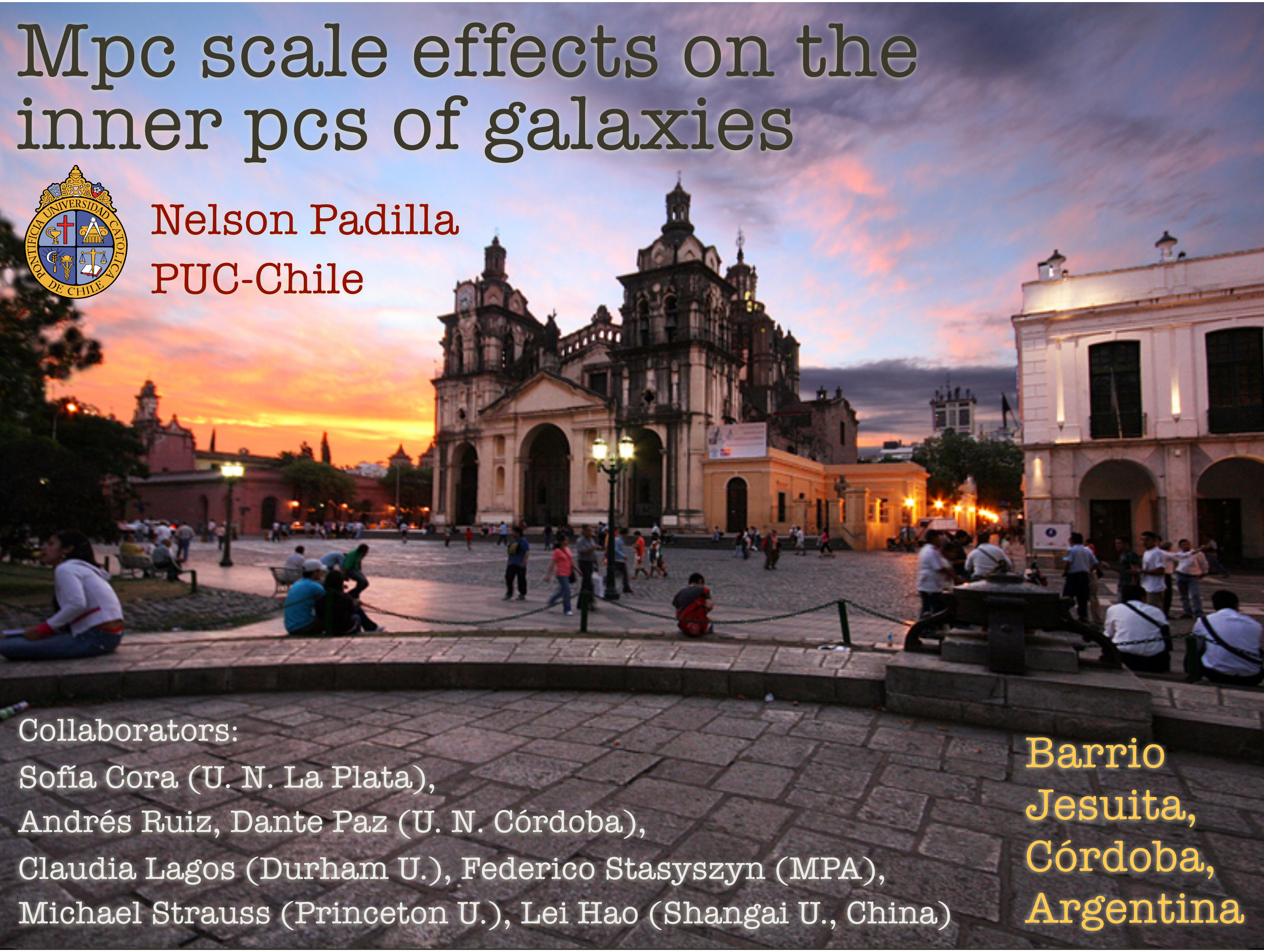

Mpc scale effects on the inner pcs of galaxies

Nelson Padilla
PUC-Chile

Collaborators:
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Andrés Ruiz, Dante Paz (U. N. Córdoba),
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Michael Strauss (Princeton U.), Lei Hao (Shangai U., China)

Barrio Jesuita, Córdoba, Argentina

This Talk

Traces from growth in structures and galaxies from Mpcs to pcs

Tools

Tool:
A model to track the evolution of galaxies according to that of the structure:
Semi-analytic model which includes the SMBH mass and spin
Lagos, Padilla & Cora 2009

Tool:
What is the inclination of a galaxy?
Use distributions of b/a to find their intrinsic shapes and then get statistical distributions of orientation angles.
Padilla & Strauss 2008

Results

Large-scale alignments, TTT:
Overdensities in the direction perpendicular to the angular momentum of galaxies are higher
Paz, Stasyszyn & Padilla 2008
Paz, Sgró, Merchán & Padilla 2011

Orientation of the stellar disc with respect to the BH torus.
Assuming unified AGN model: Non-random
Lagos, Padilla, Strauss, Cora & Hao, 2011

This Talk

Mpc .... pc

- LSS - galaxy connection (models)
- Alignments in LSS -> effects from the initial environment
- Consequences down to pc scales?

This Talk

Mpc .... pc

- LSS - galaxy connection (models)
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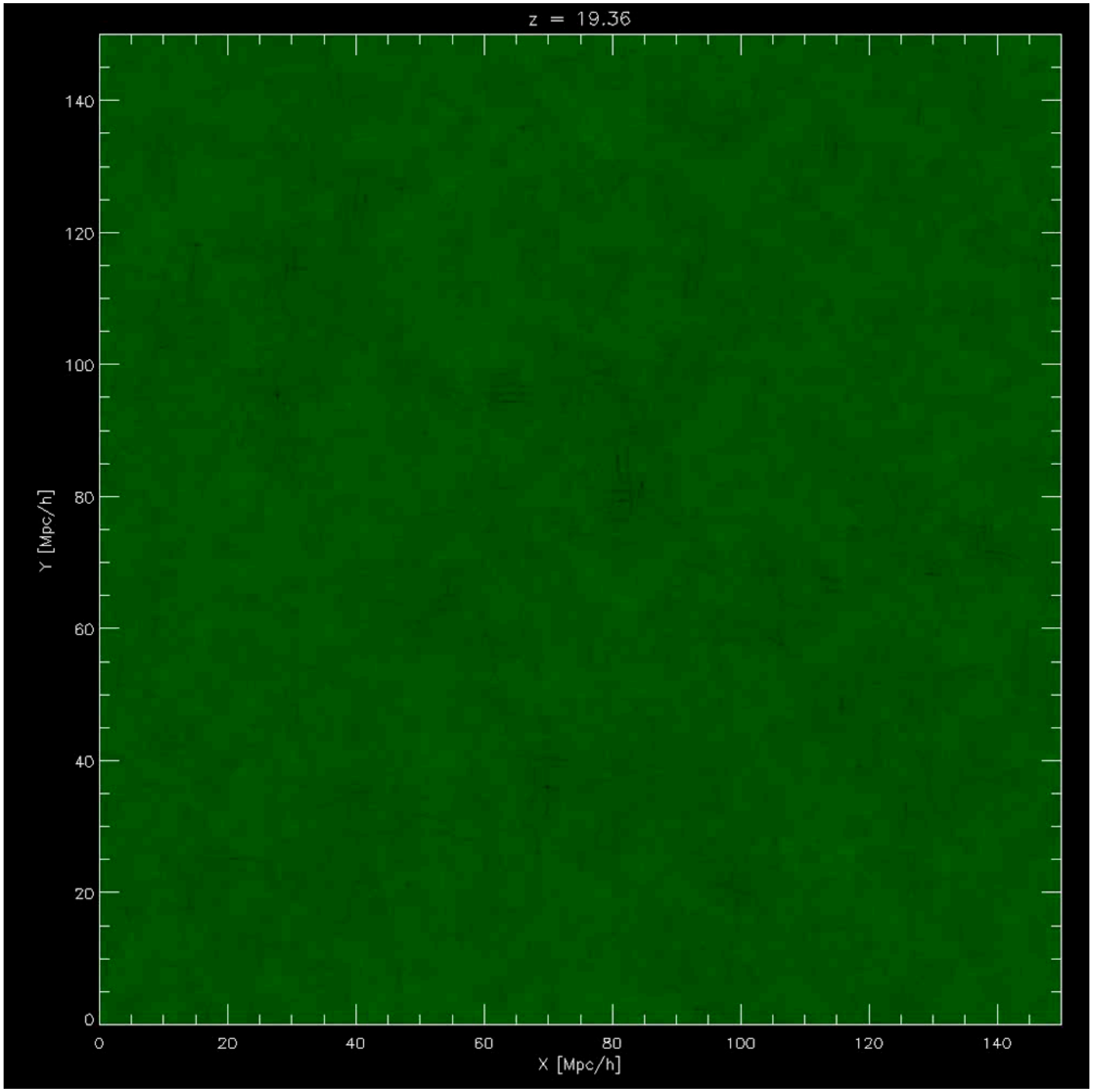
- Consequences down to pc scales?

