STRONGGRAVITY
EU FP7-SPACE research project 312789 2013 - 2017

SEVENTH FRAMEWORK PROGRAMME

CAMK PAN

Nicolaus Copernicus Astronomical Center
of the Polish Academy of Sciences

The intermediate line region (ILR) in AGN

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20 October 2016

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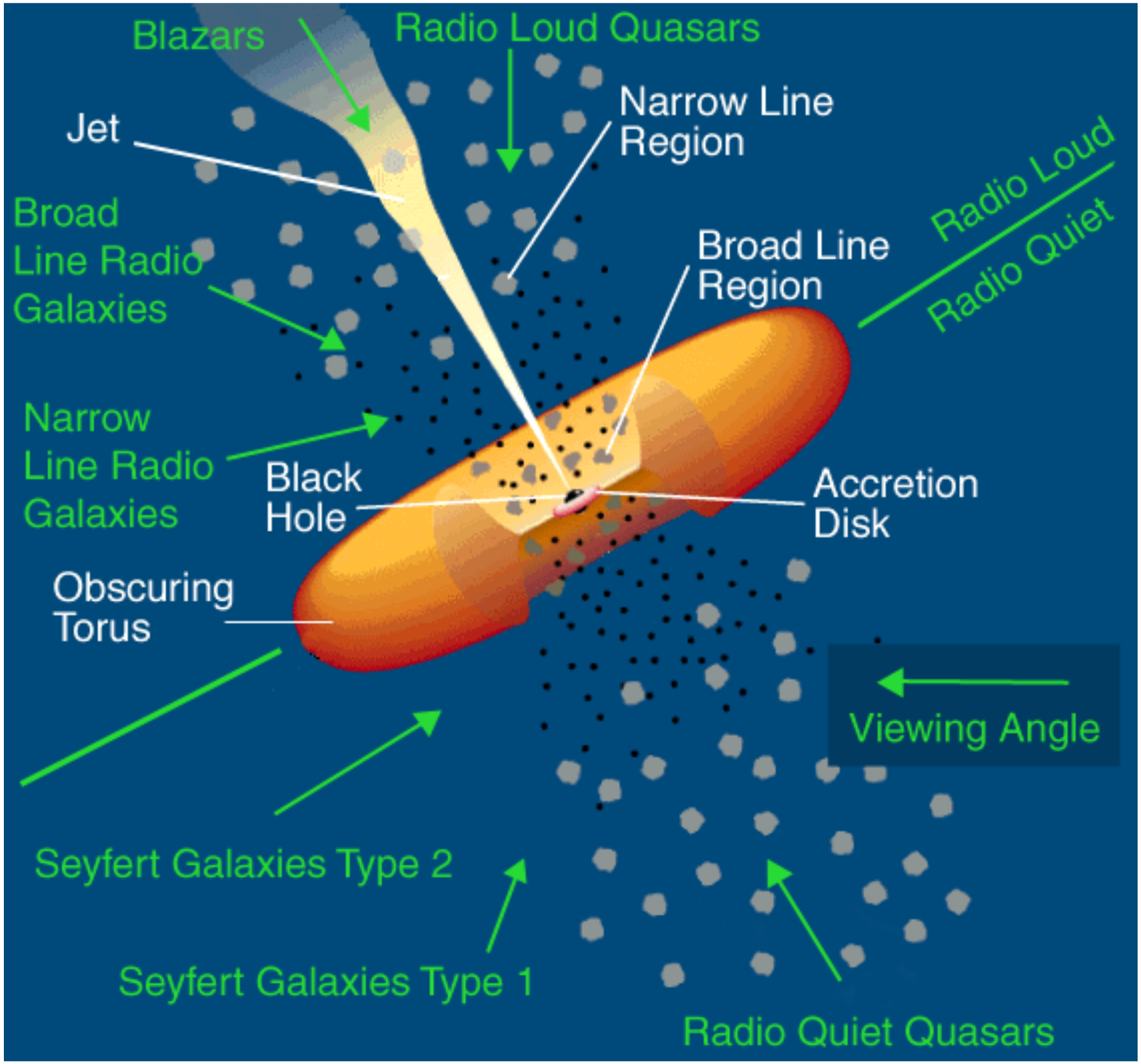
INTERNATIONAL CONFERENCE ON
SHINING FROM THE HEART OF DARKNESS: BLACK HOLE ACCRETION AND JETS
Kathmandu, Nepal, October 16 - 21, 2016

