ERASMUS MUNDUS JOINT MASTER DEGREE
MASTER IN ASTROPHYSICS AND SPACE SCIENCE

Introduction to Active Galactic Nuclei

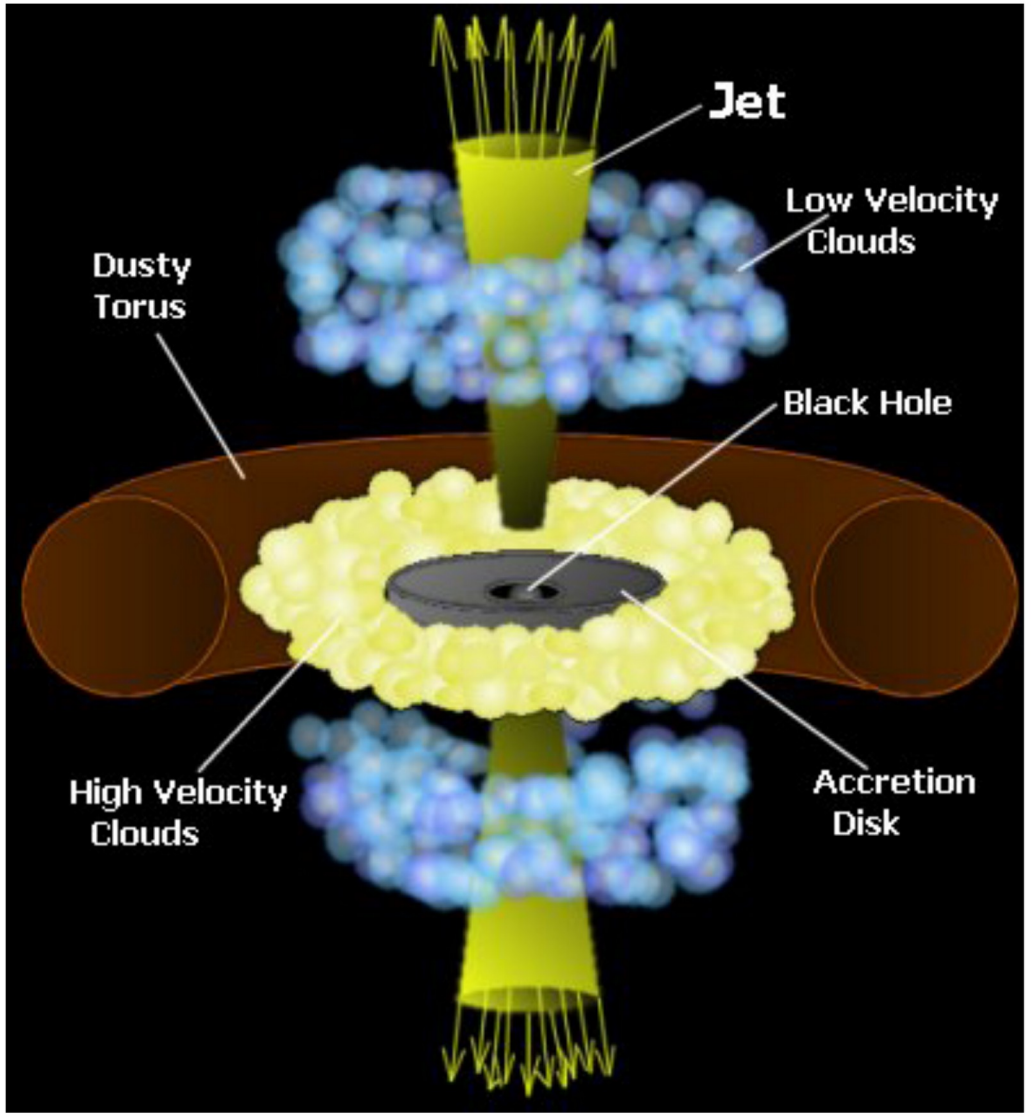
Tutorial 4

How to find a quasar?

