Warped Discs and the Unified Scheme

- Introduction
- Problems with the torus
- Warped discs
- Simple model

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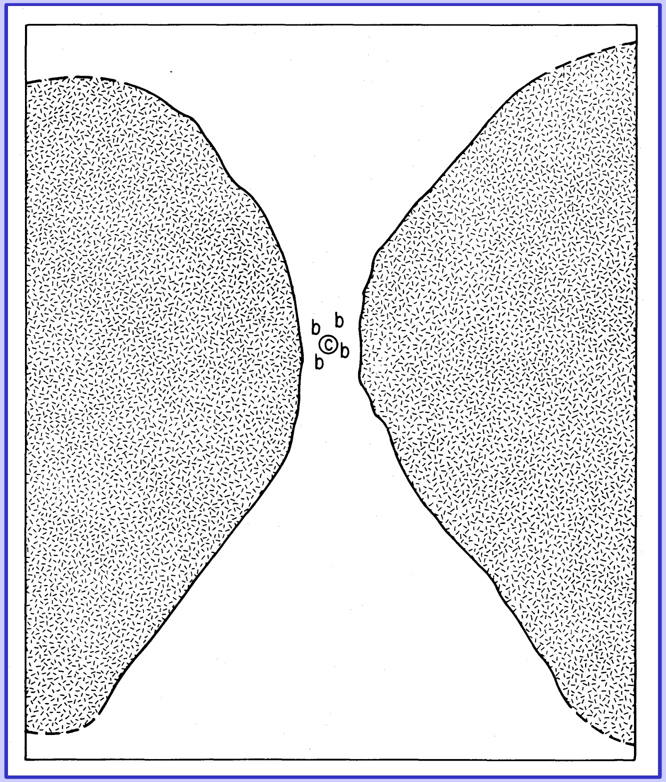
Introduction

Strawman Model

- Accn disk
  + BLR
  + obscuring torus
  + NLR

- Type II = Type I seen through torus
  - see MIR and Narrow Lines only
- Torus geometrically thick (H/R ~ 1)
- Torus at 1pc (Sy) - 10pc (Quasar)
- Produces UV extinction
  and X-ray absorption
- Most (80%) AGN obscured
  - to fit X-ray background



Antonucci and Miller 1985
Krolik and Begelman 1988

Evidence for axisymmetric obscuration

- polarisation mirrors in some SyIIs perp to radio axis
- emission line cones seen in some cases
- NLRGs larger than BLRGs and quasars
- BLRG polzn $\parallel$ radio axis
- NLRG polzn $\perp$ radio axis

Problems

Physical implausibility

- need vertical motions ~ rotational ~ 1000 km/s
- very supersonic (T~200K)
- clouds in virial motion ?
- should dissipate rapidly

more natural ways to make thick structures :

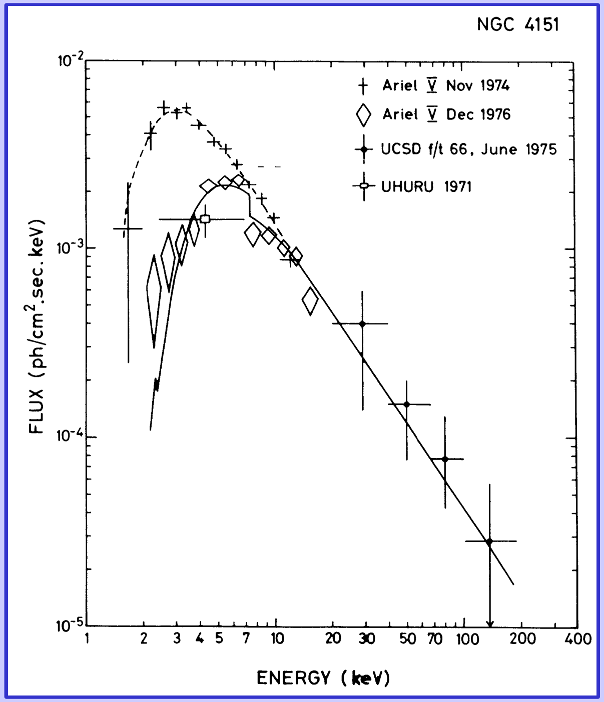
- radial outflow (Elvis 2000)
- warped disc (Phinney 1989, Sanders et al 1989)

