The AGN as a Protostar

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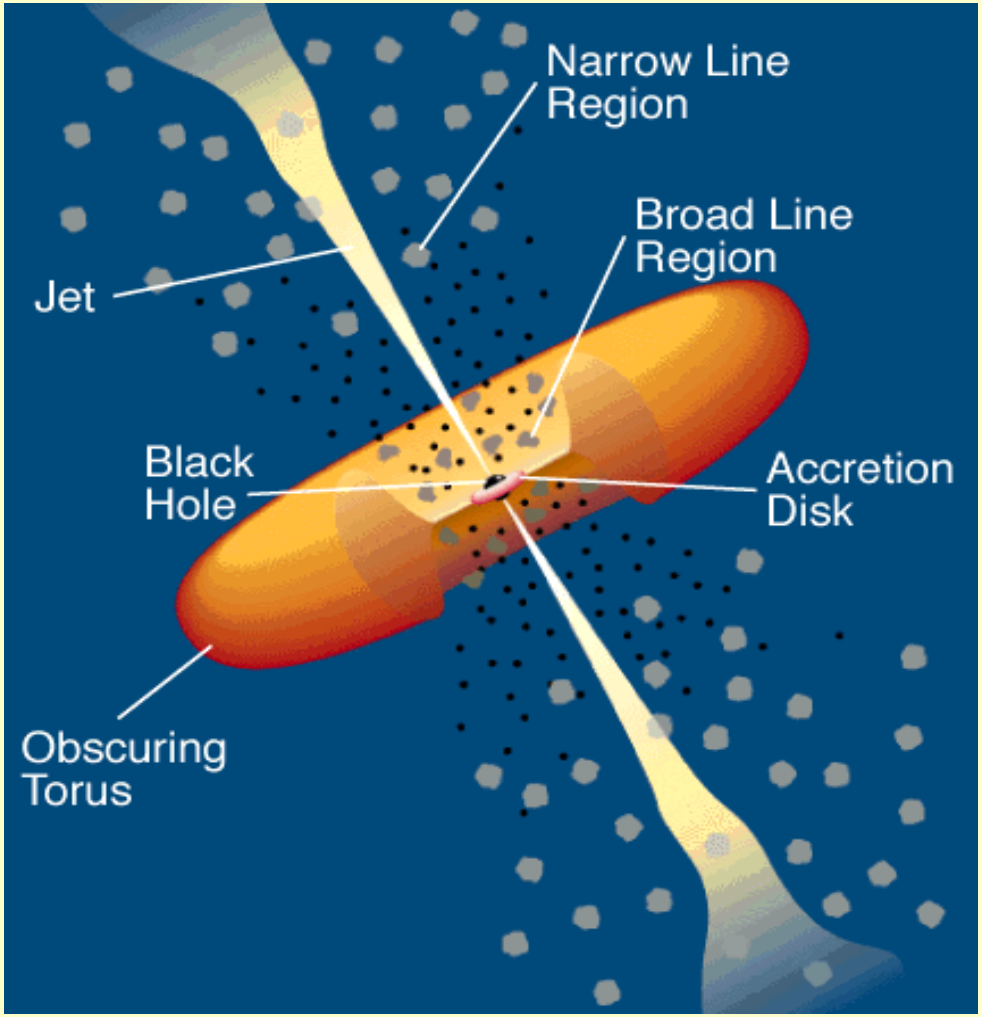
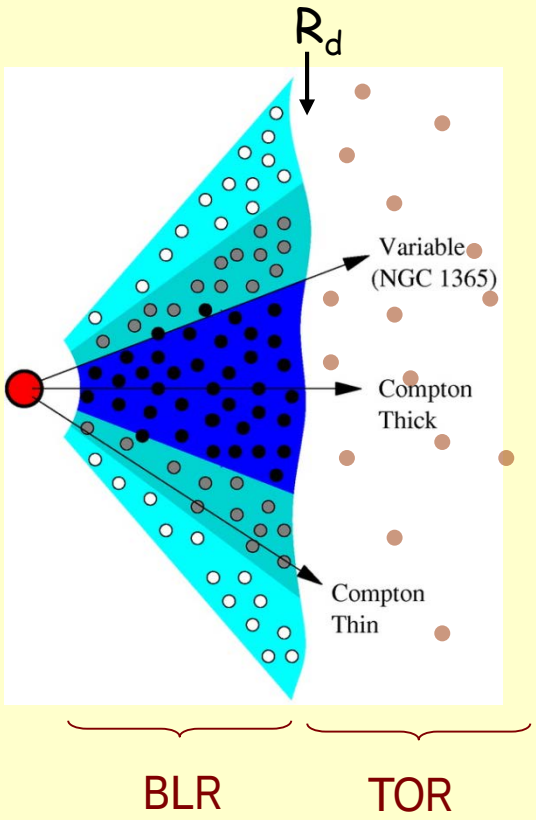
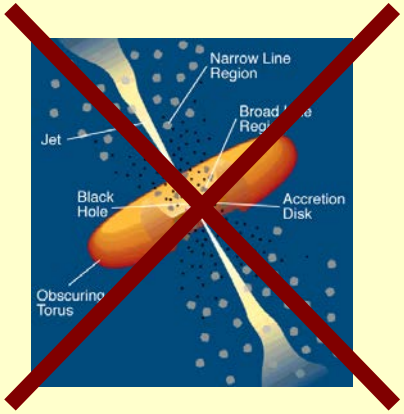
Unified Scheme for AGN



Single Cloud Distribution

$R_d = 0.4\ L^{1/2}_{45}$ pc





$r < R_d$ — dust free clouds:
Broad **L**ine **R**egion

$r > R_d$ — dusty clouds:
Toroidal **O**bscuration **R**egion

AGN gravitational sphere

$R_{BH} = 35\text{pc}\ (M_{\bullet 7}/\Omega^2_1)^{1/3}$

BLR and Torus Structure:

Environment of Accreting Point Mass

Prime Example: Star Formation

From Doug Lin

Relevant physical parameters

Planetary systems:

1. Mass ratio: 10^{-6} -10^{-3}
2. Period: days-centuries
3. Radius/semi major axis: 10^{-4}

Protostellar disks

1. Disk mass/star mass: 0.01-0.1
2. H/r = 0.05-0.2
3. Q > 10
4. Persistent time scale: 3-10My

Galactic center system:

1. Mass ratio: 10^{-6} -10^{-3}
2. Period: yrs- millenium
3. Radius/semi major axis: 10^{-4}

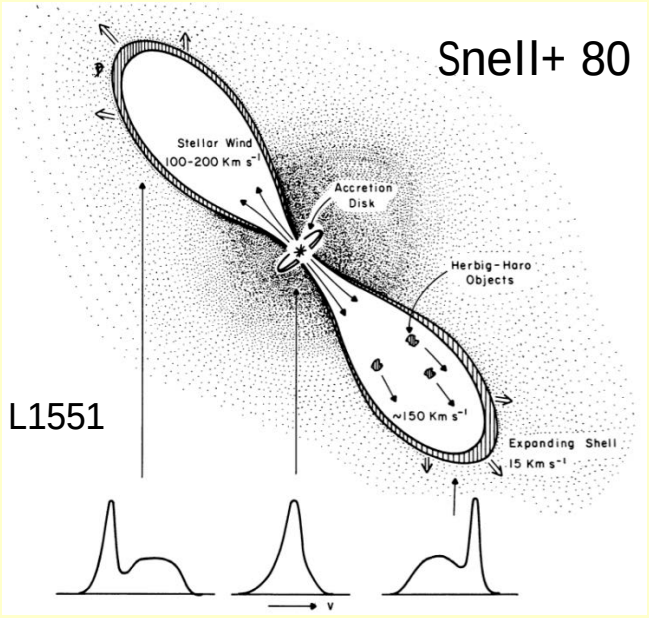
AGN and young stellar disk

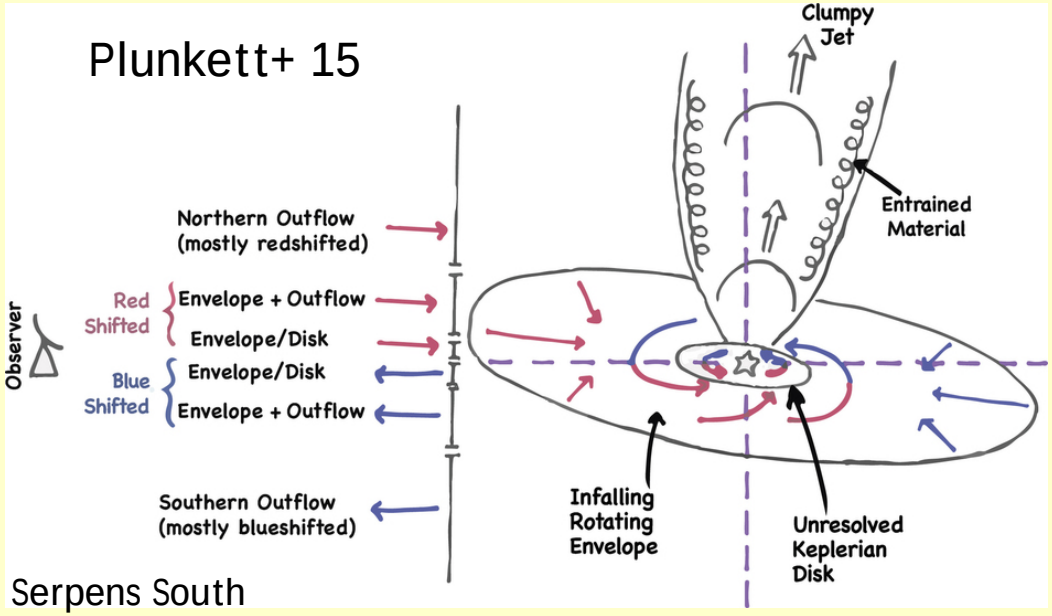
1. Disk mass/star mass: ~0.01
2. H/r ~ 0.01-0.1
3. Q: ~ 1
4. Persistent time scale: 1-100My

BLR and Torus Structure:

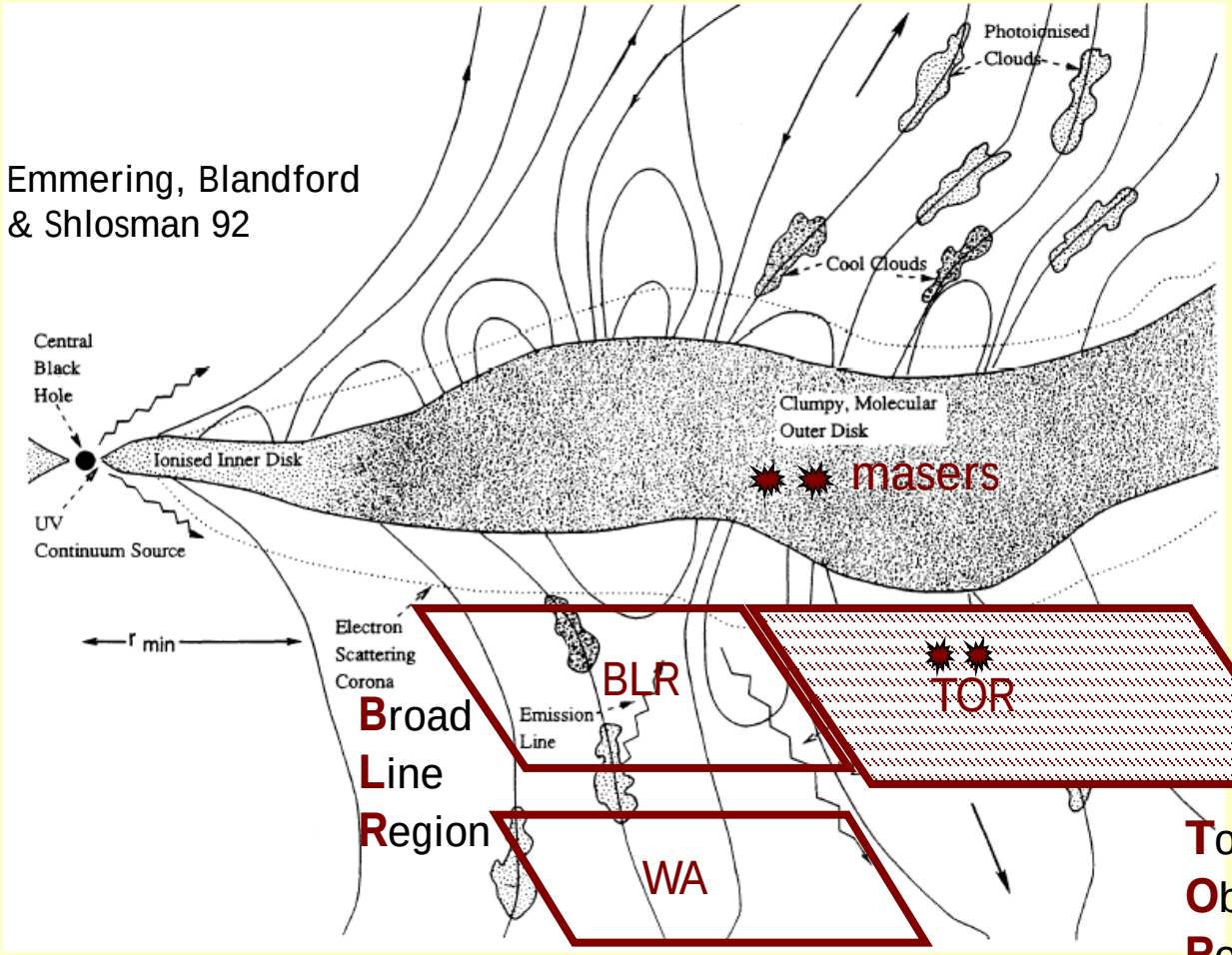
Environment of Accreting Point Mass

Prime Example: Star Formation

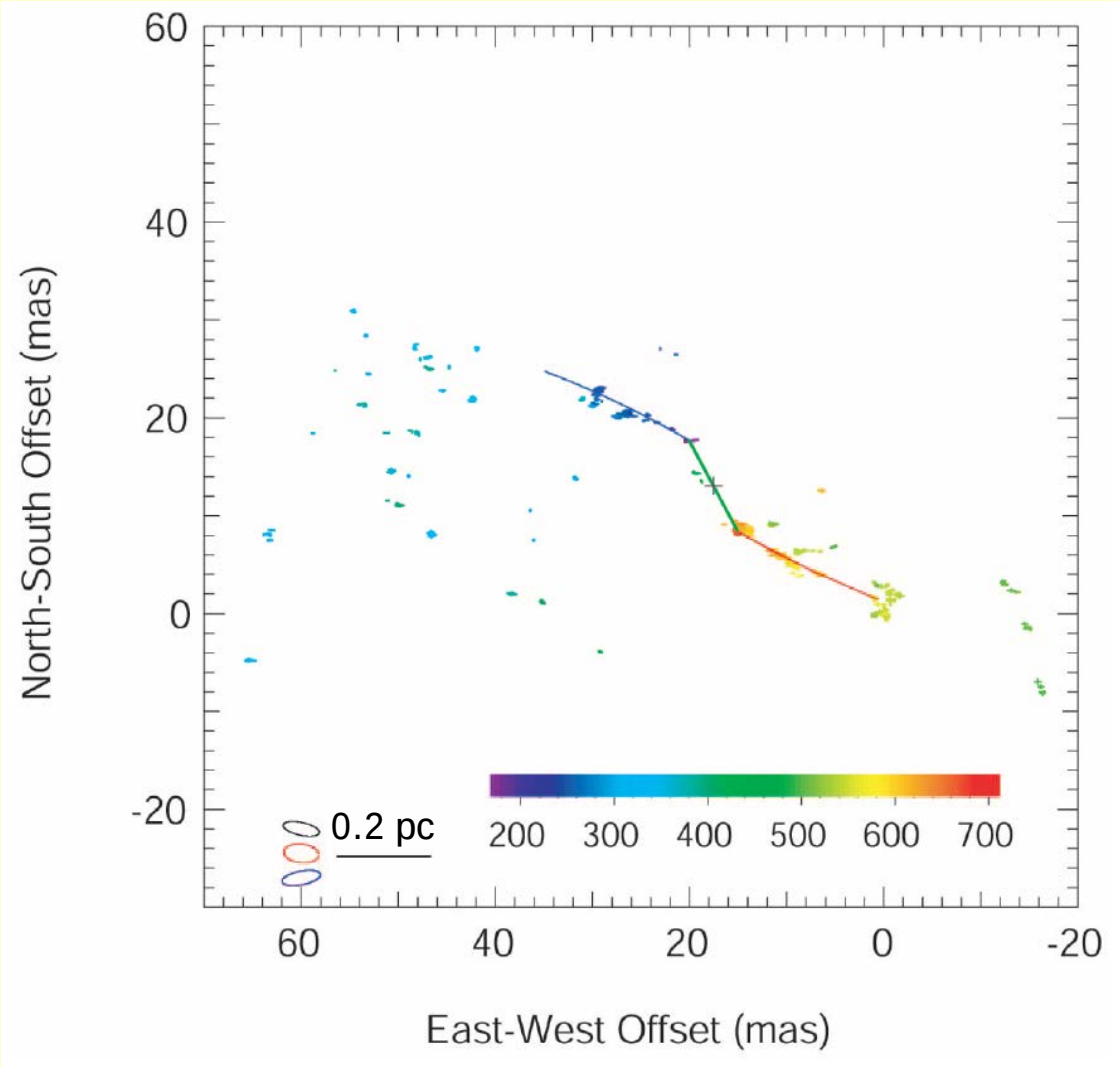




Grand Unification Theory

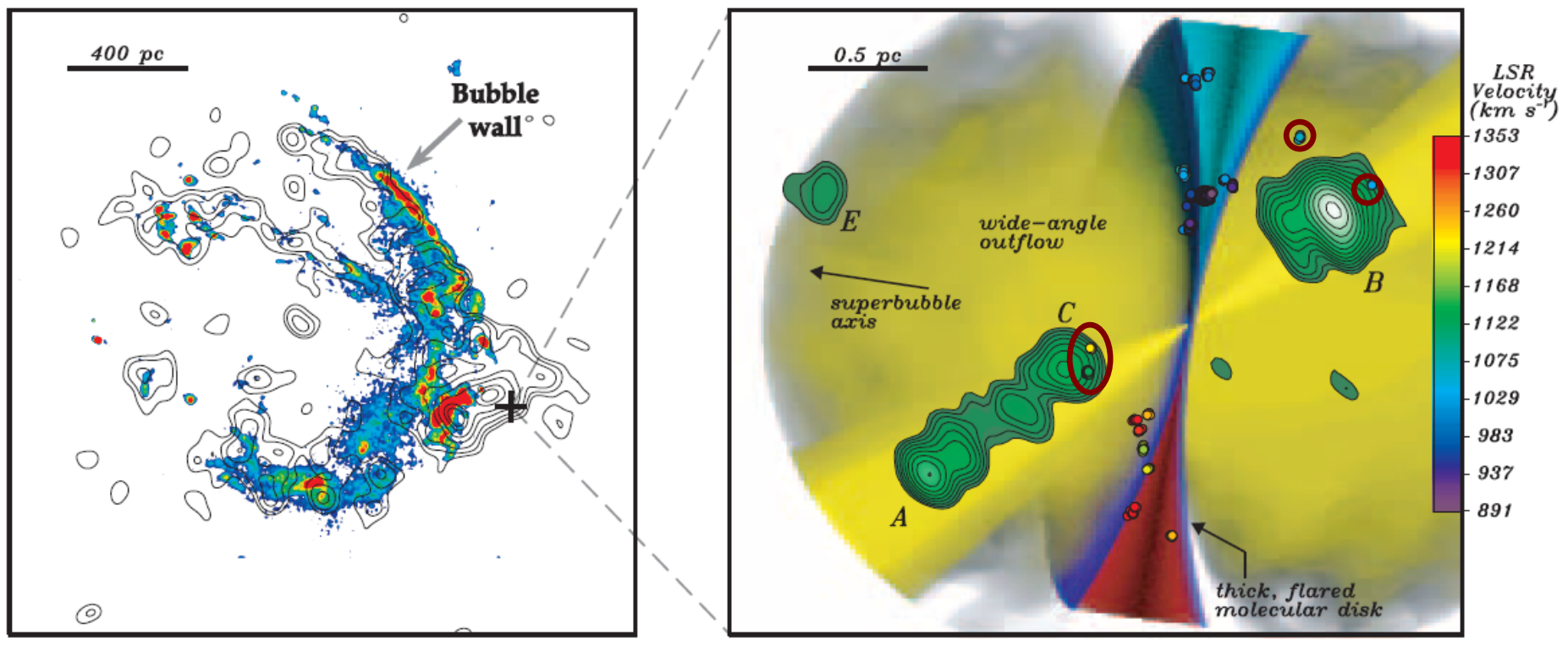


Circinus Water Masers



Greenhill+ 03

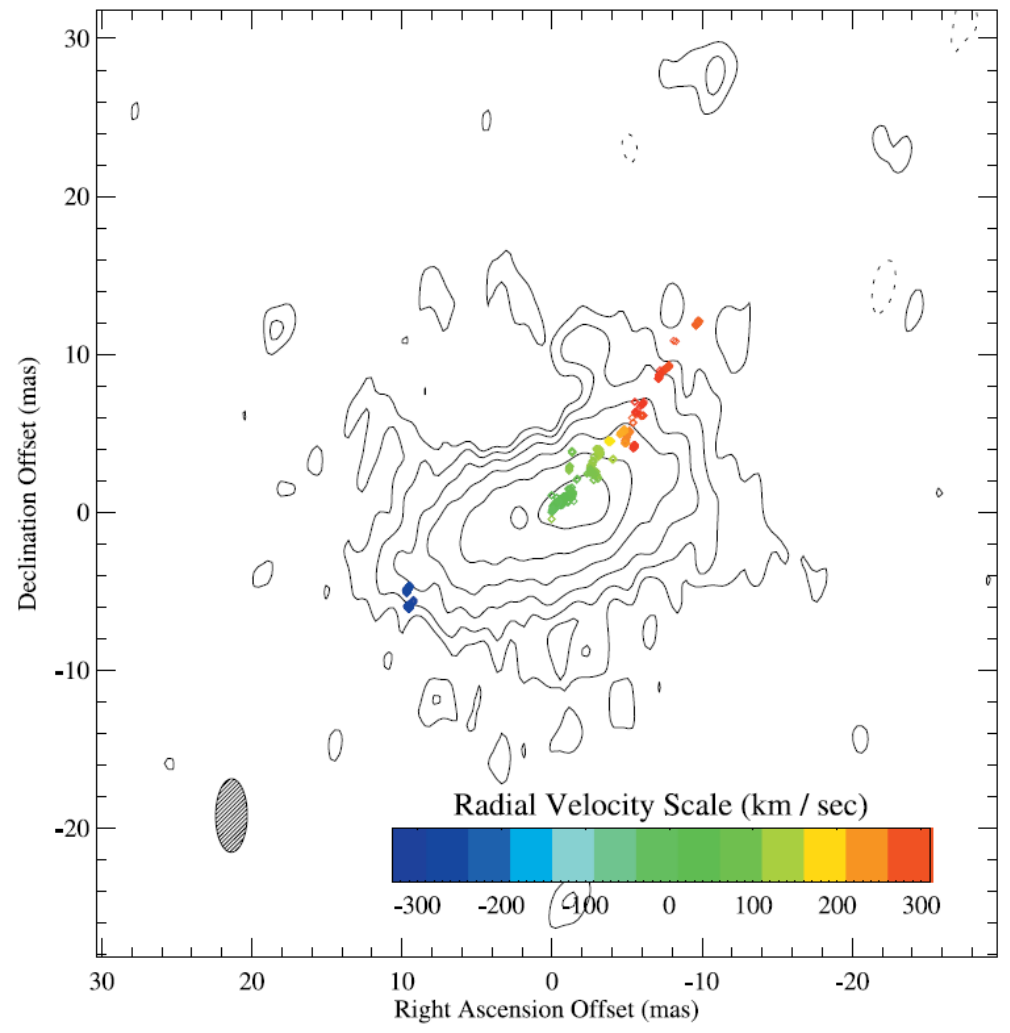
Water Masers in NGC 3079



Kondratko, Greenhill & Moran ‘05