April 2023

Part I: AGN Diagnostics using narrow emission lines

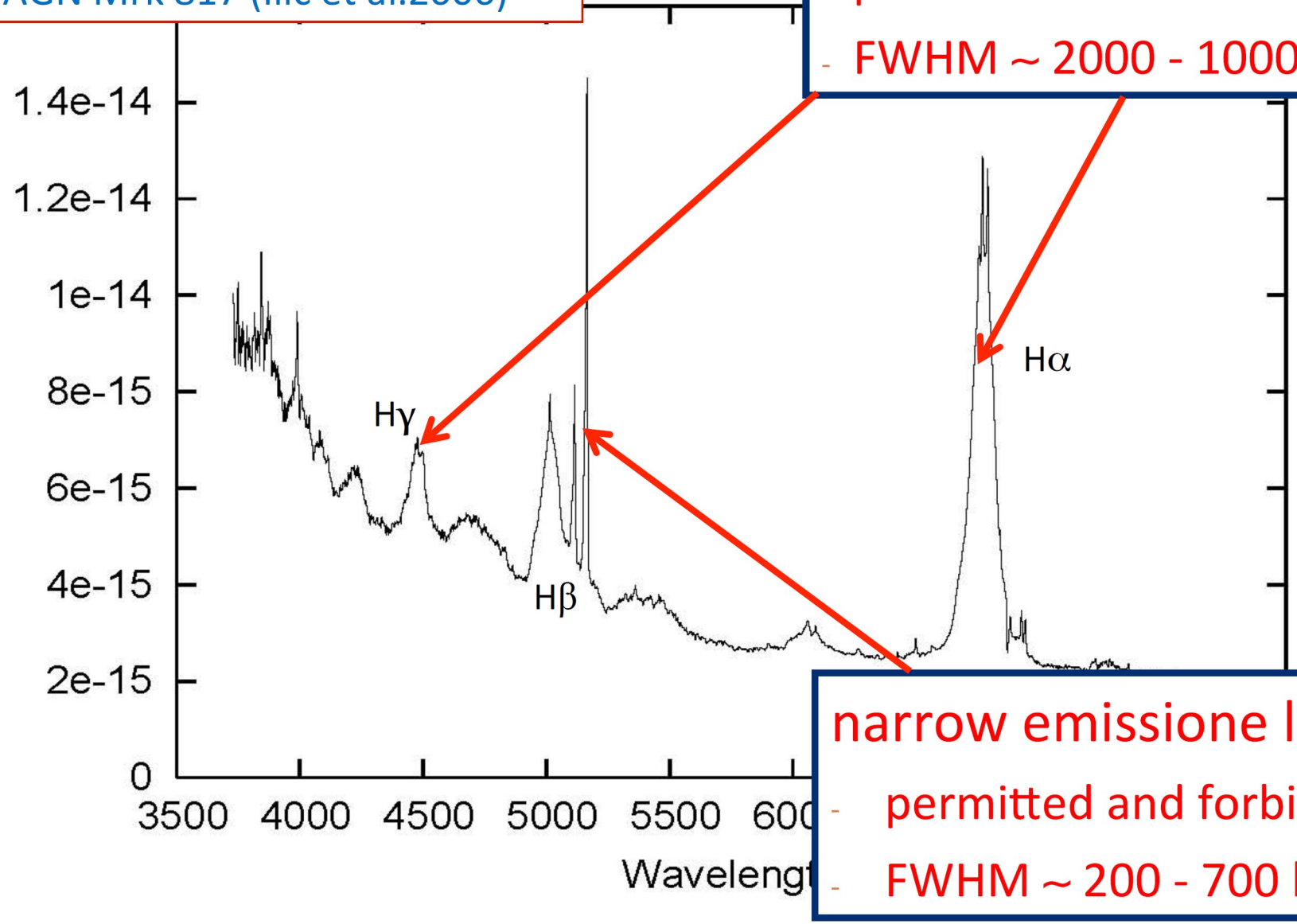
Emission line regions



- Narrow Line Region = NLR
- Broad Line Region = BLR

Optical spectrum

AGN Mrk 817 (Ilic et al.2006)



broad emission lines

- permitted transitions
- FWHM ~ 2000 - 10000 km/s

narrow emissione lines

- permitted and forbidden
- FWHM ~ 200 - 700 km/s

Narrow line gas properties

- line intensities, corrected for reddening, can be used for diagnostics
- T from e.g.[OIII] lines: 1-2 x 10^4 K (depending on n_e)
- n_e from e.g. [SII] ratios: 3-4 x 10^2 cm^{-3}