Ruiz, Padilla, Domínguez, Cora (2011)

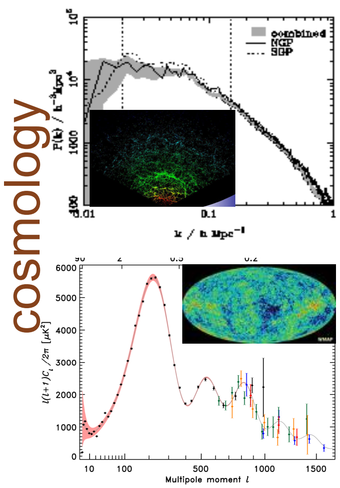
LSS-Galaxy connection: simulations (Tool #1)

Cosmological periodic box simulation of 150Mpc/h a side, 1200^3 particles.

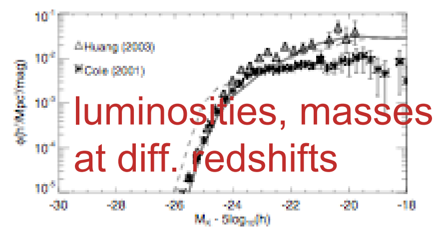
DM particles of $10^8 h^{-1} M_{sun}$ and haloes of >300 particles of $3x10^{10} h^{-1} M_{sun}$.

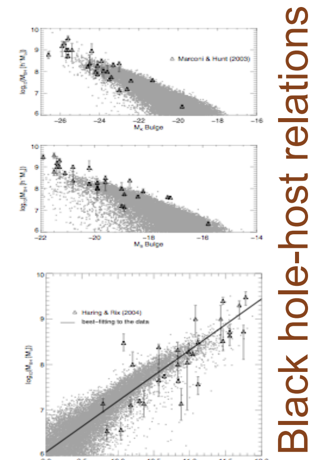


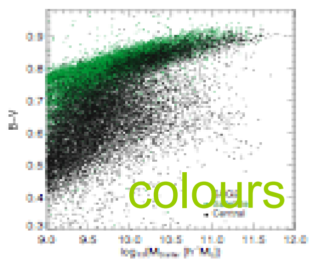
LSS-Galaxy connection: SAM (Tool #1)

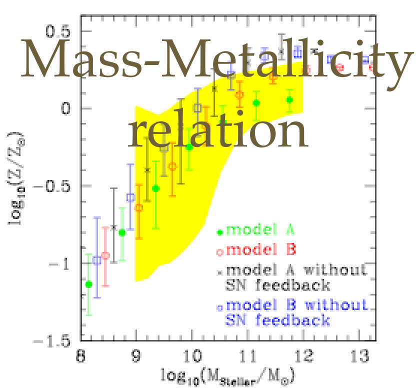


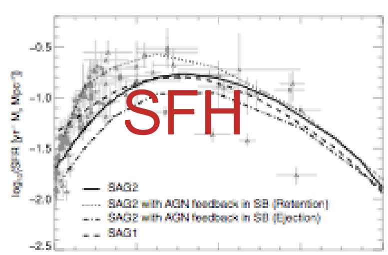
- Standard Cosmology
- DM only simulations
- Measured merger trees, substructures included, minimum of 300 particles for angular momenta.
- Baryons via semi-analytic recipes: Cooling, SF, SN feedback and chemical enrichment, AGN, BH spin
- A Semi-analytic model provides statistical samples of galaxies, for which we can measure distributions of parameters and compare them to observations.