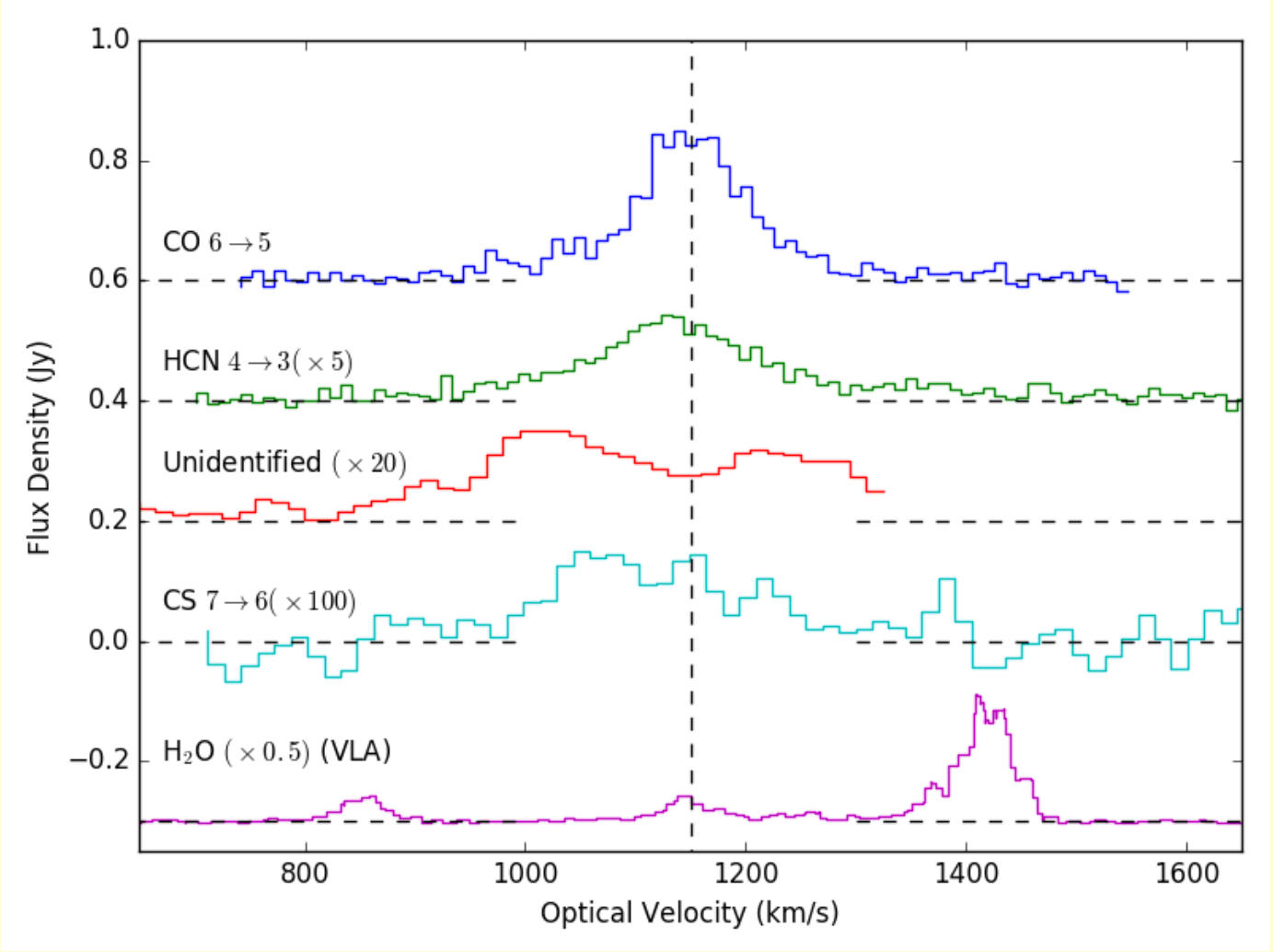
High-latitude features — disk rotational imprint: uplifted clouds

NGC 1068 — radio continuum & H_2O masers



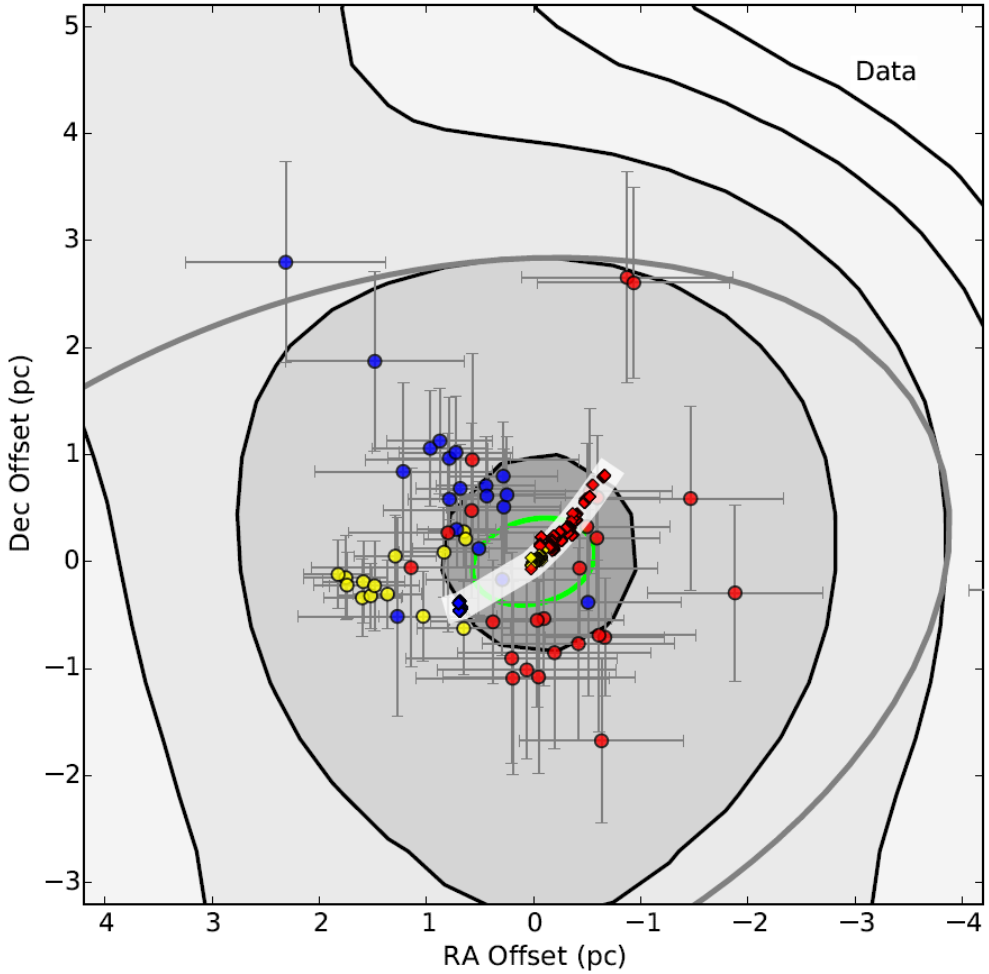
Gallimore+ 04

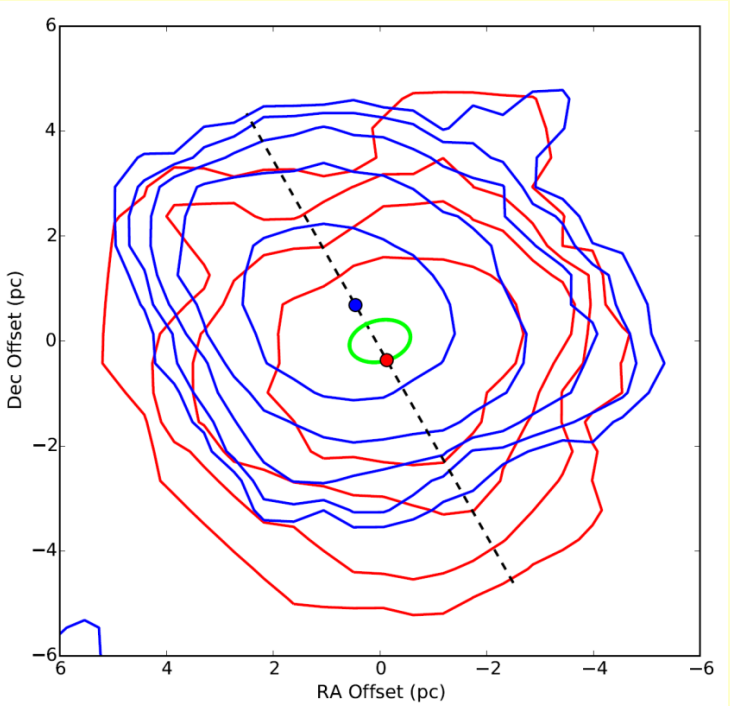
ALMA Spectra of NGC 1068 Nucleus



Gallimore+ 2017

NGC 1068 Nucleus





S1 (VLBA)