X-ray absorption

- X-ray absorbed AGN ≠ obscured AGN
  - objects with large N_H but Broad Lines
  - (Mushotzky et al 1978, Wilkes et al 2005)
  - dust/gas low by factor 200
  - N_H varies rapidly (Barr et al 1977, Elvis et al 2004)

- .. a different phenomenon

- dust-free gas close to nucleus
- closest gas X-ray transparent ("warm absorber")



Barr et al 1977

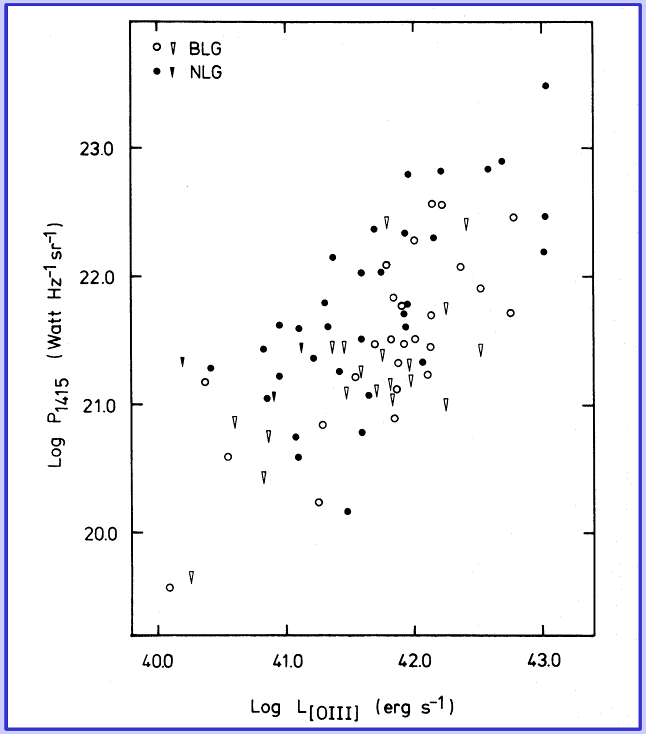
Range of covering factors

- OIII/radio larger for BL than NL
  - Whittle 1985; Jackson&Browne 1990; Lawrence 1991; Grimes et al 2005

- R_{OIII} ~ 4 at given L
  - radio gals : Grimes et al 2005
  - Sy : this talk

- requires a range of covering factors
  - radio : pre-obscured power
  - OIII : uncovered fraction

- standard torus model : no prediction for distribution of covering factors



Whittle 1985

True quasar fraction

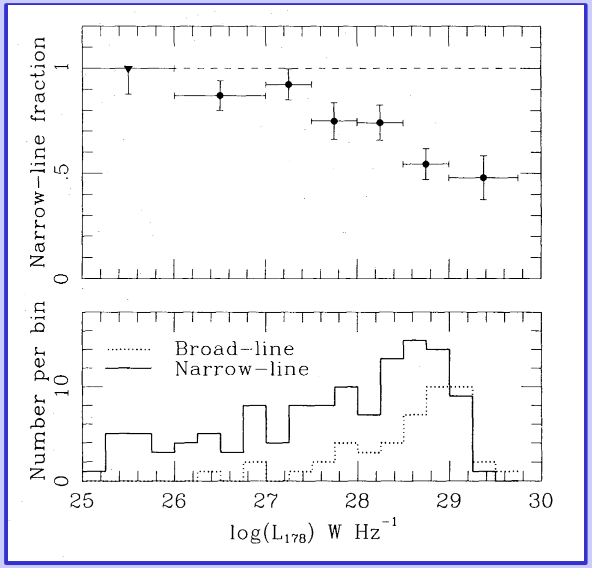
- f_Q varies with L
  for radio and OIII samples
  - Lawrence 1991; Simpson 2005