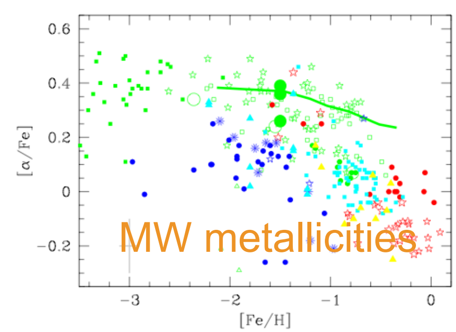


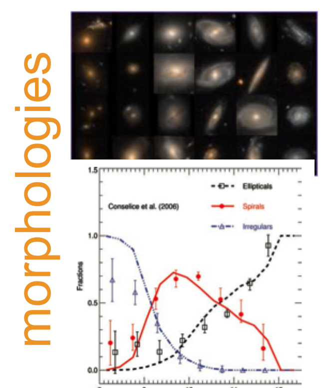






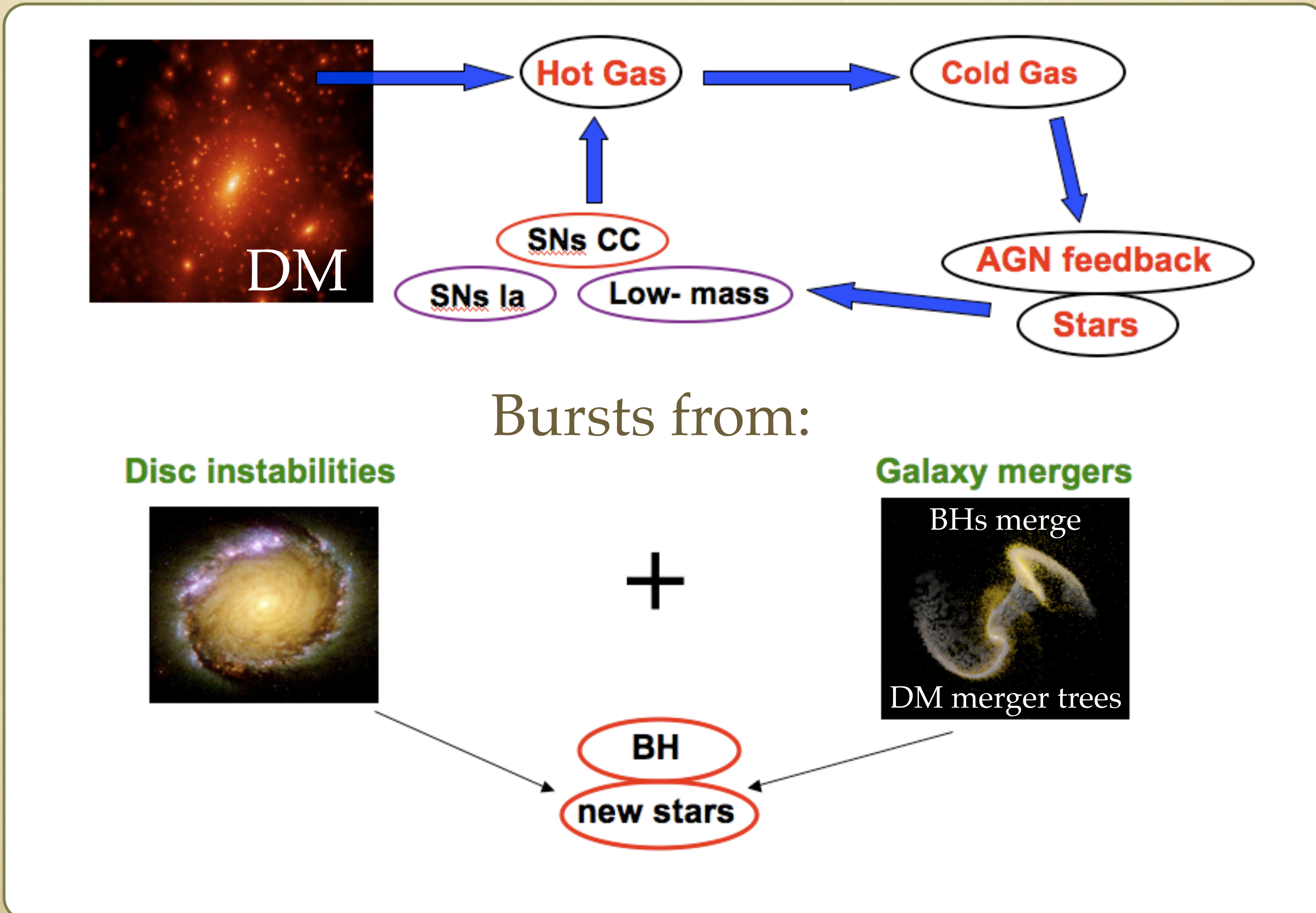






Springel et al. (2001), Lagos, Cora & Padilla (2008), Lagos, Padilla & Cora (2009)

Semi-analytic model (Tool #1)



Semi-analytic model (Tool #1)

SF and BH accretion during starbursts:

- **Enough massive disk** Disk component may become unstable

$$\epsilon = \frac{V_{\rm Max}}{(G M_{\rm Disk}/r_{\rm Disk})^{1/2}} < \epsilon_{\rm DI} \approx 1$$

Disk: Stars + Cold Gas → BULGE → New stars / BH

$$\Delta M_{\rm BH,mer} = f_{\rm BH} \frac{M^{\rm sat}}{M^{\rm central}} \times \frac{M_{\rm ColdGas}}{1 + (200\,{\rm km\,s^{-1}}/V_{\rm vir})^2}$$

- **Galaxy fusion**

$$T_{\rm friction} = \frac{1}{2} \frac{f(\epsilon)}{C} \frac{V_{\rm c} r_{\rm c}^2}{G m_{\rm sat} \ln \Lambda}$$

$$\frac{M^{Satellite}}{M^{Central}}$$

Major Merger: both galaxies → Disk: Stars + Cold Gas → CENTRAL BULGE, New stars / BH

Minor Merger: Satellite Stars → CENTRAL BULGE

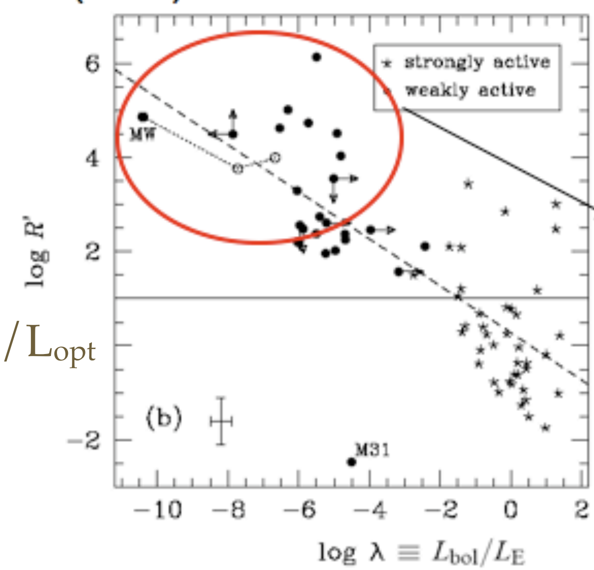
Both galaxies: Cold Gas → CENTRAL BULGE, New stars / BH

Springel et al. (2001), Lagos, Cora & Padilla (2008), Lagos, Padilla & Cora (2009)

Semi-analytic model (Tool #1)

BH accretion during cooling:

Ho (2002)

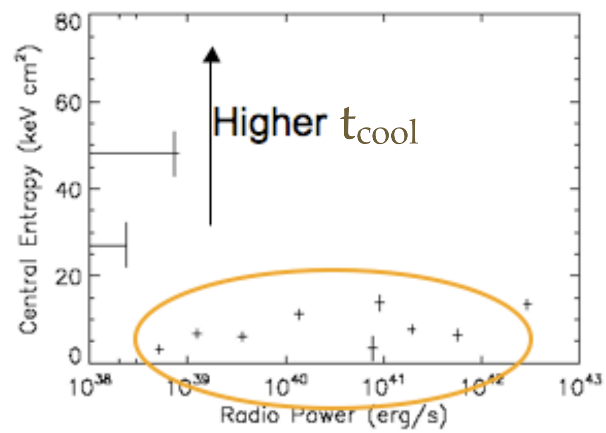


L_R/L_{opt}

Radio-loud systems

→ *Low accretion rates*

Donahue et al. (2005)



$$\dot{M}_{\rm BH} = \kappa_{\rm AGN}\frac{M_{\rm BH}}{10^8 M_\odot} \times \frac{f_{\rm hot}}{0.1} \times \left(\frac{V_{\rm vir}}{200\,{\rm km\,s^{-1}}}\right)^3 \longrightarrow L_{\rm BH} = \eta\, \dot{M}_{\rm BH} c^2$$