  $\rightarrow$ most likely 10^2 $cm^{-3} < n_e < 10^4$ cm^{-3}
- the abundances are estimated to be almost the same as in our Galaxy:

  $\rightarrow$ H most abundant, He is less abundant for factor of 10, then O, Ne, N, C

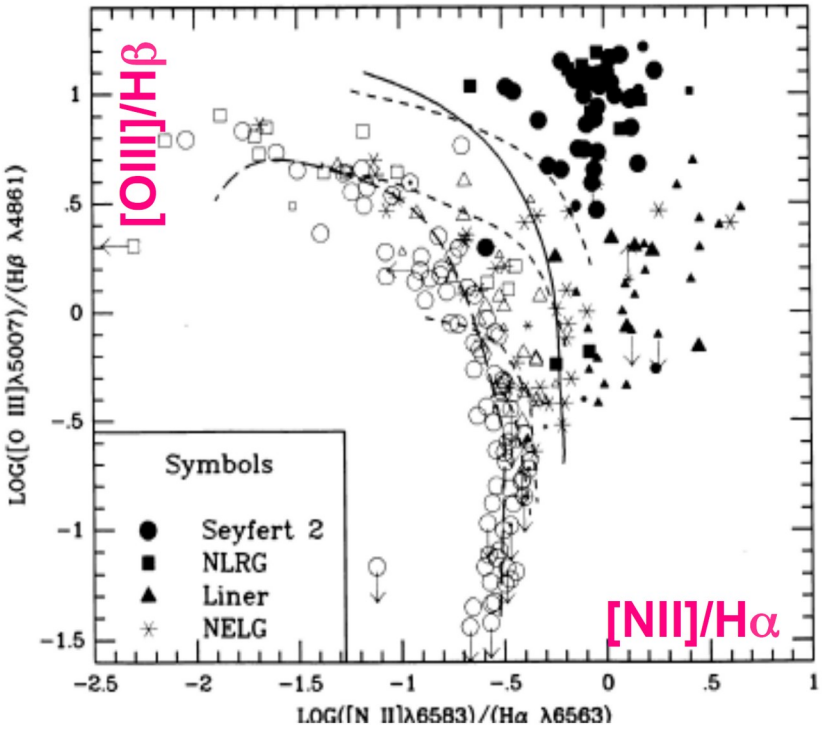
photoionization of NLR

- at these T, photoionization most probable mechanism of energy input
  - → also shock-wave heating, but not important at these T
  - → or collisional heating, but again cooling by CEL more important
- for sure, ionization is NOT from hot stars or PNe
  - → we need "harder" continuum for high ionization
  - → featureless continuum observed in every AGN
  - → in optical-UV: $L_\nu = C\nu^{-\alpha} \quad \alpha \approx 1\text{-}2$
  - → the power-law continuum can explain the observed line intensities and ionizations