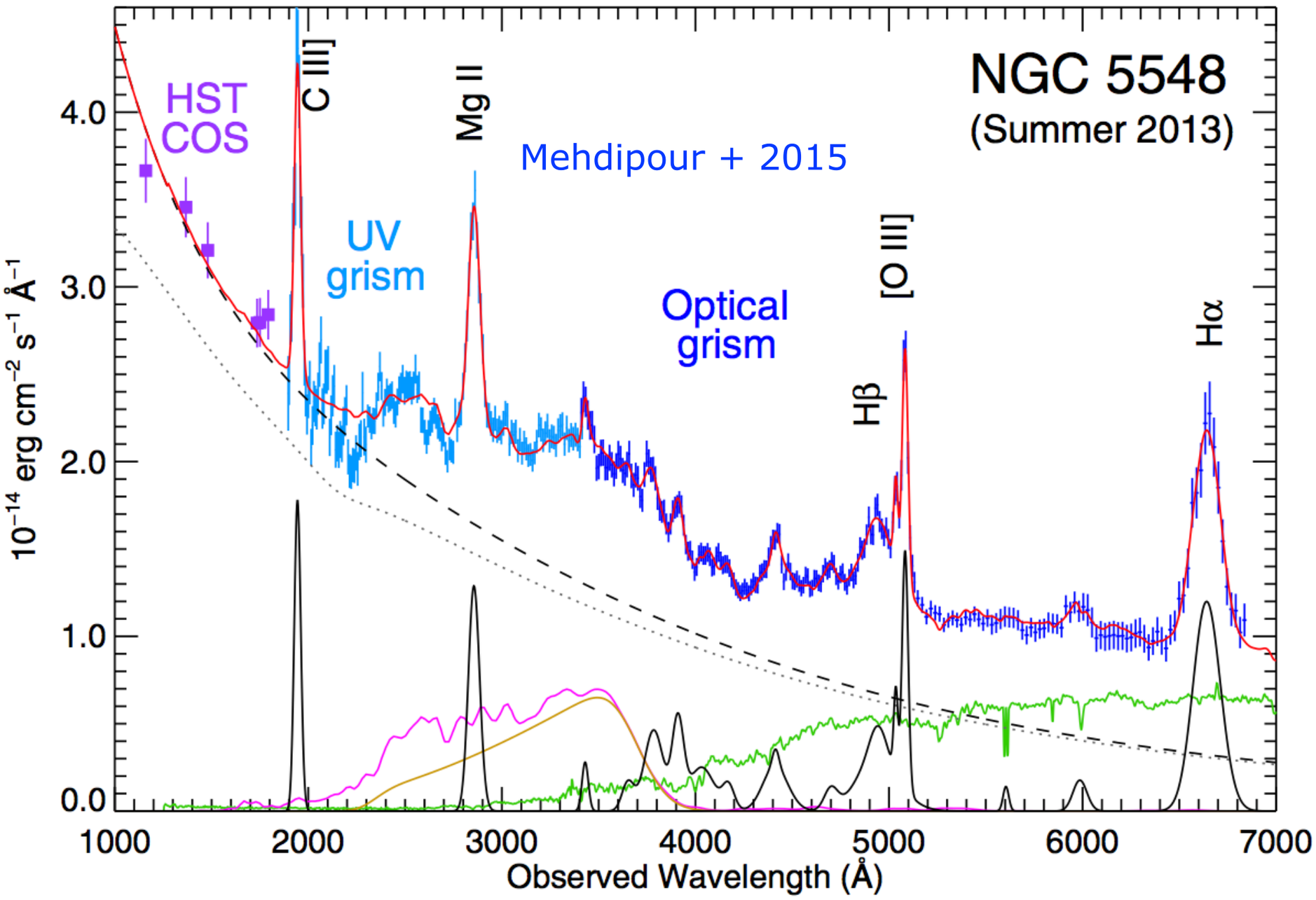


Credit:Pierre Auger Observatory

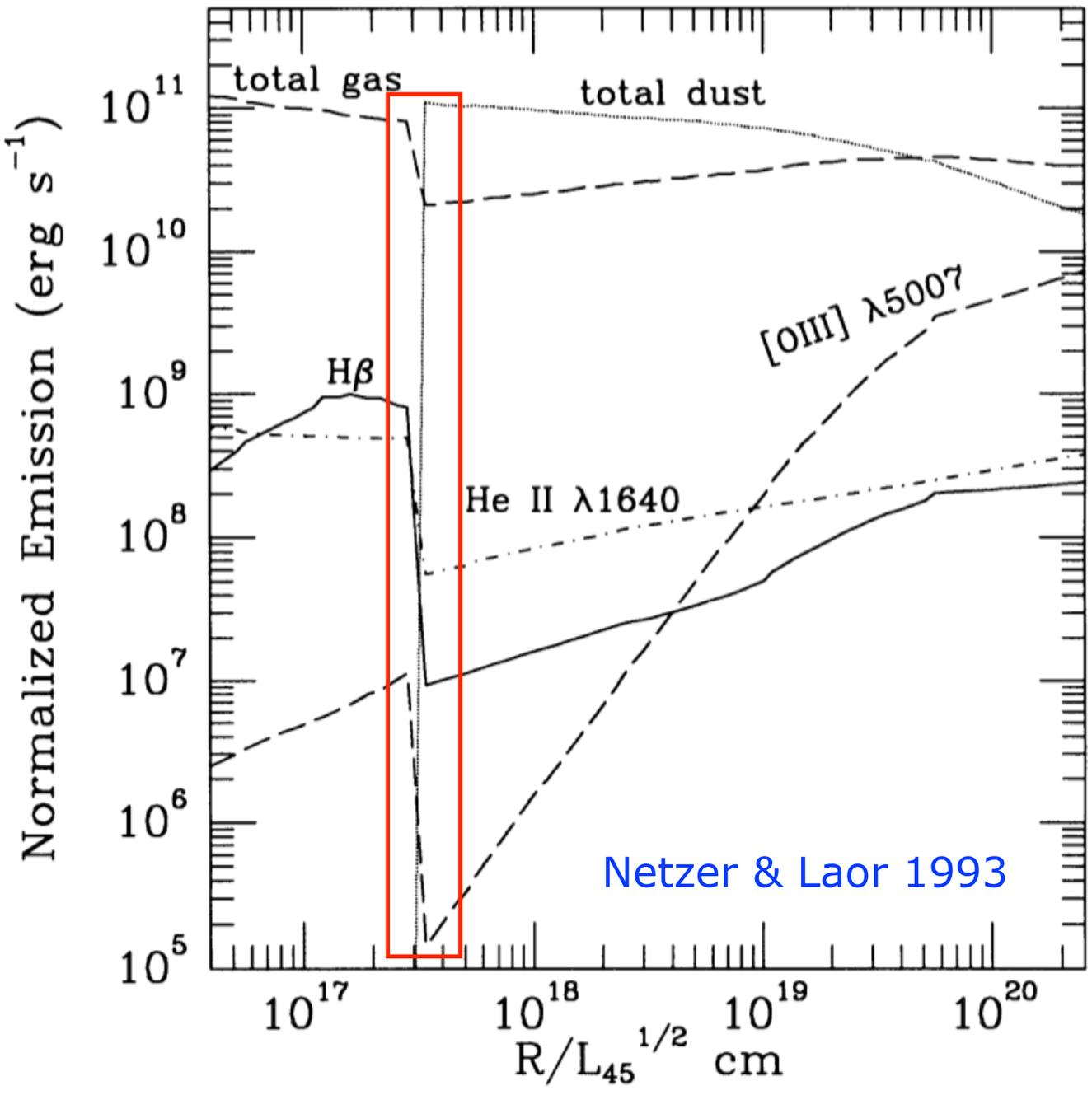
Emission lines in the spectra of AGN

narrow lines: FWHM~500 km /s broad lines: FWHM>2000 km /s

Intermediate lines: FWHM ~ 700-1200 km /s ?



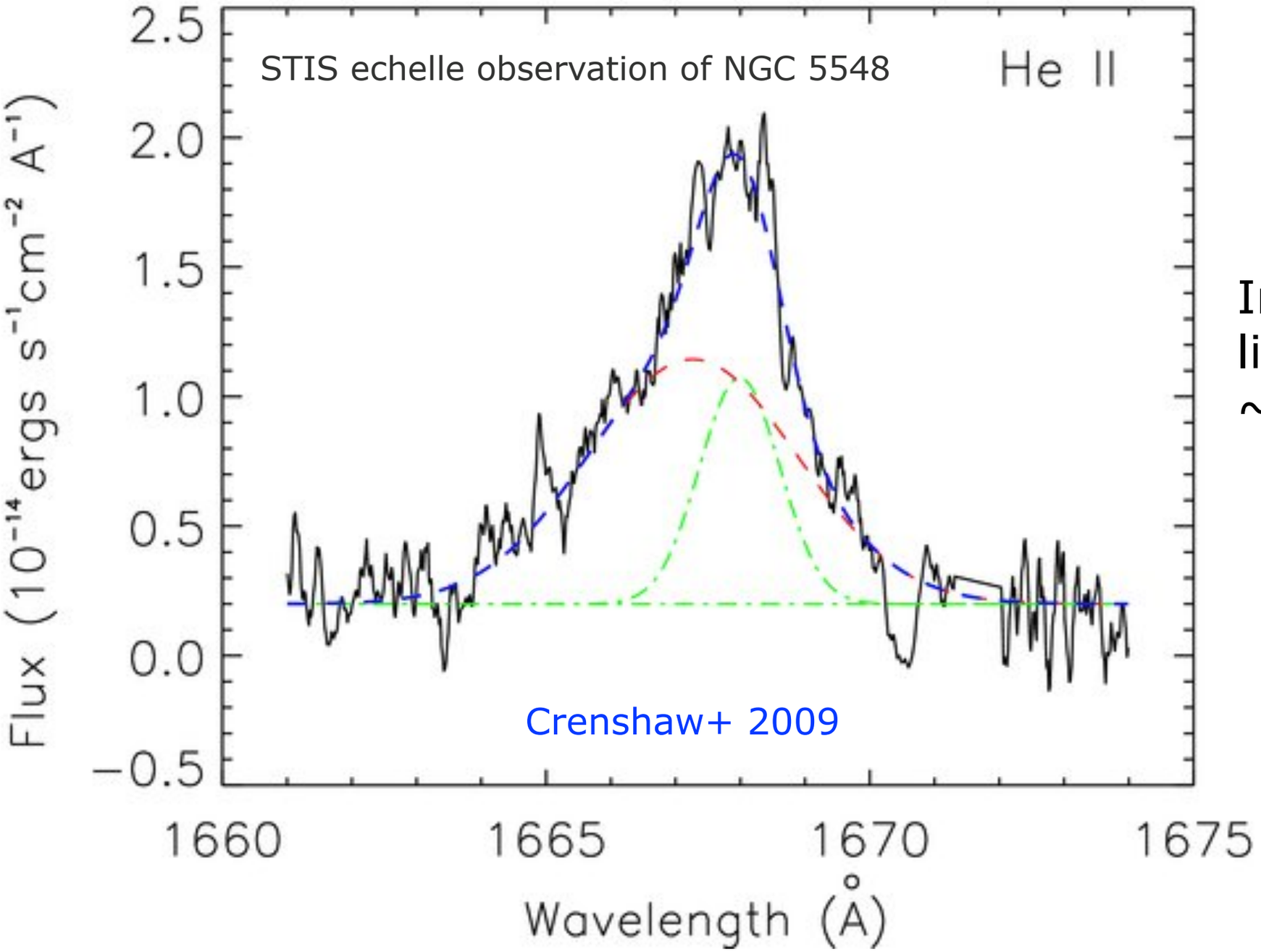
"Line emission vs radius" in AGN



Netzer & Laor 1993 assumptions

- constant density clouds
- $n_H \propto R^{-3/2}$, $N_H \propto R^{-1}$
- n_H, N_H at 0.1 pc = $10^{9.4}$ cm^{-3} & $10^{23.4}$ cm^{-2}
- Solar composition <=0.1 pc
- ISM composition with dust grains >0.1 pc

Recent observations (Puchnarewicz & Jones 1996, Crenshaw & Kraemer 2007, Hu+ 2008a,b, Crenshaw+ 2009, Zhu+ 2009, Li+ 2015) of some AGN shows intermediate line emission