Gravitational attraction

The gas reservoir

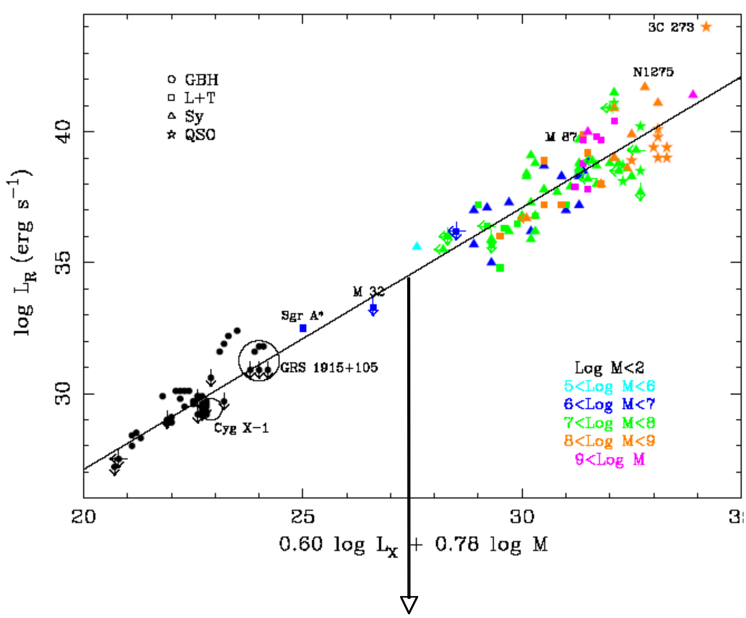
environment

EDDINGTON LIMIT

The spin paradigm (pc and kpc together)

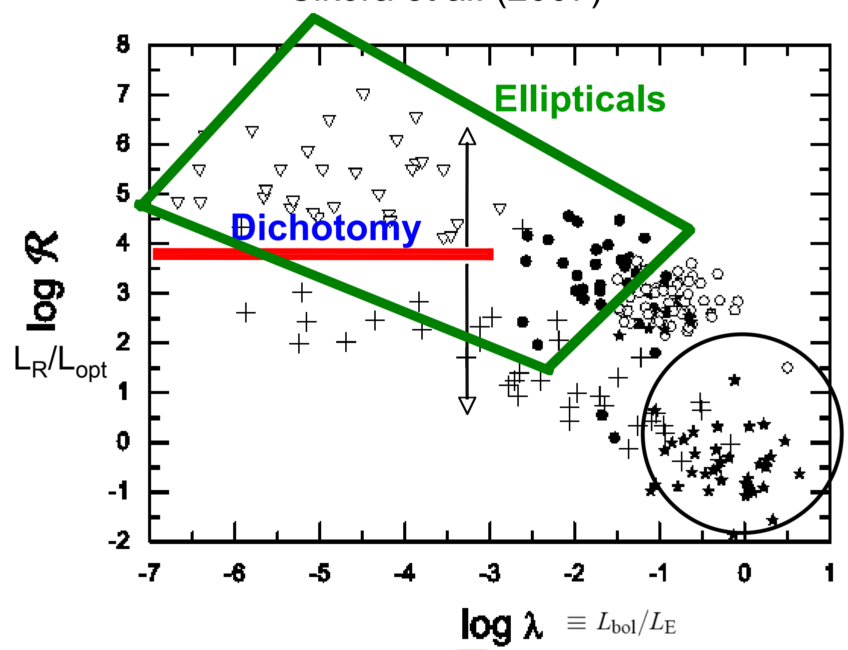
- Motivation: Why complicate the model with the BH spin?

Merloni, Heinz & Di Matteo (2003)



Jet production depends only on the state of the accretion disc

Sikora et al. (2007)



- Accretion rate is not the only parameter regulating radio-loudness.
- Radio-loudness occurs preferentially in Elliptical galaxies.

Semi-analytic model (Tool #1)

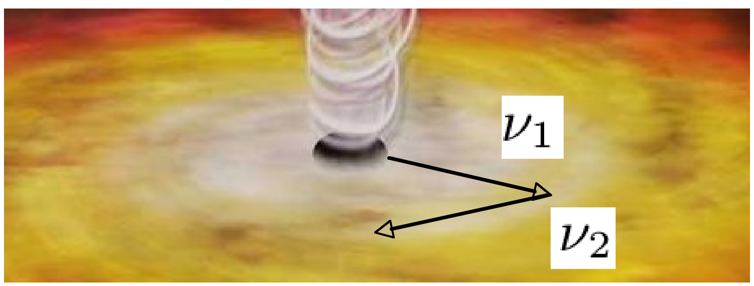
The implementation of the BH Spin

Blandford (1990)

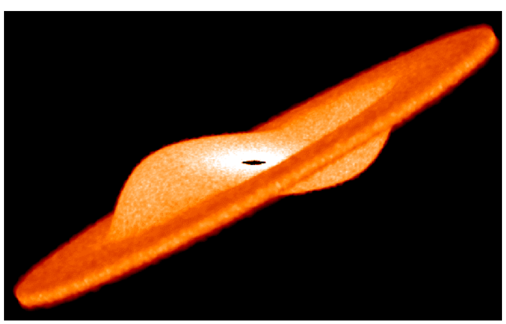
$$\hat{a} \equiv J_{\rm h}/J_{\rm max} = cJ_{\rm h}/GM_{\rm BH}^2$$

Shakura & Sunyaev (1973):

The α-model



+



King et al. (2005)

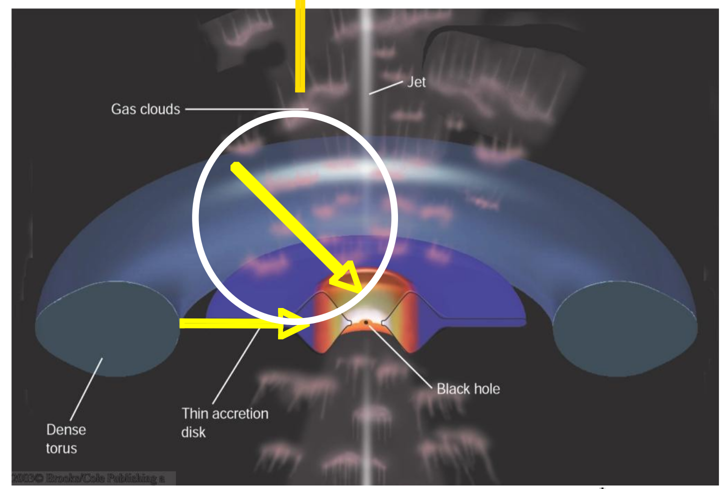
Low accretion rates

$H/R < \alpha \ll 1$ → $\nu_2/\nu_1 \approx \alpha^2$

Papaloizou & Pringle (1983)

High accretion rates

$L_{BH} > L_{edd}$ (Volonteri et al. 2004)