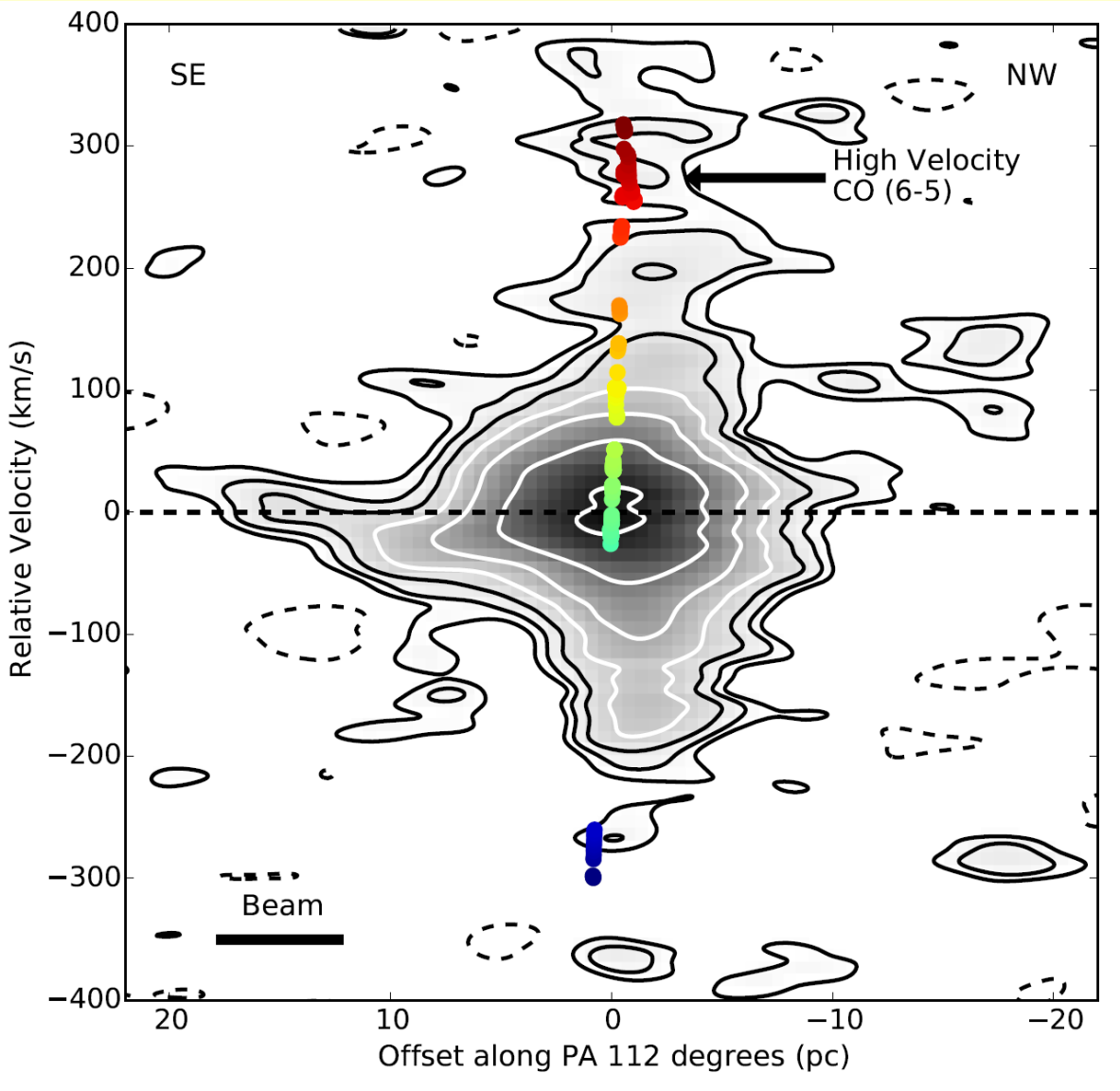
Extended CO (J=6-5)

CO Peaks

H_2O Masers

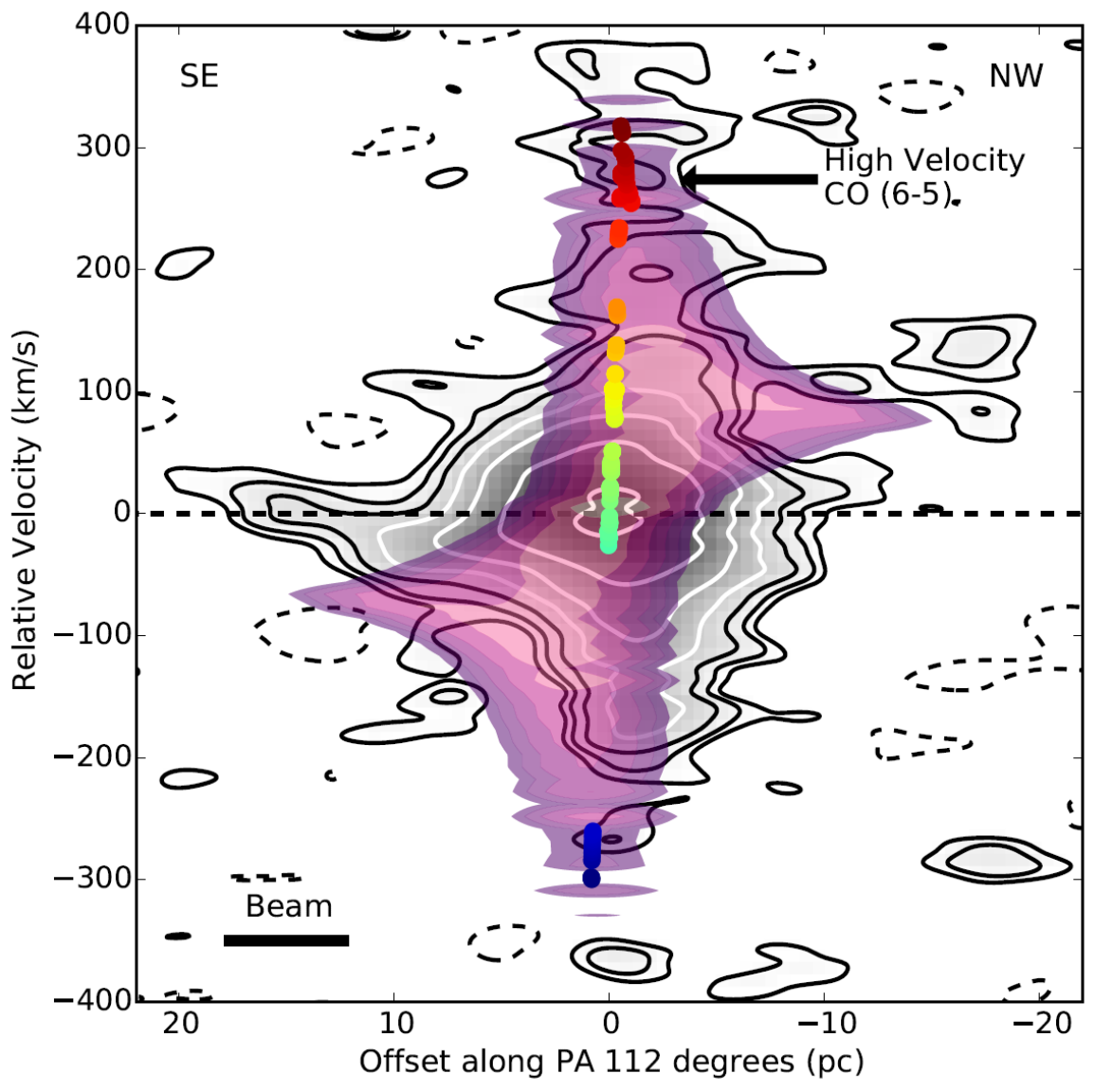
Gallimore+ 2016

NGC 1068 p-v Diagram



NGC 1068 p-v Diagram

Rotation!