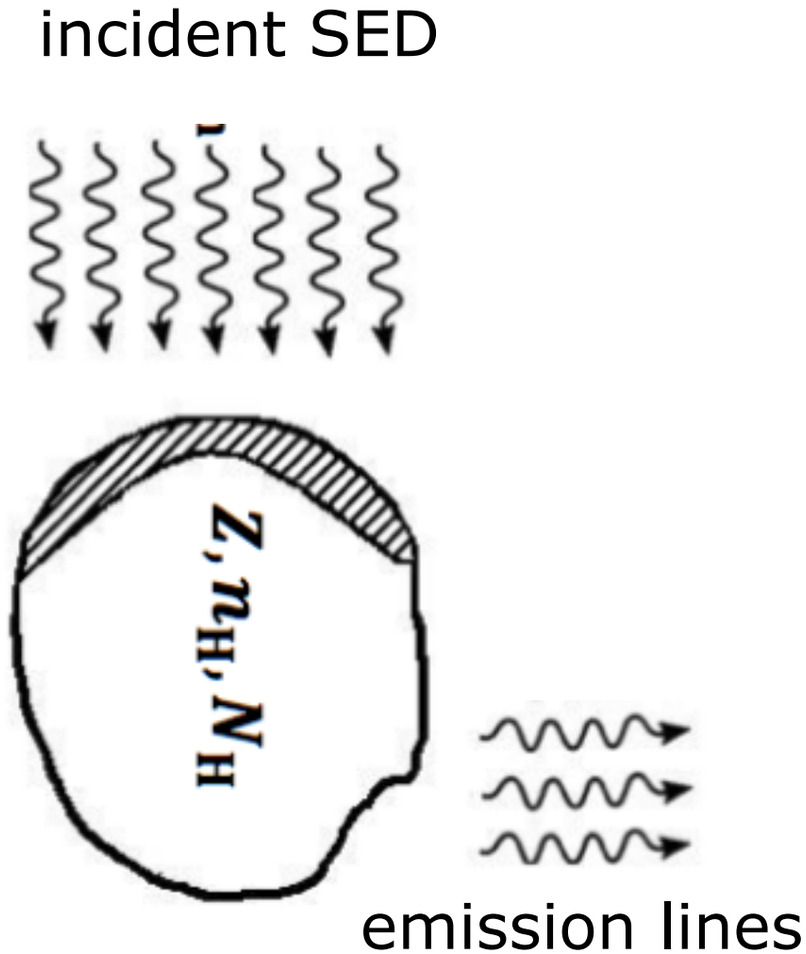
Crenshaw+ 2009

Intermediate lines: FWHM ~700-1200 km /s

continuum + BLR (lower dotted–dashed green), continuum + BLR+ NLR (upper dotted–dashed green), continuum + BLR + ILR (dashed red) and continuum + BLR + ILR + NLR (upper dashed blue)

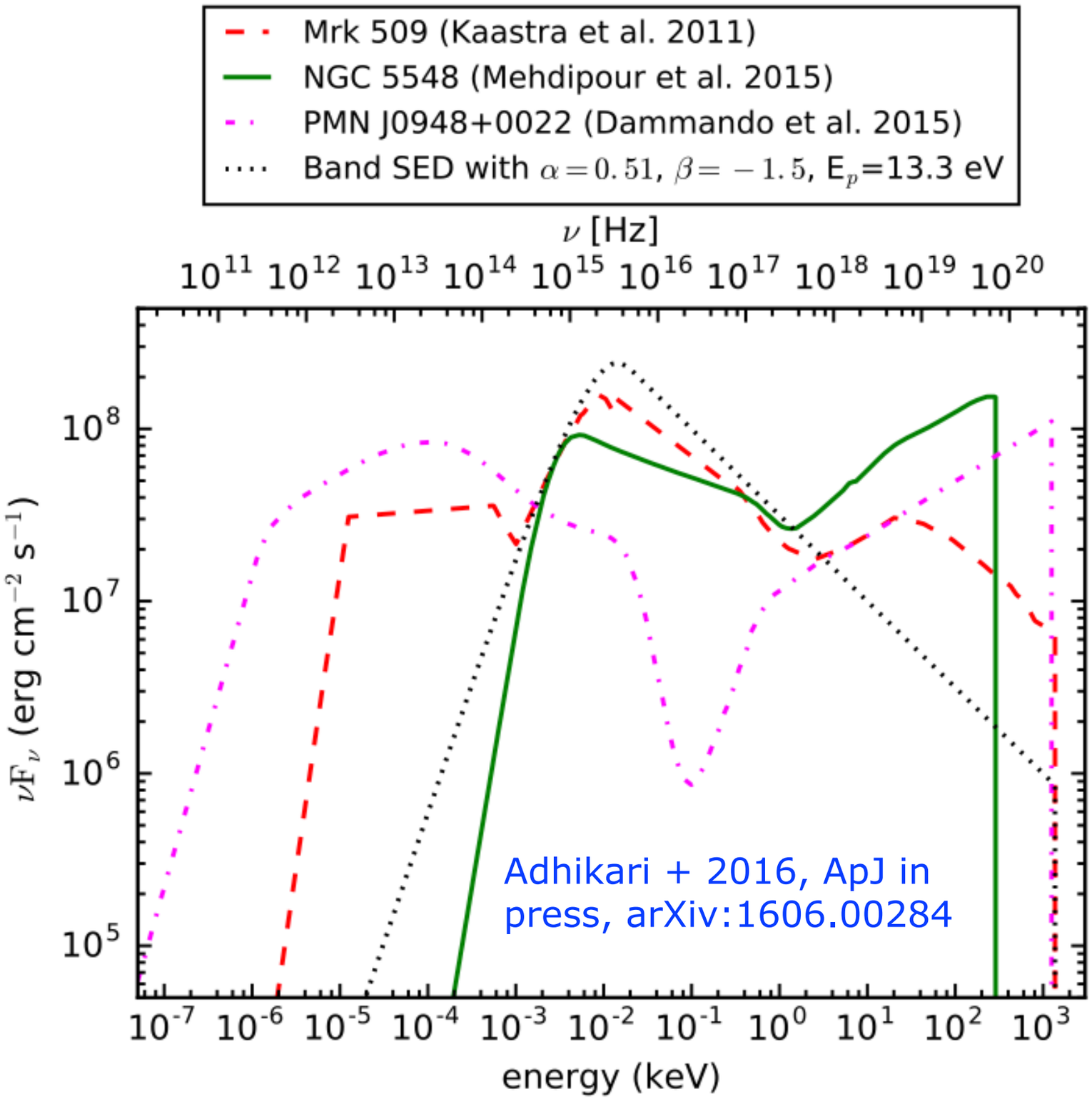
Photoionisation modelling of the emitting gas