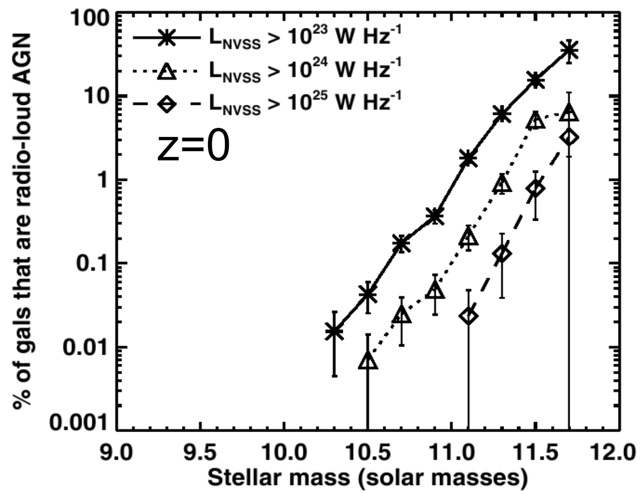
→ $\alpha > 0.1$

Dubus et al. (2001)

Semi-analytic model (Tool #1)

Observational results on the fraction of RL galaxies

Best et al. (2007)

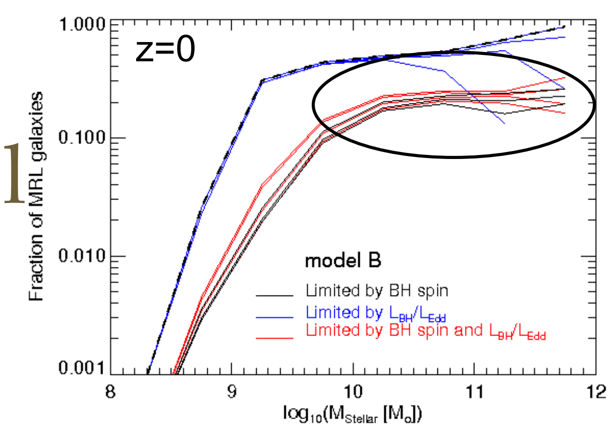


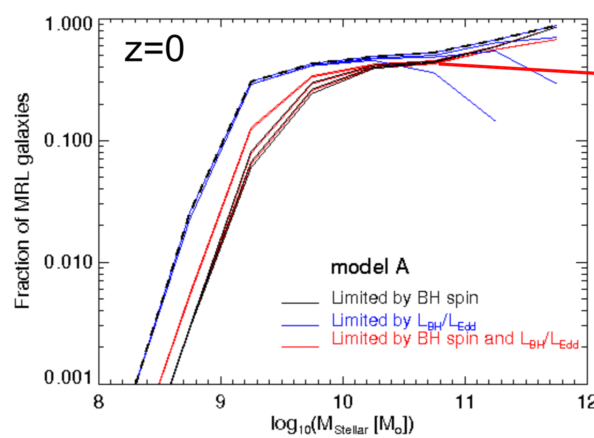
Increasing relation with stellar/BH mass

$\hat{a} \equiv J_{\rm h}/J_{\rm max} = cJ_{\rm h}/GM_{\rm BH}^2$ → normalized spin

$\lambda = L_{\rm BH}/L_{\rm Edd}$ → accretion rate

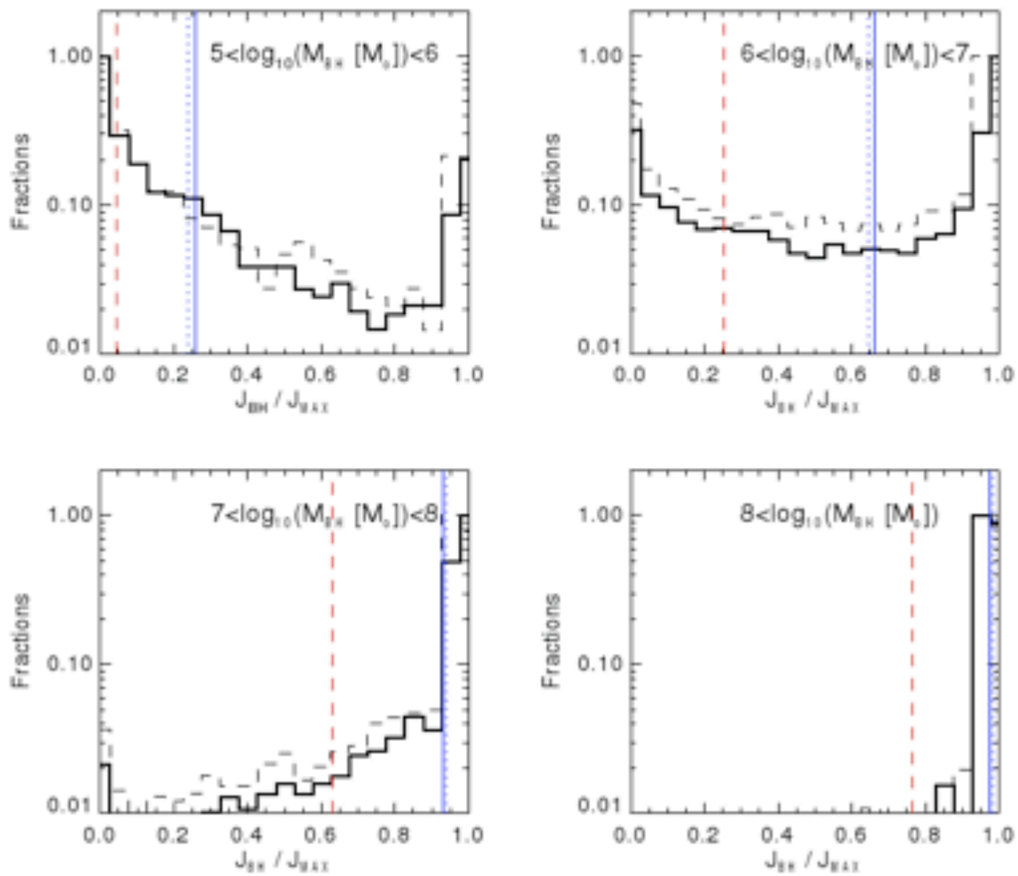
Model





Increasing relation

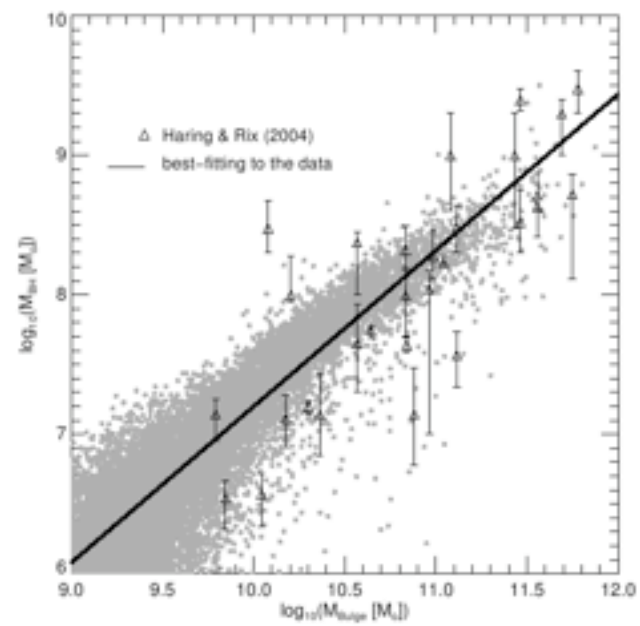
Spin values as a function of BH mass



Lagos, Padilla & Cora (2009a)

High mass BHs have, on average, higher spin values

Lagos, Cora & Padilla (2008)



Springel et al. (2001), Lagos, Cora & Padilla (2008), Lagos, Padilla & Cora (2009)

Semi-analytic model (Tool #1)

The implementation of the BH Spin

Coherent spin evolution:
There is some memory of the direction of the angular momentum of the infalling material.