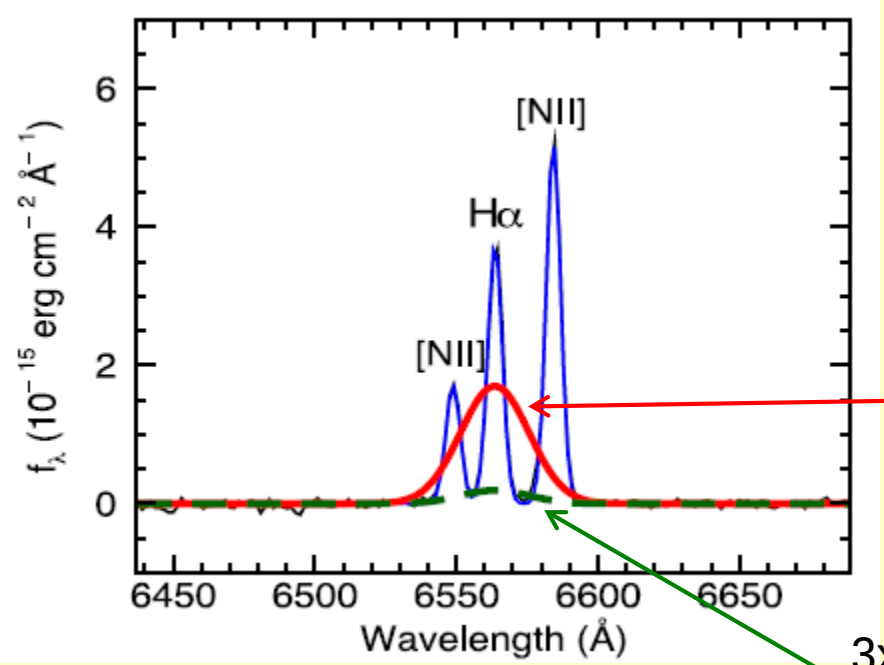
NGC 1068 CO ALMA Observations

- Biploar molecular outflow
- Signature of rotation

First clear evidence for a disk outflow

Low Luminosity = Low Accretion

- Torus disappears
  - Obscuration (Chiaberge+ 99, Maoz+ 05, Hernandez-Garcia+ 16)
  - Thermal dust emission (Wysong+04, Trump+11, Gonzalez-Martin+17)
- Broad Lines disappear (true type 2)



GSN 069 (Miniutti+ 13)

$L = 10^{43}$ erg s^{-1}

$M = 1.2 \times 10^6$ M_o

$L/L_{Edd} = 0.53$

expected Hα

3x residuals (upper limit)
~ 9x less than expected

Fundamental Constraint

- Obscuration, broad line emission require minimal column, N_{min}
- $N_R = \int n(R)\, dR > N_{min}$
- Disk-outflow mass continuity:

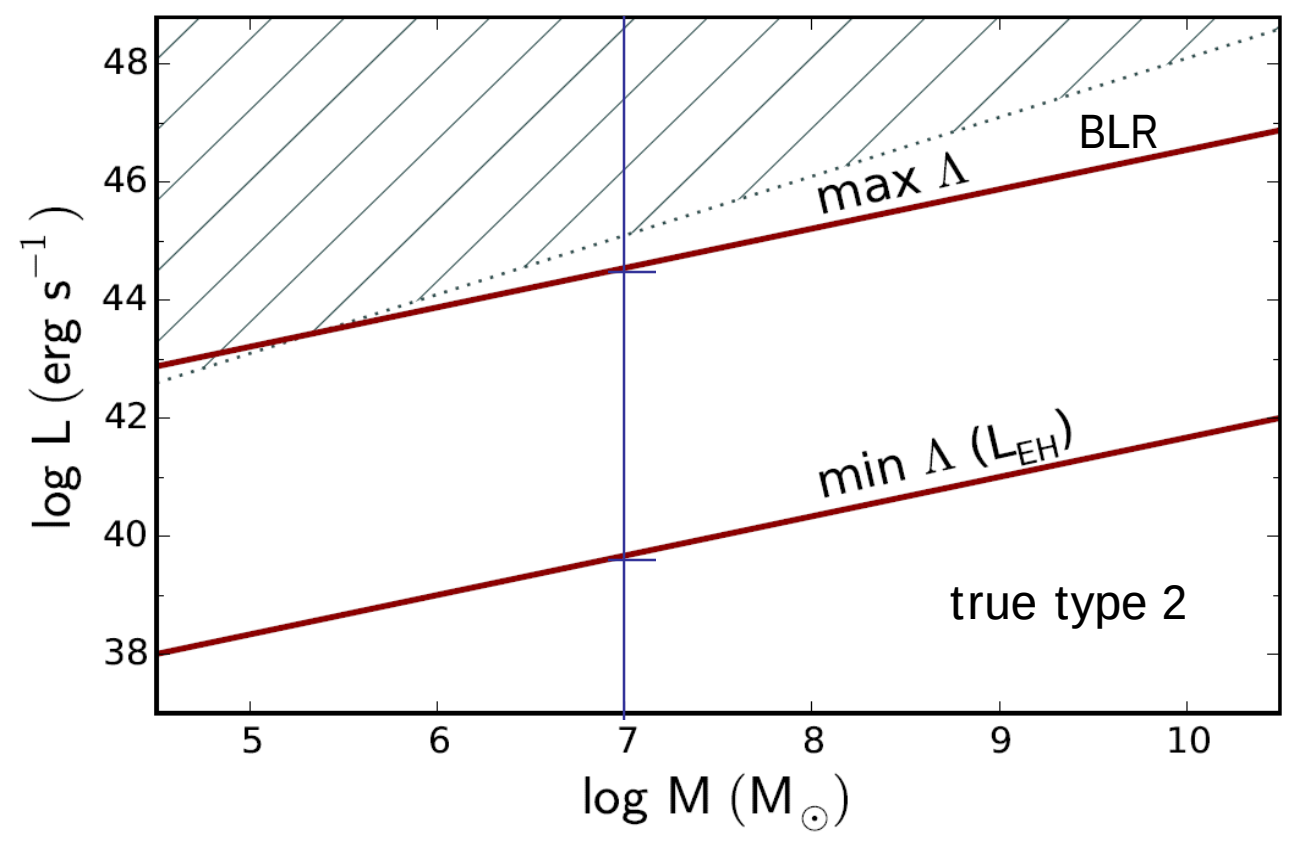
$$L > L_{min} = \Lambda M_7^{2/3}$$

$$\Lambda = 3.3 \times 10^{45} (\varepsilon r l)^{4/3} \ \text{erg s}^{-1}$$

BLR/TOR must disappear at some low L!

Elitzur & Shlosman '06

Broad Line Emission Constraint

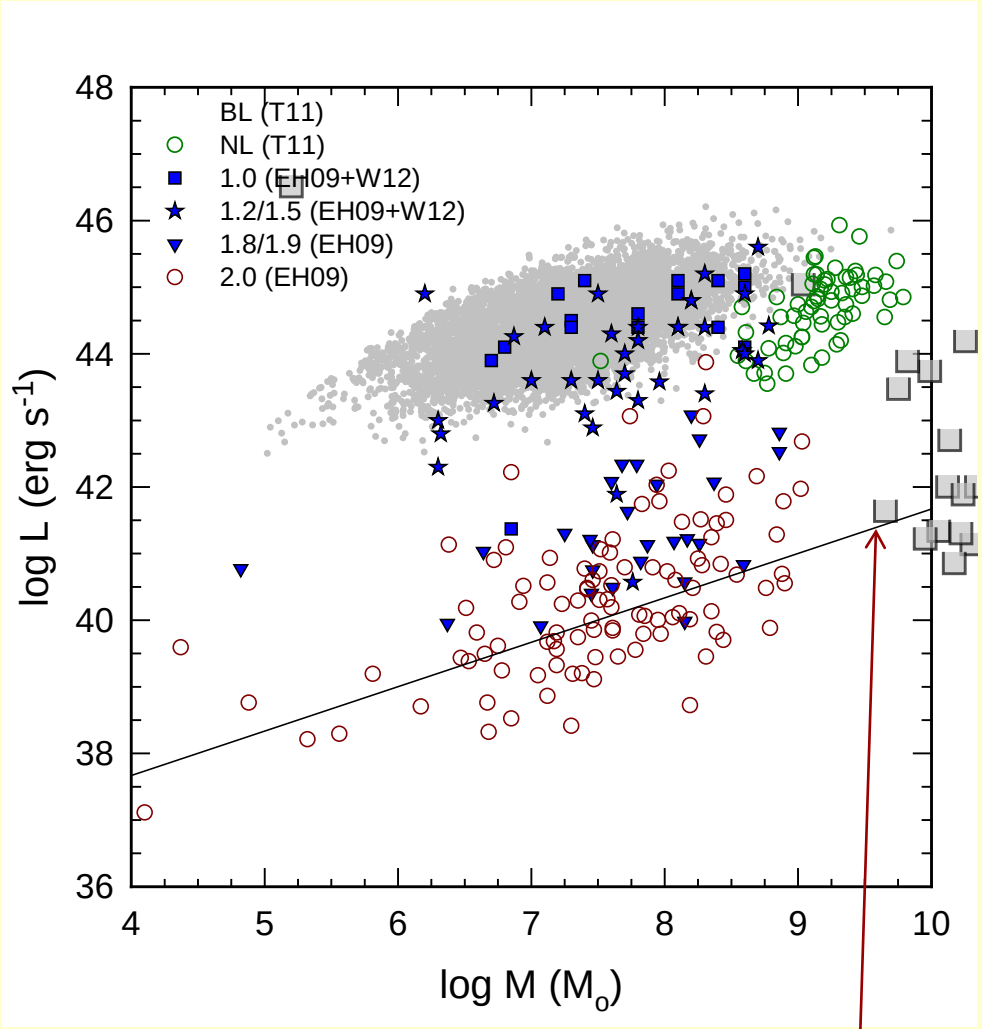


$L > L_{min} = \Lambda M_7^{2/3}$ $\Lambda = 3.3 \times 10^{45} (\varepsilon r l)^{4/3}$ erg s^{-1}