Diagnostic diagrams

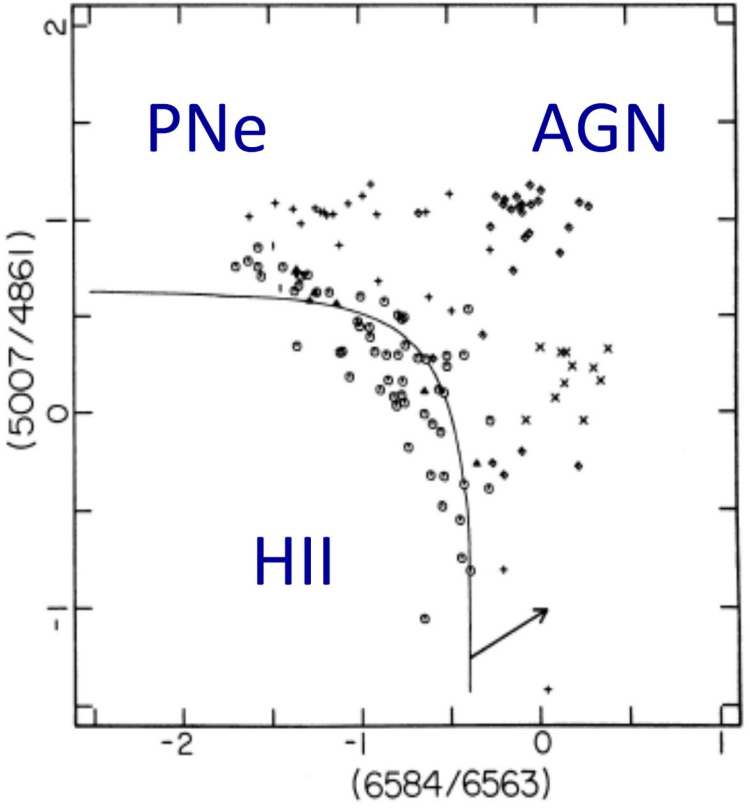
- based on difference in emission line ratios for different object types
  - → [O III]/Hβ - mean level of ionization and T
  - → [O I]/Hα and [S II]/Hα - relative importance of a large partially ionized zone produced by high-energy photoionization
  - → [N II]/Hα - good separator
  - → comparison with sequences of photoionization models