Chaotic spin evolution:
No memory.

Springel et al. (2001), Lagos, Cora & Padilla (2008), Lagos, Padilla & Cora (2009)

Semi-analytic model (Tool #1)

Following the angular momentum of galaxies

Bulge component: only the direction

Disc component: direction + magnitude

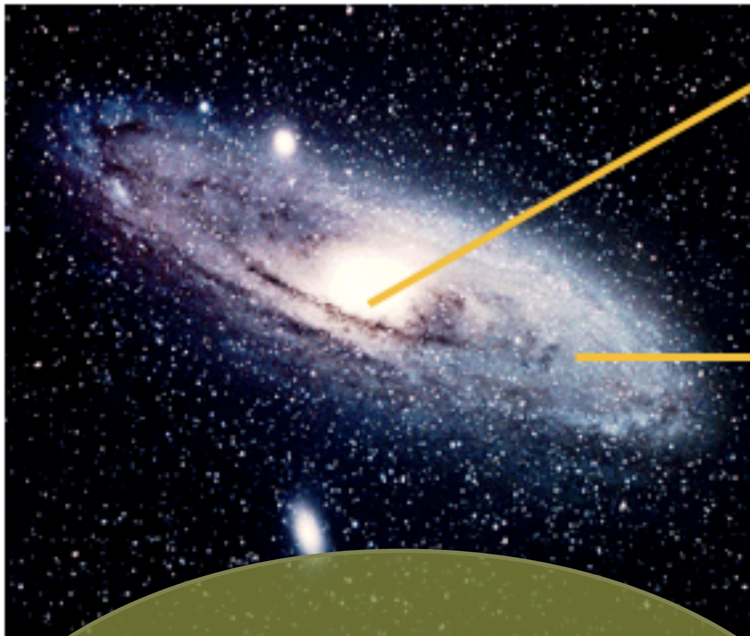
$$\vec{J}_{\rm New} = \vec{J}_{\rm Old} \times \frac{M_{\rm Old}}{M^{\rm New}_{\rm Total}} + \sum_i \vec{J}_i \times \frac{M_i}{M^{\rm New}_{\rm Total}}$$

$$M^{\rm New}_{\rm Total} = M_{\rm Old} + \sum_i M_i$$

Springel et al. (2001), Lagos, Cora & Padilla (2008), Lagos, Padilla & Cora (2009)

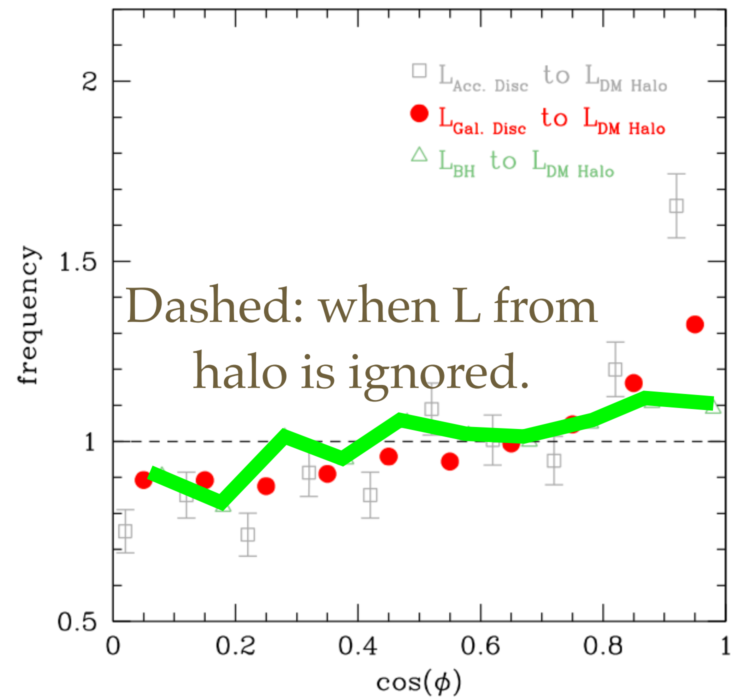
Semi-analytic model (Tool #1)

Following the angular momentum of galaxies



Bulge component: only the direction

Disc component: direction + magnitude



Dashed: when L from halo is ignored.

BH spins with residual alignments in coherent model.