- but not for MIR samples
  - Rush et al 1993; Keel et al 1994

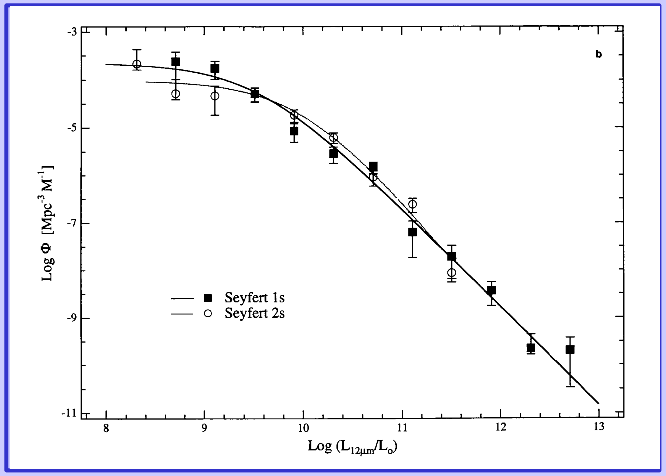
- Lum. effect due to low-L
  low-excitation population
  - Laing et al 1994; Willott et al 2000
  - switched off quasars ?

- correct f_Q ~0.4
  - Radio : Willot et al 200
  - IRAS : Rush et al 1993, Keel et al 1994
  - Spitzer : Lacy et al 2005

- standard torus model : no natural explanation for f_Q



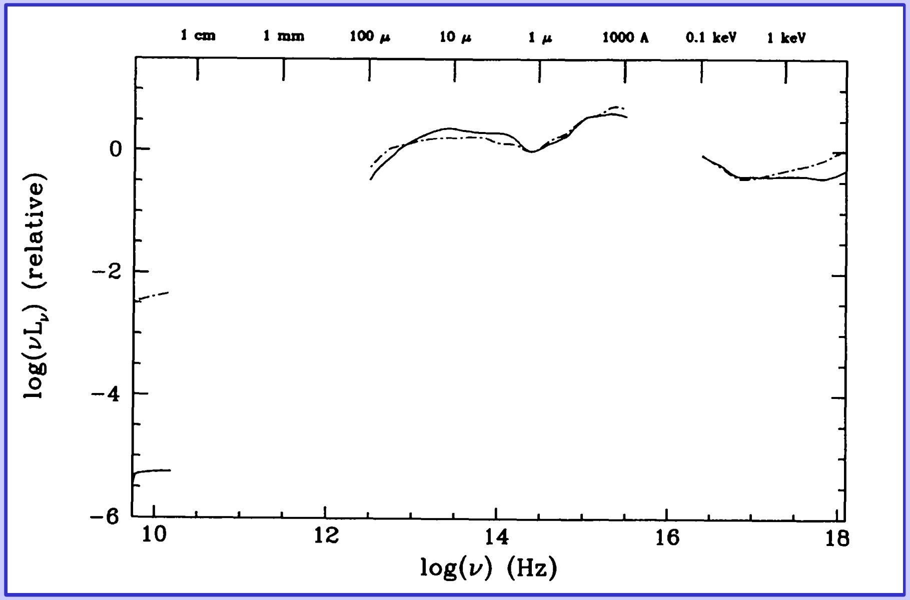
Lawrence 1991



Rush et al 1993

Reprocessing

- SED peaks at 10μm
  - Sanders et al 1989, Elvis et al 1994
- T ~ 200K
  - but broad : 20-1000K
- Dust over large distance range but most reprocessing at D_{reproc} ~1pc (Sy) to 10pc (Quasar)
- Reprocessed fraction f_{reproc} ~0.3 on average
  - from L(IR)/L(UV)
  - Sanders et al 1989, Elvis et al 1994
- Standard torus model : no natural explanation for D_{dust} or L_{IR}/L_{UV}



Mean quasar - Elvis et al 1994

Note : D ~1-10pc is boundary of "sphere of influence" of black hole (Krolik and Begelman 1988)

Also dust "spherisation radius" ? (A.King, Monday talk)

Requirements

- Natural way of
  - obscuring much of sky
  - producing range of covering factors
  - producing broad range of temps
- Predicting values of
  - $R_{OIII} \sim 4$
  - $f_Q \sim 0.4$
  - $f_{reproc} \sim 0.3$
  - $D_{reproc} \sim$ 1-10 pc

Warped Discs

Warped Discs as IR reprocessor

- Proposed by Phinney (1989), Sanders et al (1989)
- Seen on large scales in many galaxies
- Several plausible mechanisms at large scales
- Inner dust does not hide outer dust
  - natural large range of temps

- what happens on pc scales ?
- can we make large covering factors ?
- can we make simple quantitative predictions ?