Veilleux & Osterbrock 1987



The BPT diagram

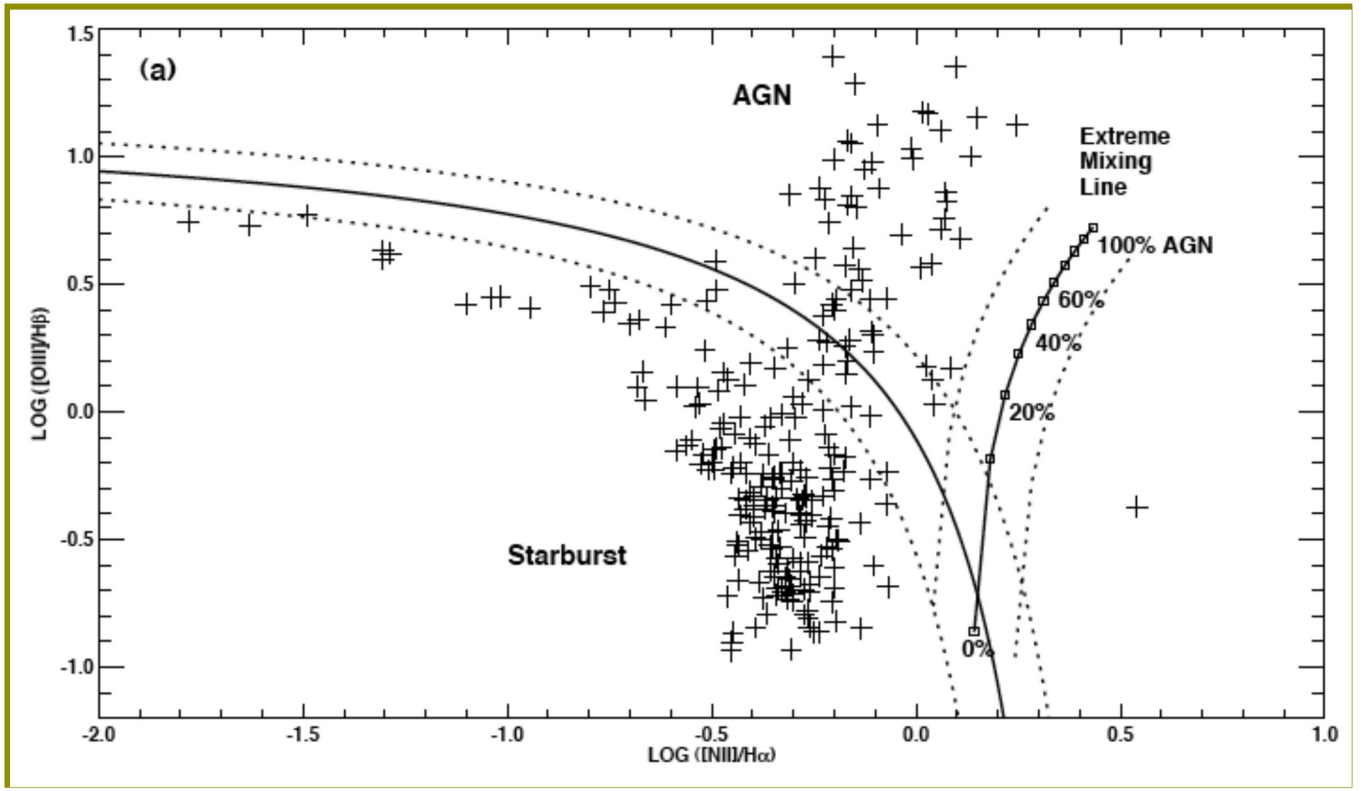
- **Baldwin, Phillips, Terlevich 1981**
- photons from PNe and AGNs are harder than those from massive stars that power HII regions
  - → they provide more heating
  - → collisionally excited lines will be brighter than in the case of ionization by massive stars only



