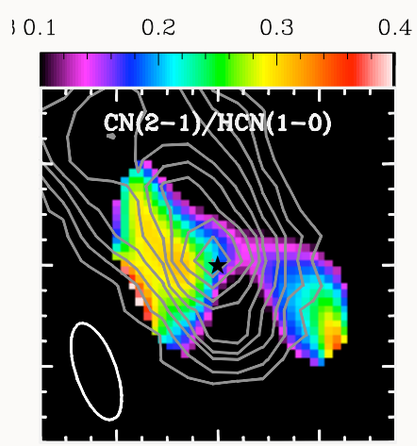
integrated column density ratios







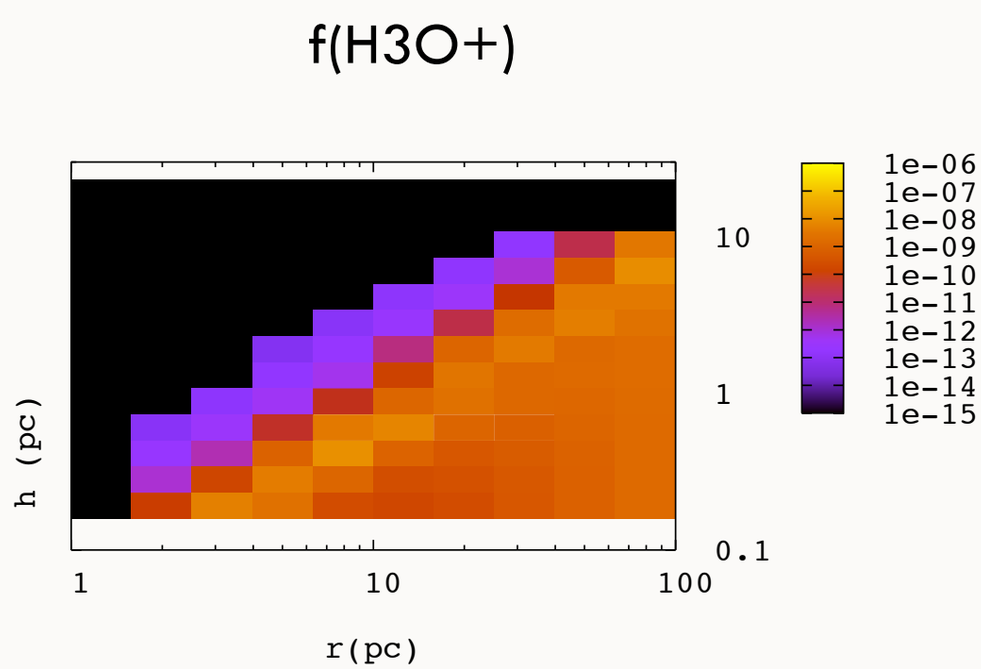


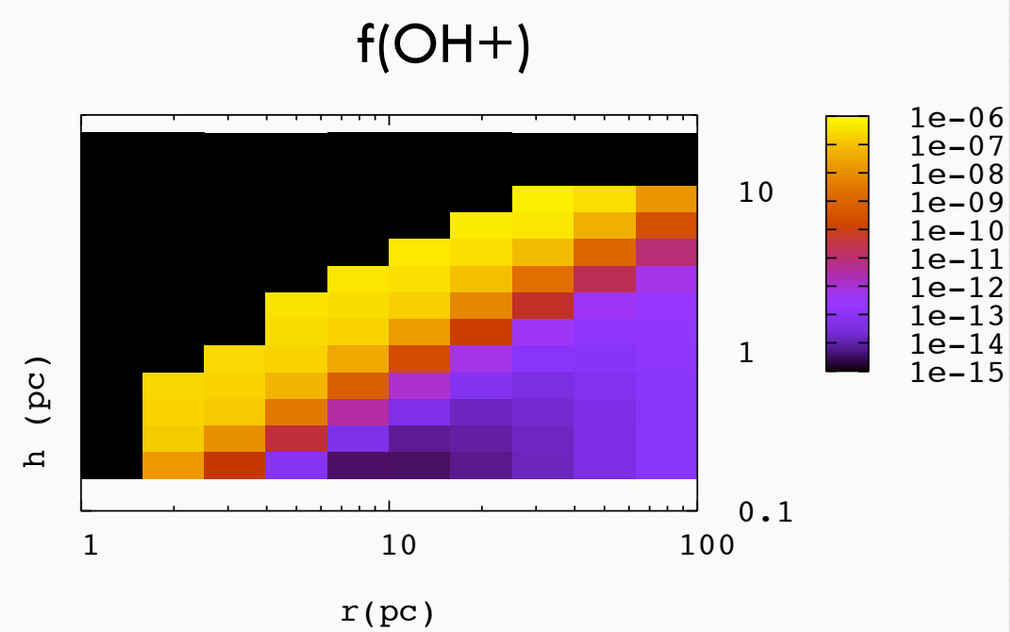


OH^+, H_2O^+, and H_3O^+

- OH^+ and H_2O^+ were detected in many sources by APEX and Herschel.
- They trace very high X-ray ionization rate.