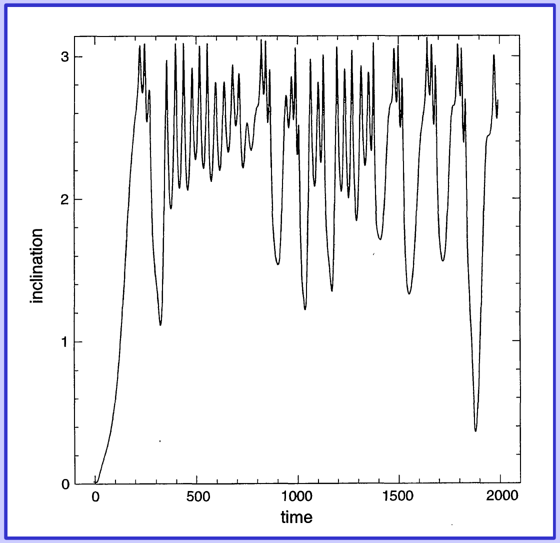
Parsec scale warp drive

- Re-radiation instability ? (Pringle 1996)
- Tumbling bar ? (Tohline and Osterbrock 1982)
- Large scale magnetic field ?

- can all produce large warps
  and a range of covering factors C

- quantitative prediction for N(C) ?

- look at general idea of disc re-alignment...



large and variable warp (Pringle et al 1997)

Simple Model

Disc re-alignment

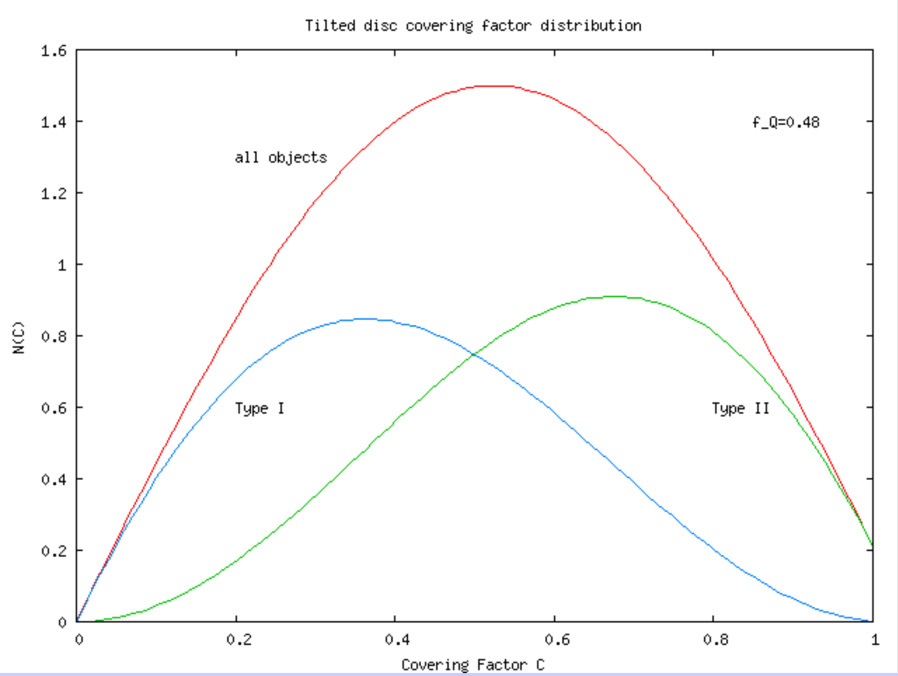
- Simple model ingredients :
- Incoming disc and nuclear disc unconnected
  - axis difference θ random
  - $dP = \sin\theta \, d\theta$
  - natural range of covering factors $C(\theta)$
- Re-aligns at some critical radius
- Covering factor depends on degree of twist :