- both ratios are based on lines close in wavelength ⇒ **nearly reddening independent**

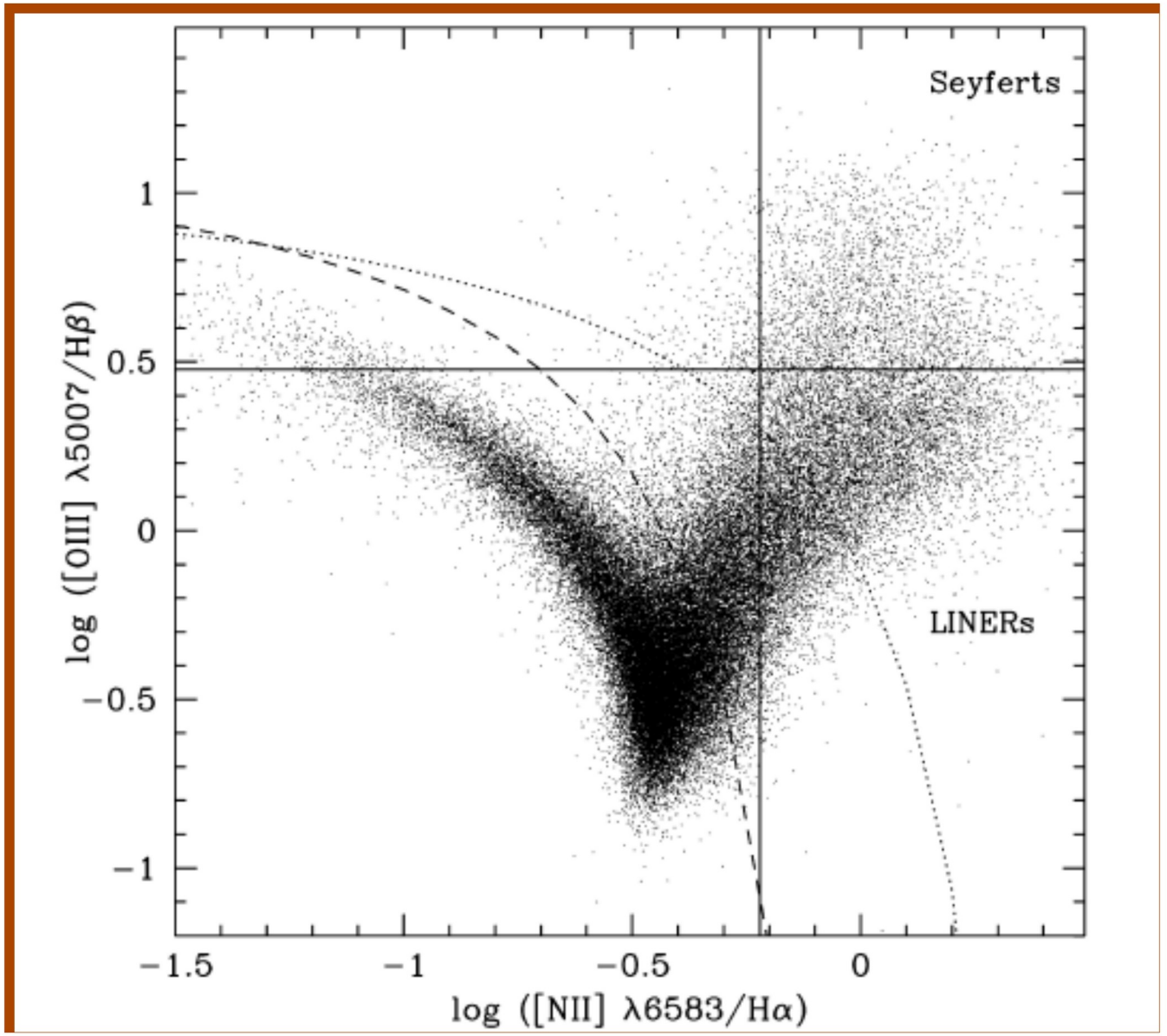
Kewley et al. 2001: theoretical classification