- Broad band SED
- Gas density n_H
- Metallicity Z
- Column Density N_H
- Ionisation parameter U
- Solving the radiative transfer, ionisation equilibrium and thermal balance
- Main Codes: CLOUDY, TITAN, XSTAR,..

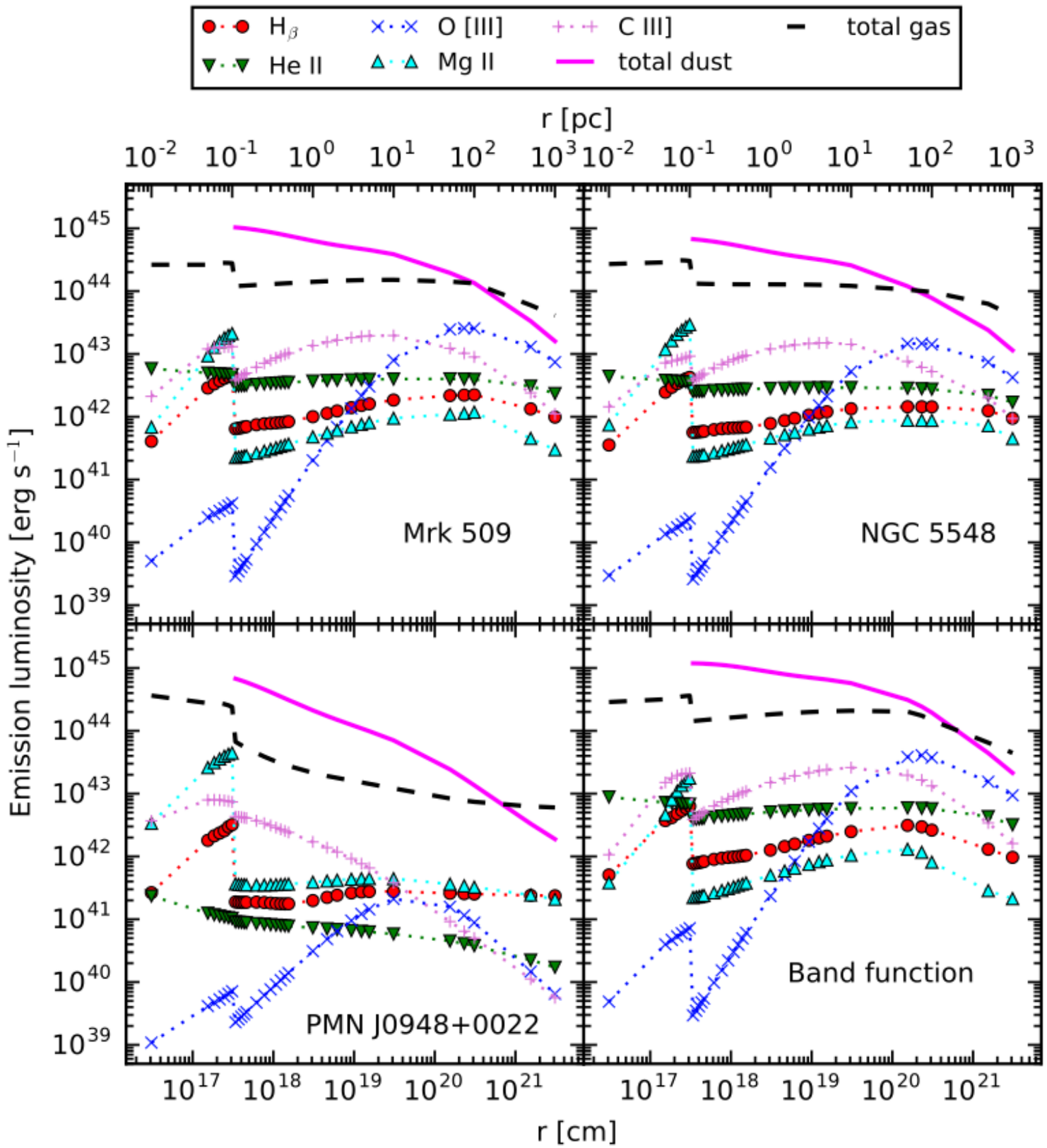


Cloudy 13.03 (Ferland + 2013)

Is the presence of ILR in some AGN connected with the shape of SED?



The answer is no!