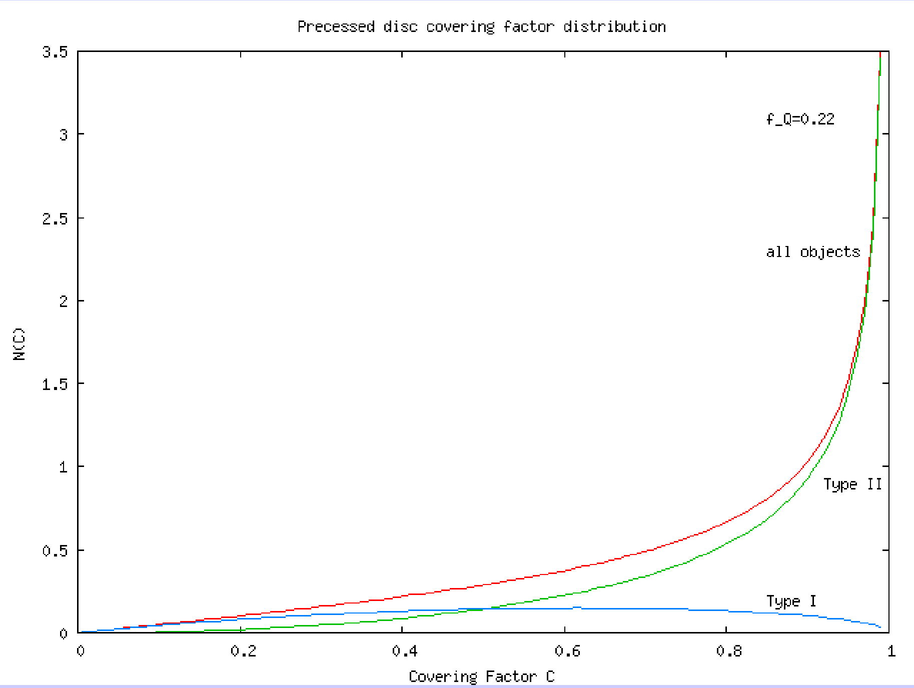
Tilt only :	$C = \theta/3$	one sided
Fully precessed :	$C = \sin\theta$	full equatorial wall

(Pringle warp is intermediate case)