- upper starburst limit: from starburst model grids (the PEGASE EUV ionizing radiation field and MAPPINGS III photoionization model)
- lower limit to starburst and AGN mixing (shock model)



SDSS revolution

- Kauffmann et al. (2003)
- empirical curve based on more than 22,000 type2 AGN



Assignment - **BPT Diagram**

Due for report: 28.04.2023. (Friday)

1) Use SDSS DR18 SQL search to find all galaxies which have only the narrow emission lines (FWHM<500 km/s), high median signal to noise ratio in g band (S/N>40), and fluxes of lines: [O III] 5007, Hβ, Hα and [N II] 6583 larger than 5 e-17 erg/s/cm^2. Set criteria so that the fluxes are larger than errors in flux multiplied with 5 in order to get good results. SQL output should be the fluxes of these lines.

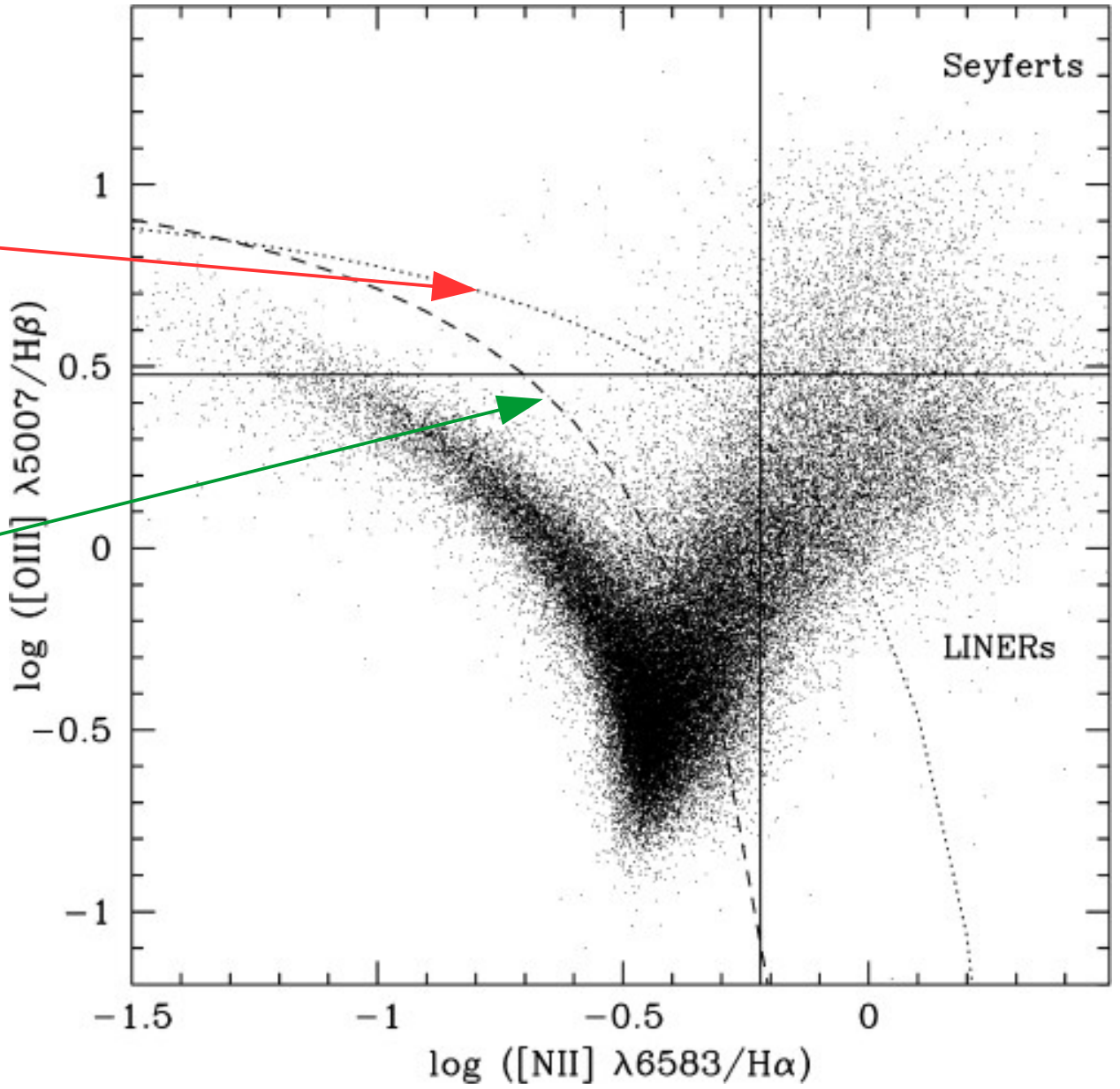
2) For the obtained sample make the diagnostic BPT (Baldwin, Philips and Terlevich) diagram. This diagram determines the dominant ionization source for the objects: accretion disk (AGN) or hot emission stars (H II - star-burst region). For the BPT diagram use the flux ratios of the lines: [O III] 5007/Hβ vs. [N II]6583/Hα.