Adhikari + 2016, ApJ in press

Our model assumptions

- constant density clouds
- $n_H \propto R^{-3/2}$, $N_H \propto R^{-1}$
- N_H at 0.1 pc = $10^{23.4}$ cm^{-2}

- n_H, N_H at 0.1 pc = $10^{9.4}$ cm^{-3} & $10^{23.4}$ cm^{-2}

Netzer & Laor 1993

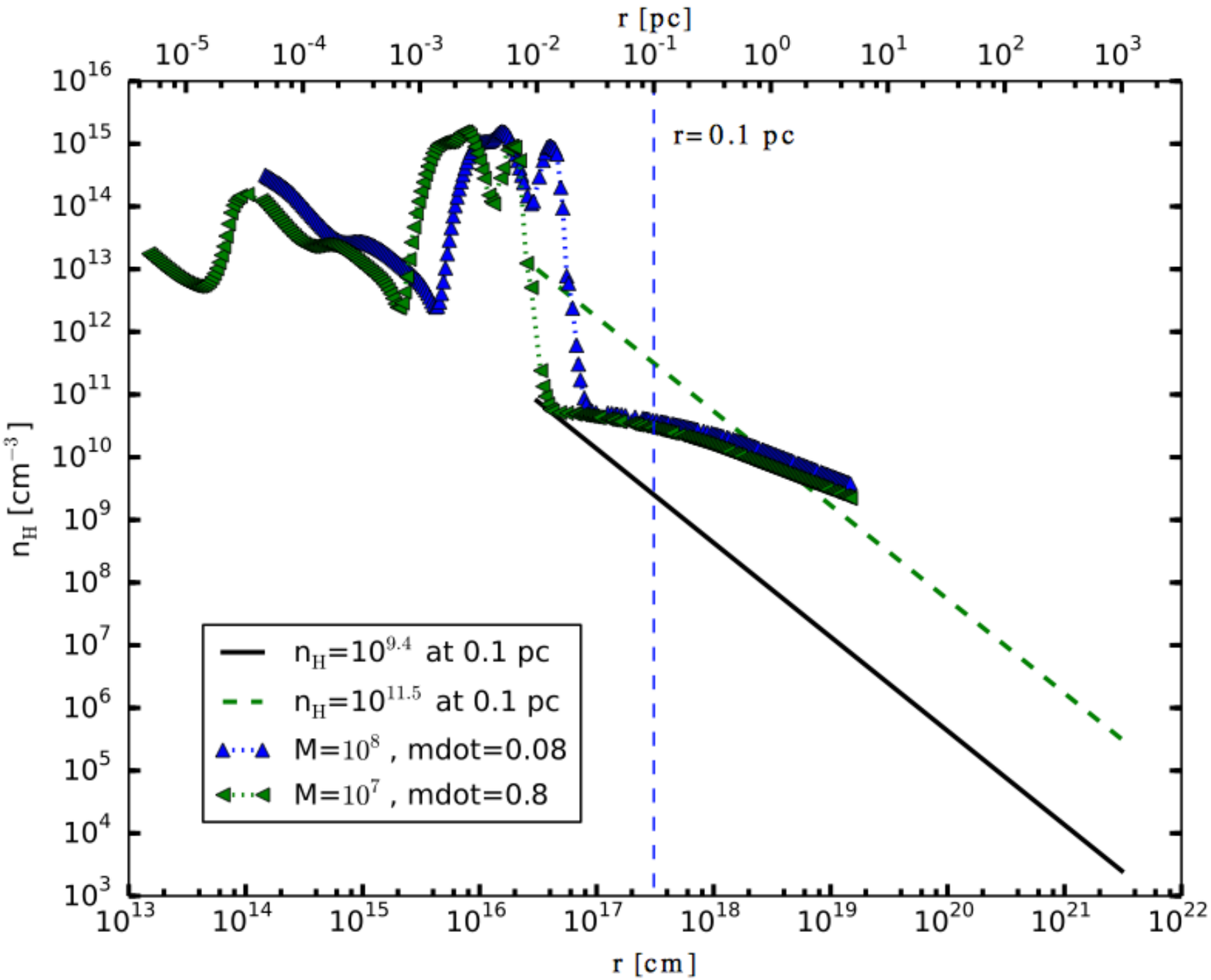
- Solar composition <=0.1 pc

- ISM composition with dust grains >=0.1 pc

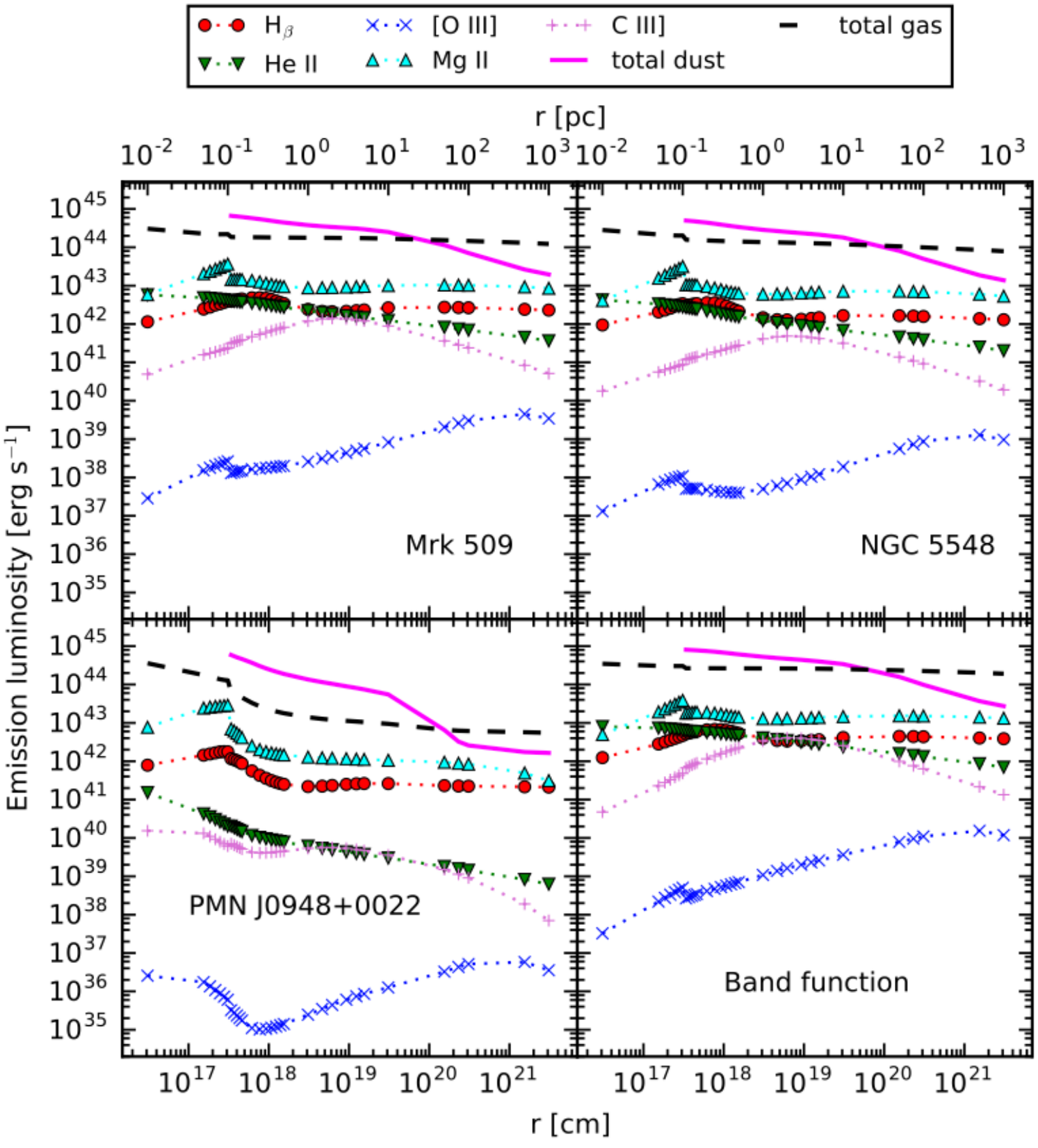