L2 L1 φ

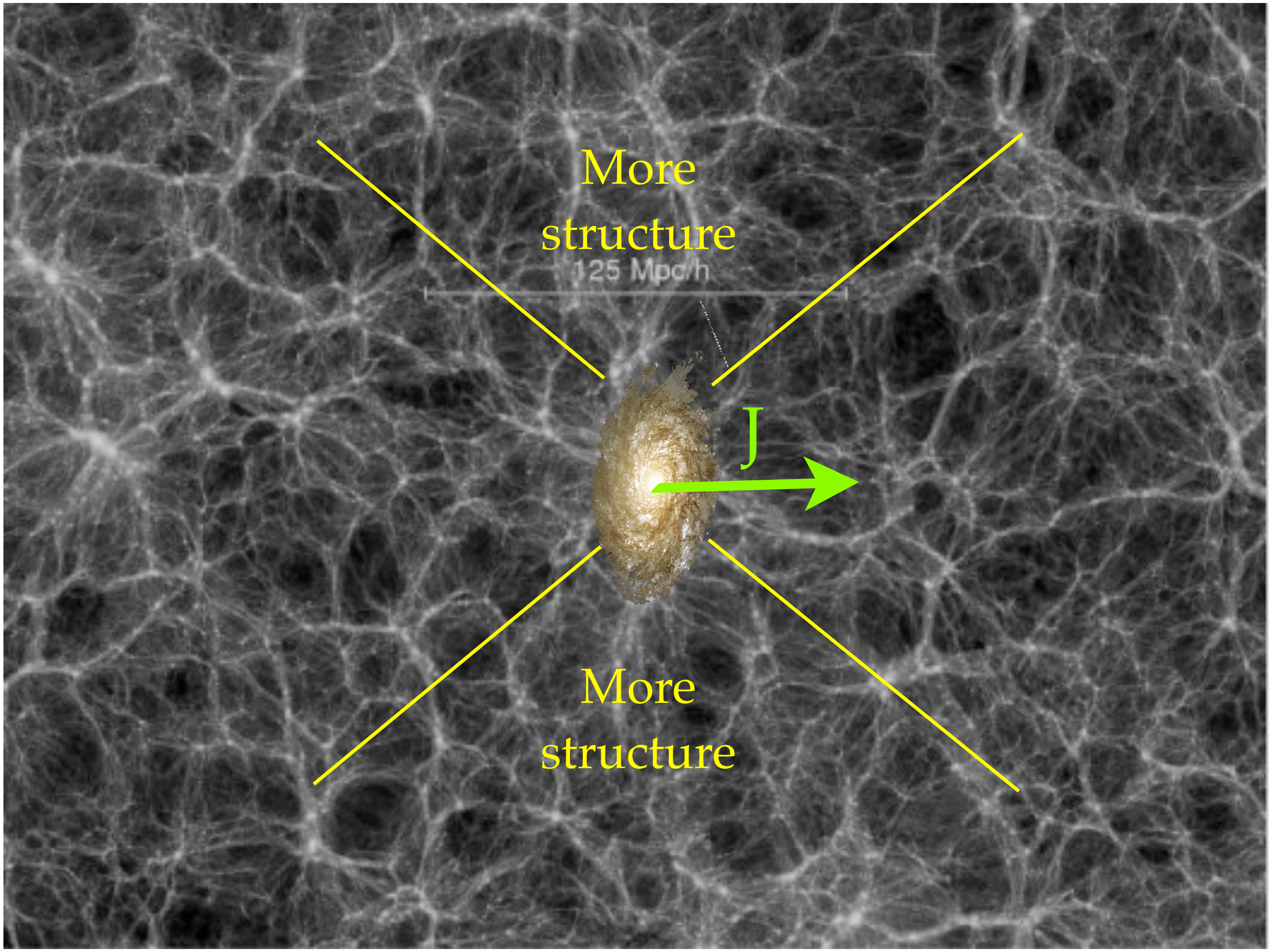
This Talk

Mpc .... pc

- LSS - galaxy connection (models)
- Alignments in LSS -> effects from the initial environment
- Consequences down to pc scales?

Paz, Stasyszyn & Padilla (2008), Paz, Sgró, Merchán & Padilla (2011)

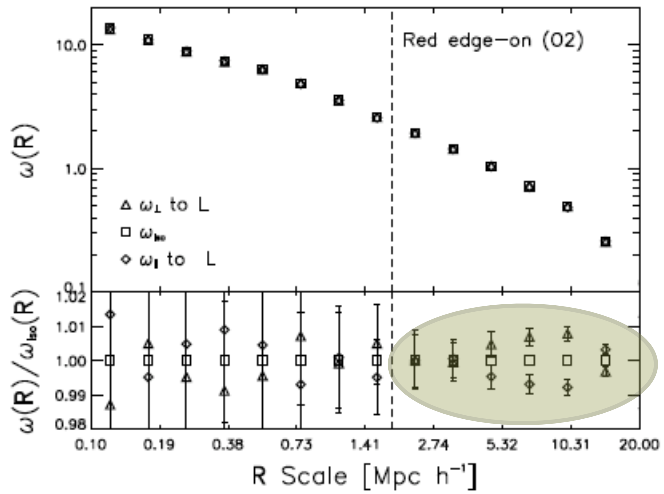
LSS alignments



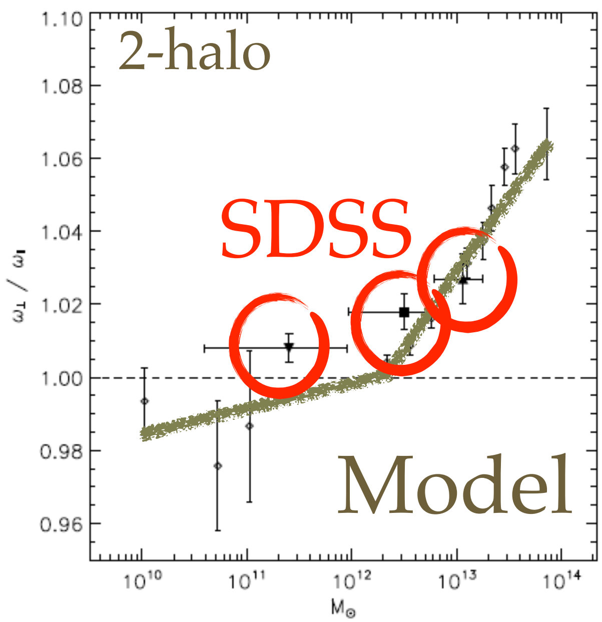
Do this in concentric sliced rings in the direction of the disc, and perpendicular to it

LSS alignments

The ratio between correlation functions in the directions perpendicular and parallel to L (perp. to the stellar disc)