5×10^{39} erg s^{-1} <~ Λ <~ 4×10^{44} erg s^{-1}

Elitzur & Netzer '15

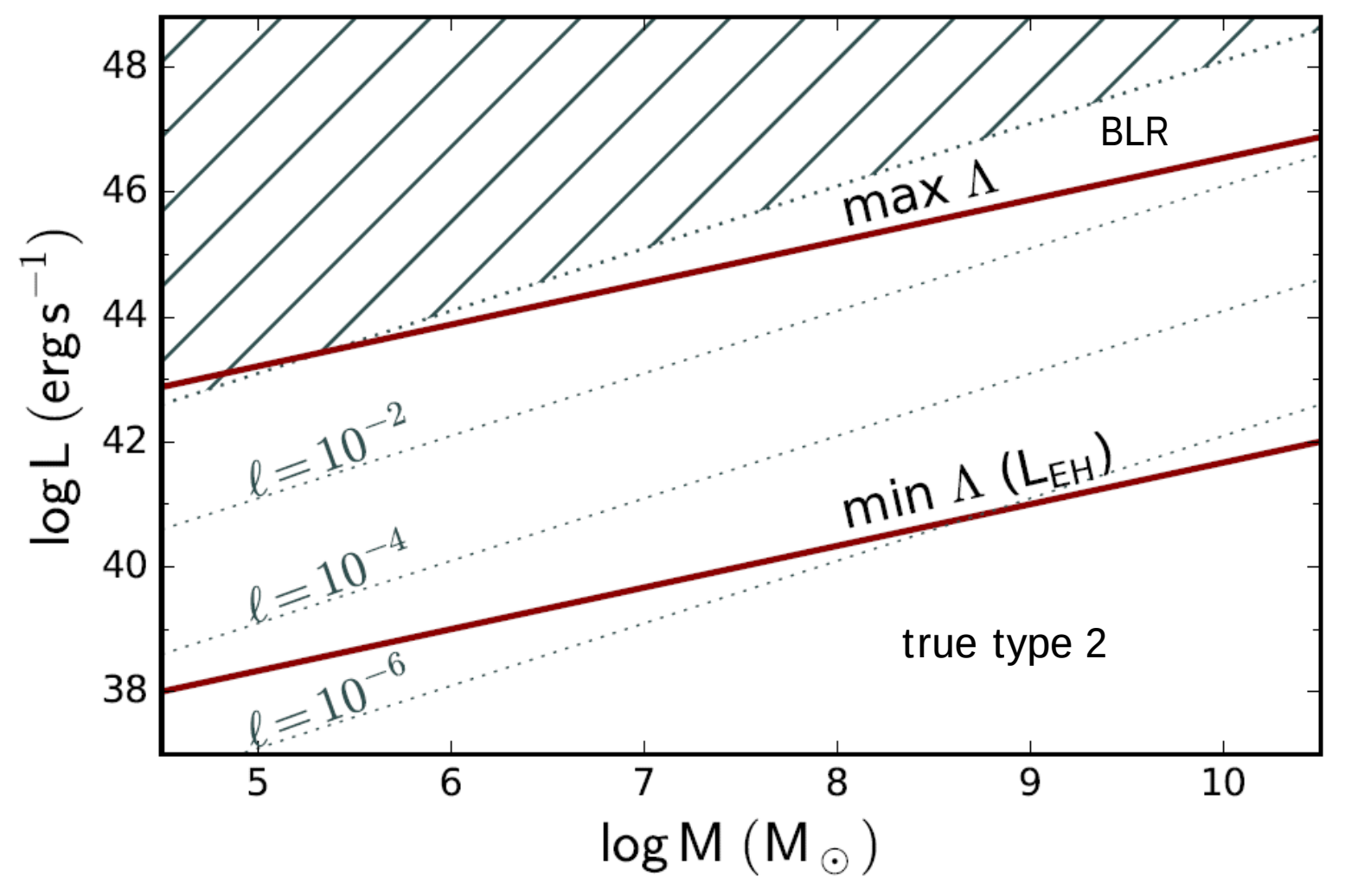
Broad Line Disappearance



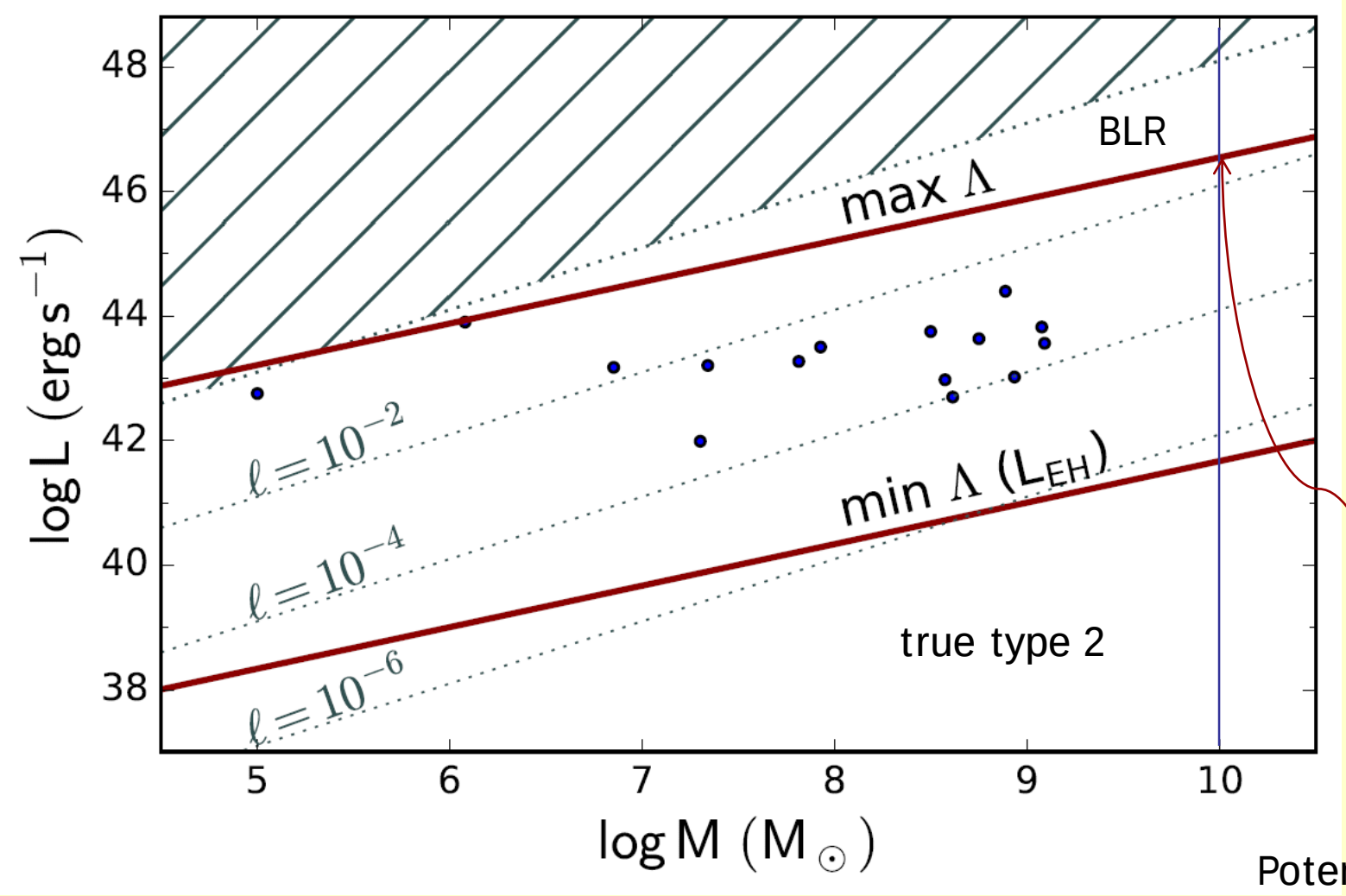
$L = 5 \times 10^{39} M_7^{2/3}$ erg s^{-1}