- n_H at 0.1 pc = $10^{11.5}$ cm^{-3}

High local densities (~ 10^{11} -10^{12} cm^{-3}) of emitting and absorbing clouds in AGN have been inferred for several sources (Leighly 2004, Bruh- weiler & Verner 2008, , Rozanska+ 2014, Hryniewicz + 2014, Modzelewska+ 2014, Sredzinska + 2016)

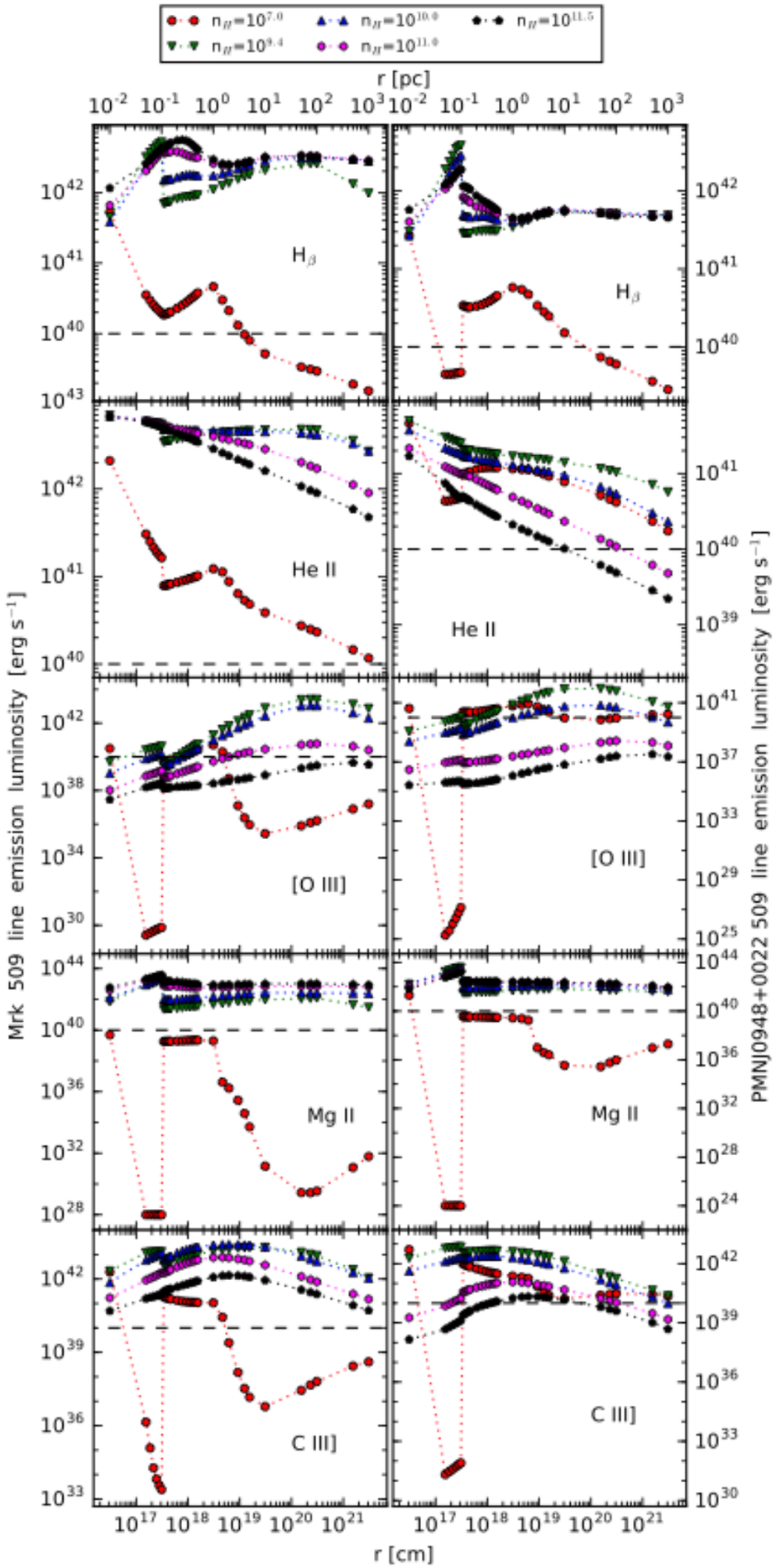
Dense clouds can be potentially formed from an accretion disk atmosphere