- Fraction C appear as Type II and (1-C) as Type I

Covering factor vs type





$f_Q = 0.48$

$f_{reproc} \sim 0.35$

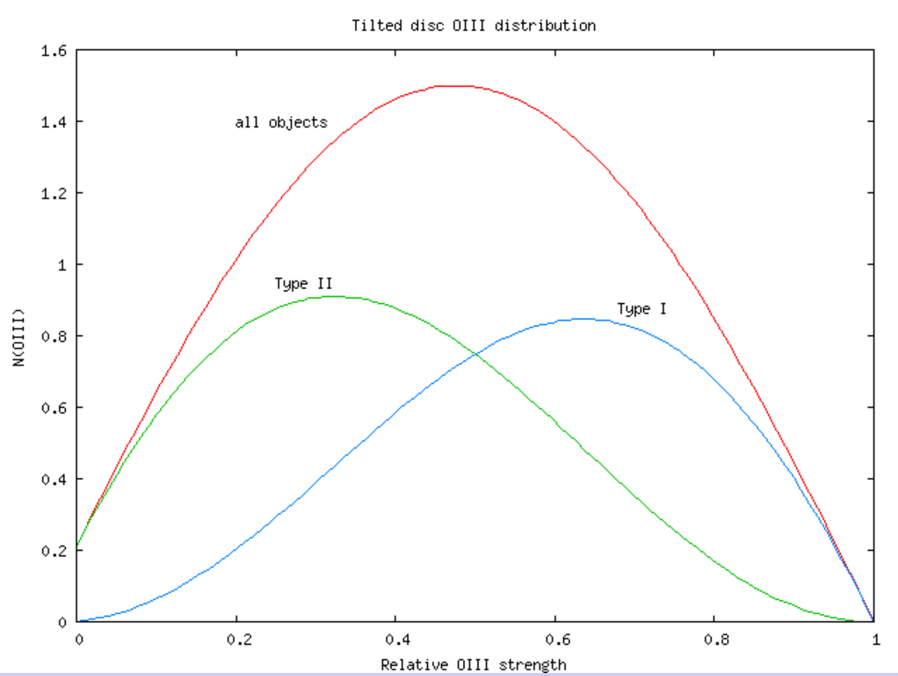
$f_Q = 0.22$

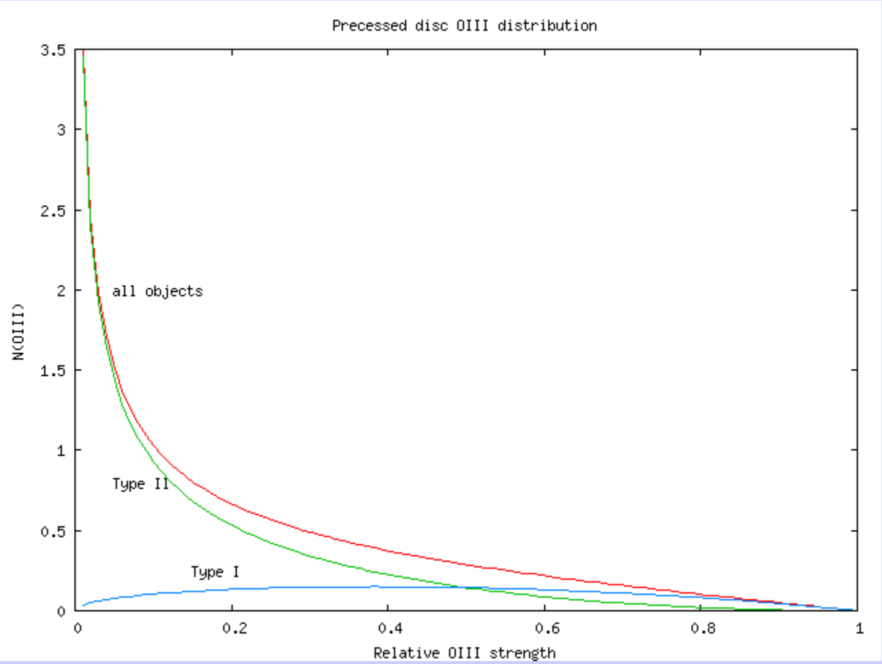
$f_{reproc} \sim 0.5$

tilted disc better fit

and additional popn of completely obscured objects

OIII strength vs type





R_{OIII} ~ 2
cf obsvns ~ 4

gives wrong distbn

tilted disc better fit but
small amount of twist needed ?

Problems

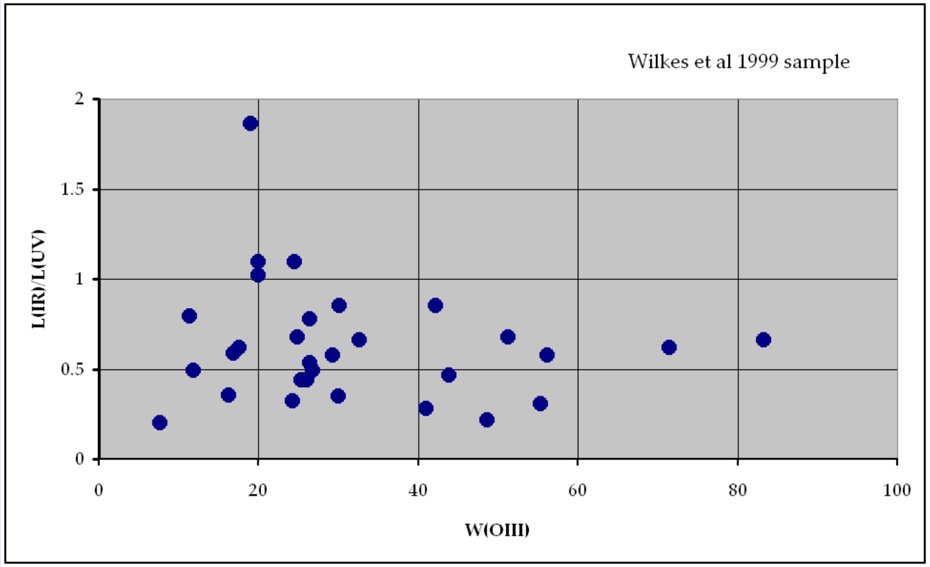
- Tilt-only disc strongly preferred, but :
  - Edge-on Type Is should exist (side-on warps)
  - Shadow cones should often be offset from radio axis
  - Jets will often run into torus
- Radiation-warp disc has similar problems

- Possible solutions
  - misalignment $\Delta\theta$ not random
  - emission line cones are not shadow cones
  - parsec scale warped discs not the answer ...
    - outflow + dust formation shell
    - dust launched outflow in outer disc

FIN

More on covering factor spread

- For Type I, OIII/UV should anti-correlate IR/UV



- Radio-size ratio II/I should depend on OIII/radio