Elitzur & Ho '09

BL Emission & True Type 2

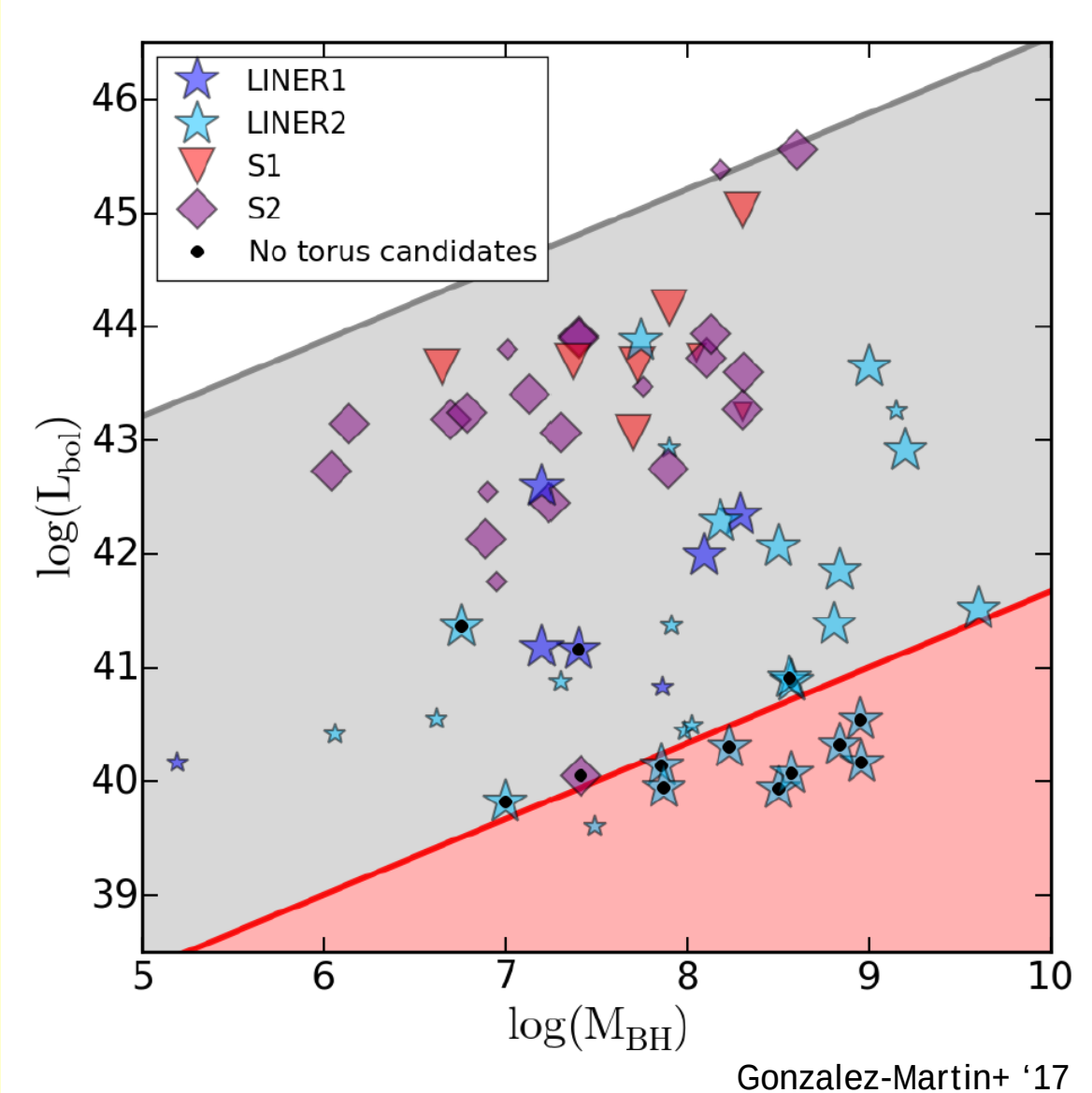


BL Emission & True Type 2



Potential true type 2!

Torus Emission & Luminosity



Gonzalez-Martin+ ‘17

BLR Low-Luminosity Evolution

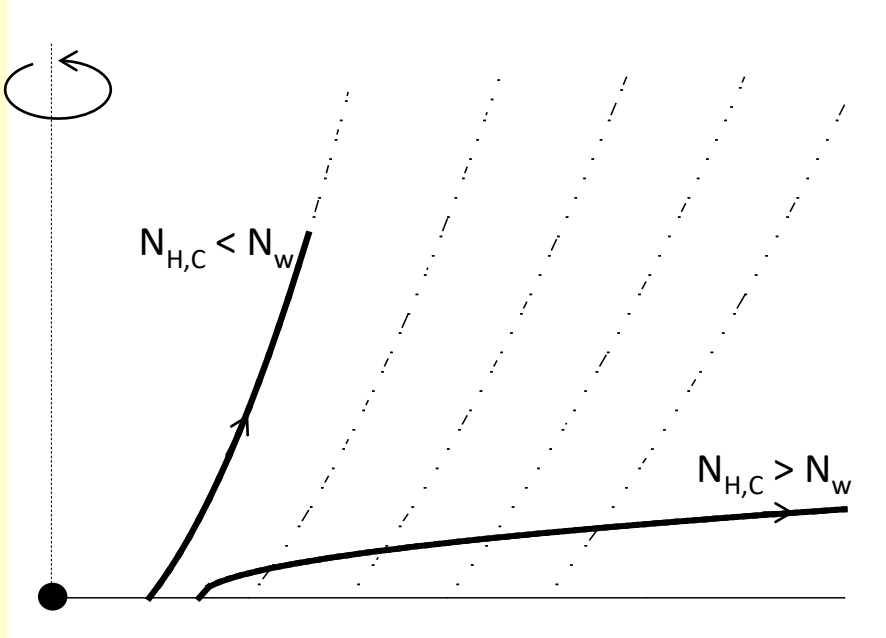
- Spectral type 1$\rightarrow$ 1.2/1.5 $\rightarrow$ 1.8/1.9 $\rightarrow$ 2 is an evolutionary sequence (Elitzur, Ho & Trump '14):
  - Evolution governed by $L/M^{2/3}$
  - Broad line "covering factor" (L_{BL}/L_{bol}) decreases
  - Double-peaked profiles emerge

Clouds

Force on a cloud = Wind ram pressure – Gravity

$$\frac{F_{grav}}{F_{ram}} \sim \left(\frac{r}{R_d}\right)^{1/2} \frac{N_{H,C}}{N_w}$$

$$N_w \propto L/M^{2/3}$$



Kartje+ ’99

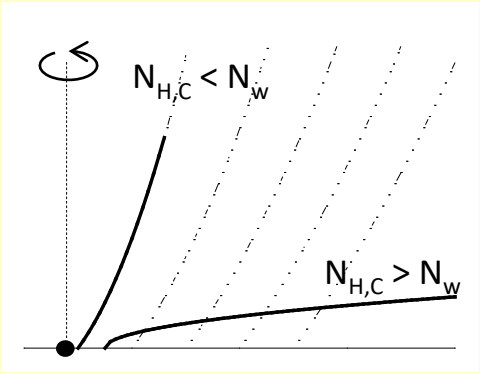
Elitzur+ ’14

A mix of “wind” + “disk” populations

A Two-Component BLR

"wind" : $N_{H,C} < N_w(R_d/r)^{½}$

"disk": $N_{H,C} > N_w(R_d/r)^{½}$



- As L decreases, N_w ($\propto L/M^{2/3}$) decreases
- More clouds become supercritical — "wind" $\rightarrow$ "disk", but not the other way!
- Less central luminosity is intercepted
- Double-peaked profiles emerge
- r-dependence — line-specific behavior

Summary

- Support for the AGN—Protostar analogy
- Protostellar structure — AGN default mental picture
- AGN disk evolution is simpler — no nuclear ignition
- BLR (and TOR) disappearance — inherent to disk winds
  - Independent of wind properties (just mass conservation!)
  - All AGN with $L <\sim 5 \times 10^{39} M_7^{2/3}$ erg s^{-1} are true type 2
  - True type 2 at any Eddington ratio & L as high as $\sim 4 \times 10^{46}$ erg s^{-1}
  - Evolution controlled by L/L_{min} ($\propto L/M^{2/3}$)