Adhikari + 2016, ApJ in press

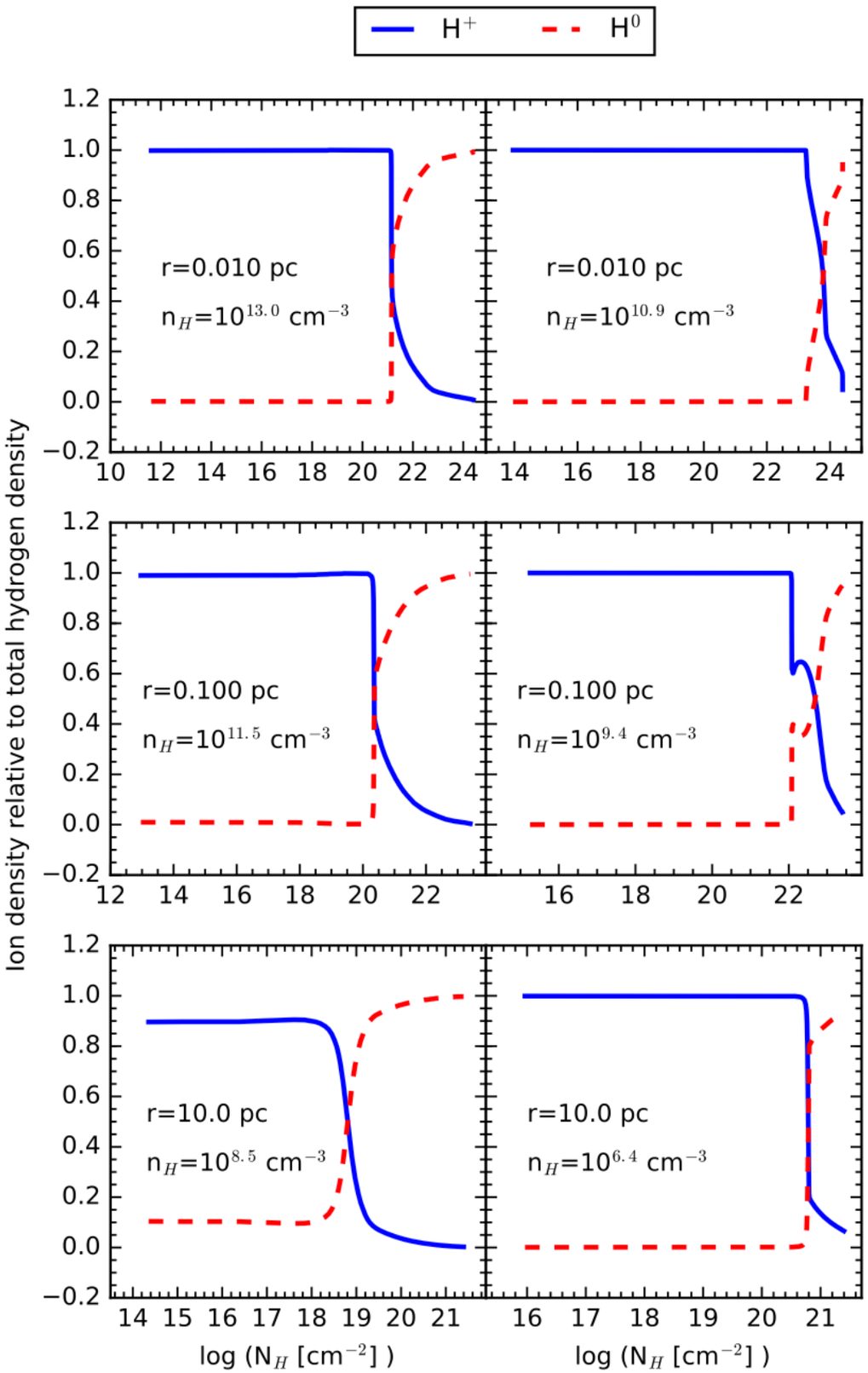


Adhikari + 2016, ApJ in press



The radial distances at which the various line luminosities peak are consistent with the results inferred from RM studies

Adhikari + 2016, ApJ in press



High density clouds have lower H^+ column

gas opacity always dominates for higher densities and it does not matter if the gas is dusty or not

Adhikari + 2016, ApJ in press

Two important predictions of our model

- Existence of ILR at distances 0.1-1 pc predicts the RM lag of ILR to be 100-1000 light-days

- In our case, the effect of dust disappears if U is less than 0.01 (threshold value). So, in LINERS where the emission lines are produced by the photoionisation of the gas at $U \leq 10^{-3}$ (Ferland & Netzer (1983)), our result clearly predicts the presence of ILR in LINERS. The presence of ILR in 33 LINERS is also shown by Balmaverde + 2016

More to be explored !

Summary

- The presence or absence of ILR is not determined by the spectral shape of the incident continuum.

- With high density at sublimation radius i.e., $10^{11.5}$ $cm^{-}3$, we obtained a continuous "line emission vs radius" showing the existence of ILR. So the density of the gas should be high enough for the intermediate line emission

- The dense cloud can be potentially formed from an accretion disk atmosphere which is dense enough below the sublimation radius in the accretion disk

- Such ILR is predicted to be located at radial distances r ~ 0.1 – 1 pc, and the expected by our model the reverberation mapping lag would be of the order of 100-1000 light-days