tenuous disks

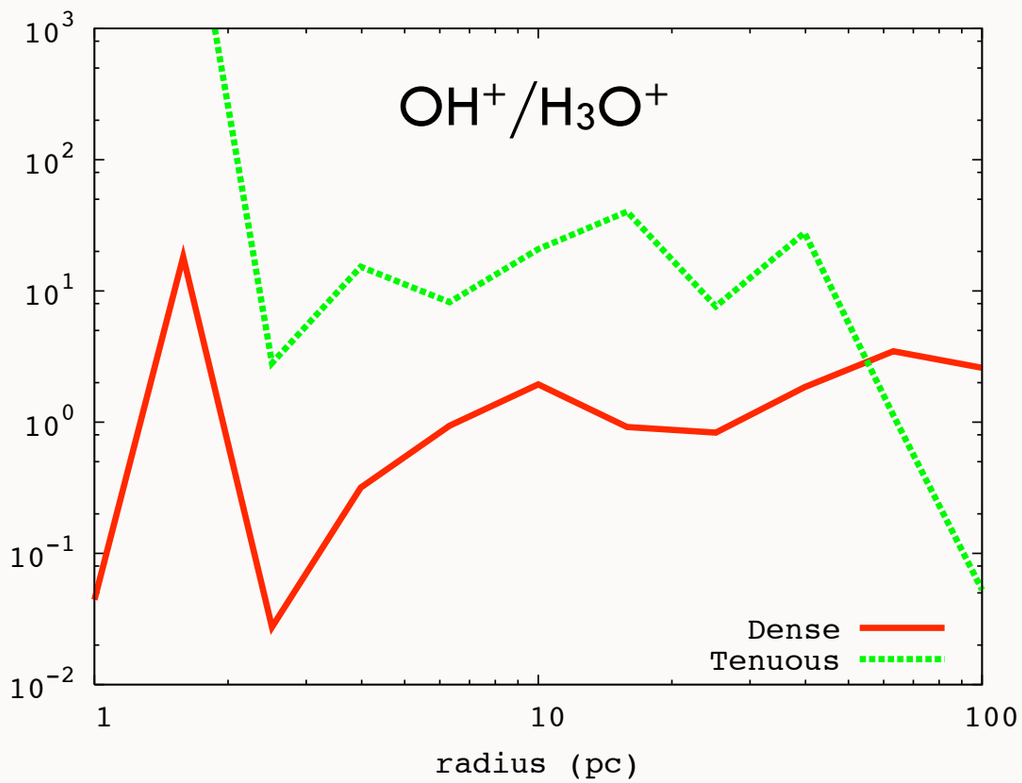


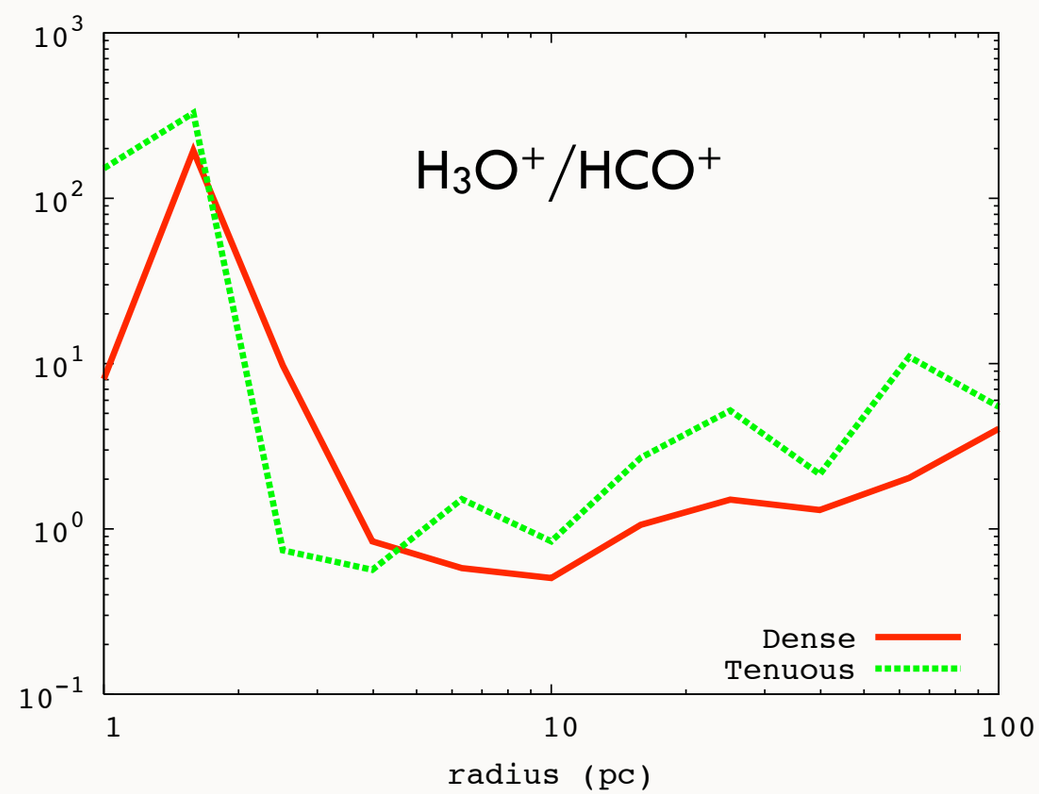


OH^+, H_2O^+, and H_3O^+

- $N(H_3O^+)/N(HCO^+)$~24 (Aalto et al. 2010) in NGC 1068

  → higher than other types of galaxies





Summary of AGN chemistry

- The abundances of HCN, CN, HCO^+, and other species are likely to change in different location of the circumnuclear disk.
- Non-steady-state abundances of CN and HCN are likely.
- Effects of stellar activity from UV-photons and cosmic-rays are negligible within r<100pc.
- Future work
  - Temperature calculation coupled with chemistry
  - Radiative transfer