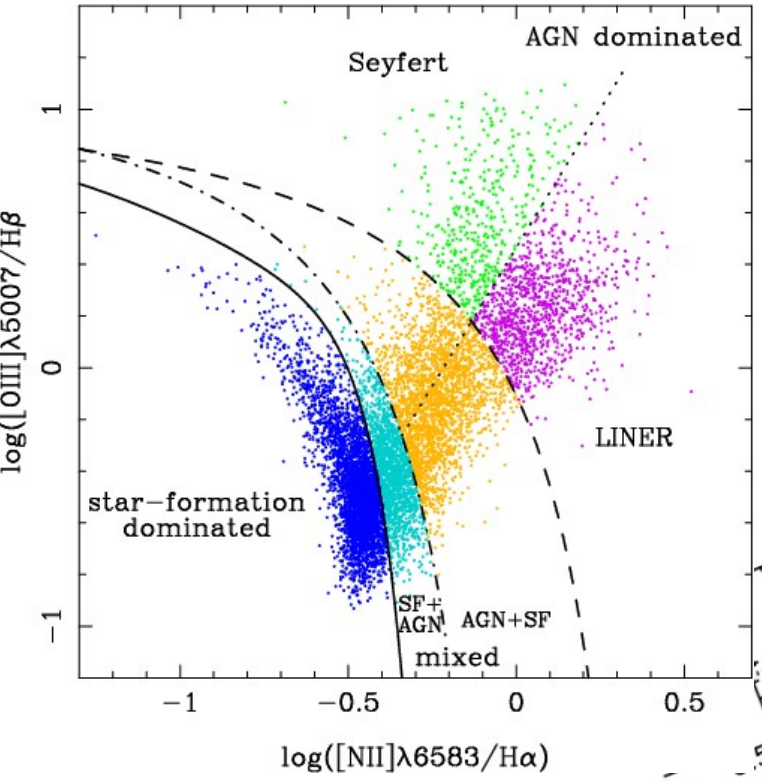
separation lines / criteria

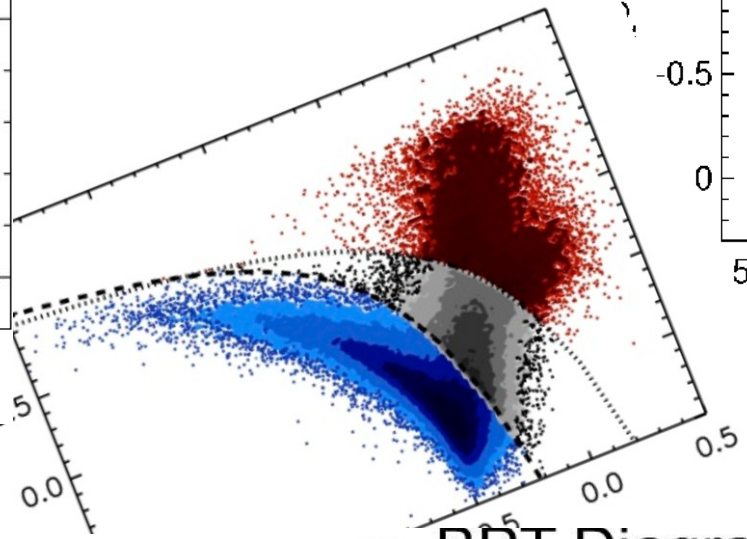
For the separation curves use:

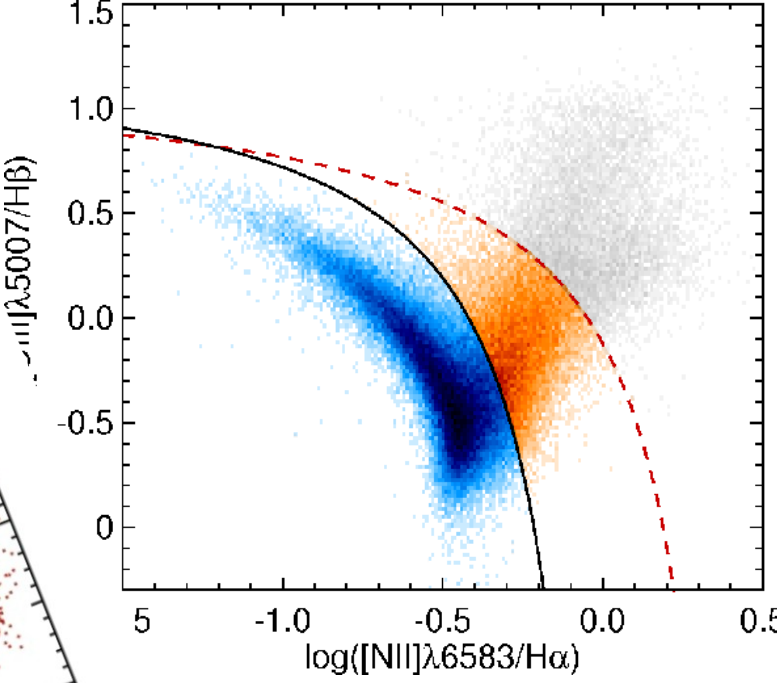
I the theoretical curve from the paper ***Kewley et al. 2001,*** *ApJ, 556, 121* (dotted line in the graph) and

II the empirical curve from the paper ***Kauffmann et al. 2003,*** *MNRAS, 346, 1055 (dashed line in the graph).*









BPT Diagram (Baldwin, Phillips, & Terlevich 198