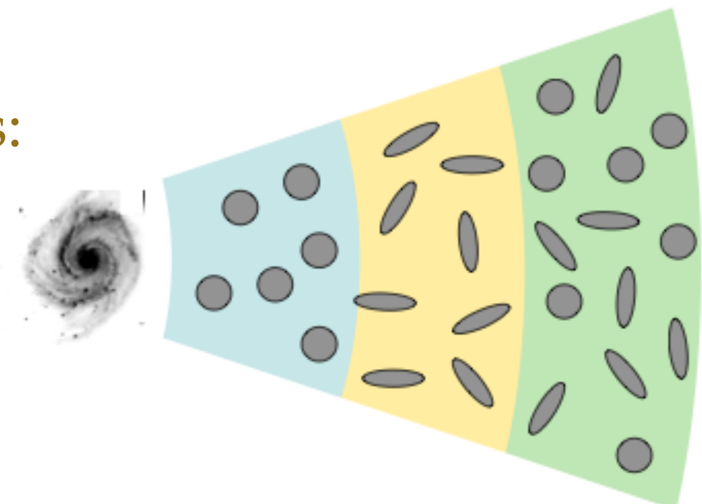
Averaged at large separations

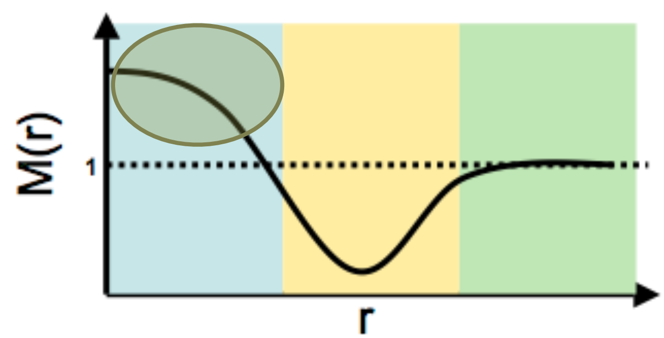


- Orientation of angular momenta somewhat perpendicular to the LSS.
- LCDM Ok

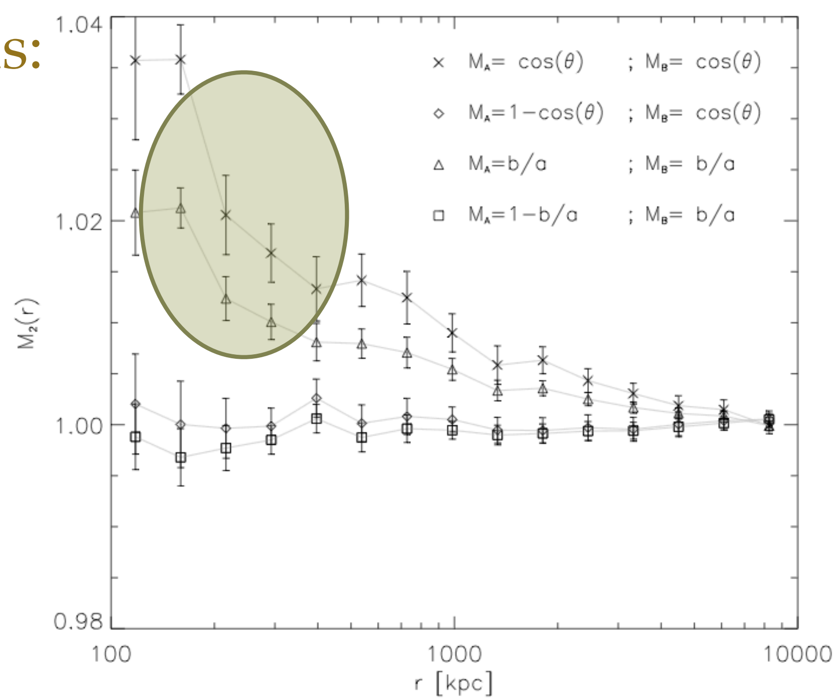
Angular momentum alignments

- Use mark correlation to measure alignments between the angular momenta of a galaxy and its neighbors:





- In models:



Paz et al., in prep

Mpc to Kpc scales

- Development of angular momentum from TTT
- Mergers with angular momenta in a slightly non-random orientation.
- Unequal fraction of pro- and retrograde mergers?

This Talk

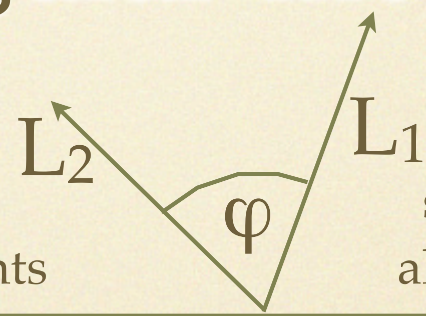
Mpc .... pc

- LSS - galaxy connection (models)
- Alignments in LSS -> more effects from the initial environment
- Consequences down to pc scales?

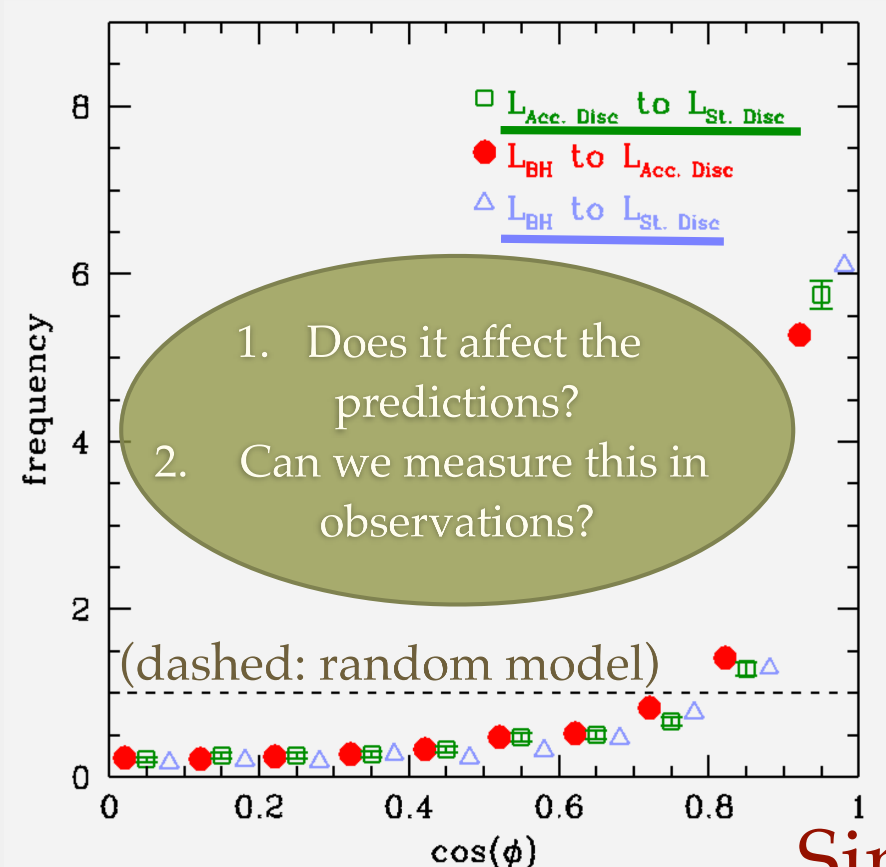
Lagos, Padilla & Cora (2009b)

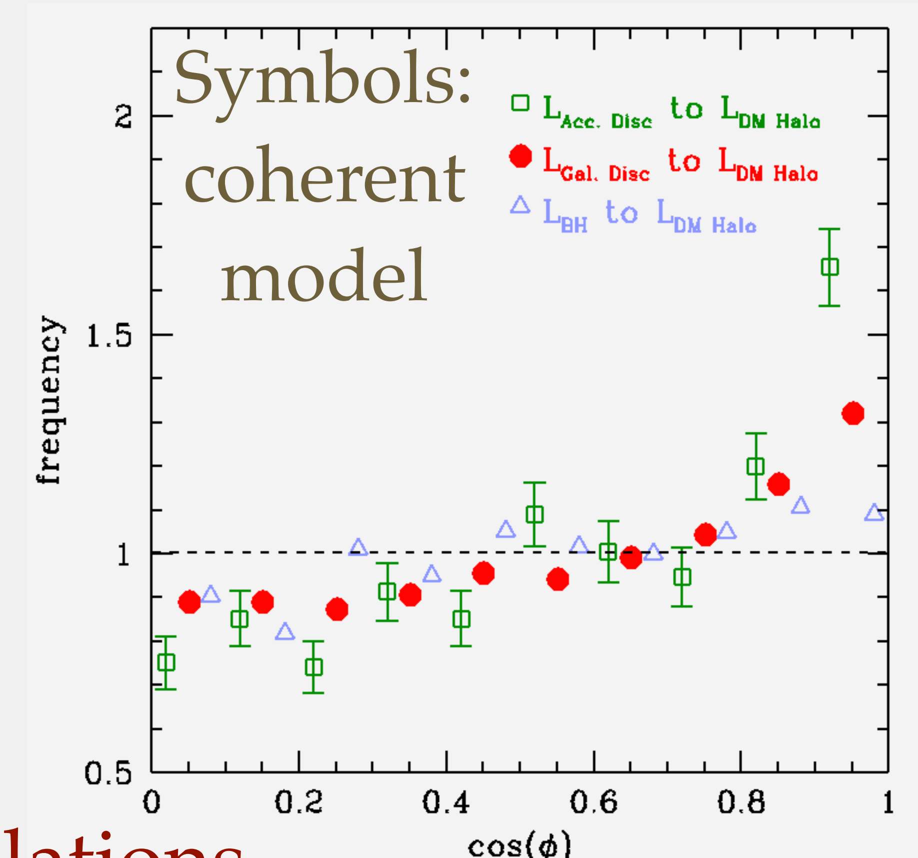
Model results: The BH spin and other angular momenta

Using the DM L to infer the cooling gas L, and therefore other galaxy components



Alignment with DM substructure L is present, although to a lower degree.



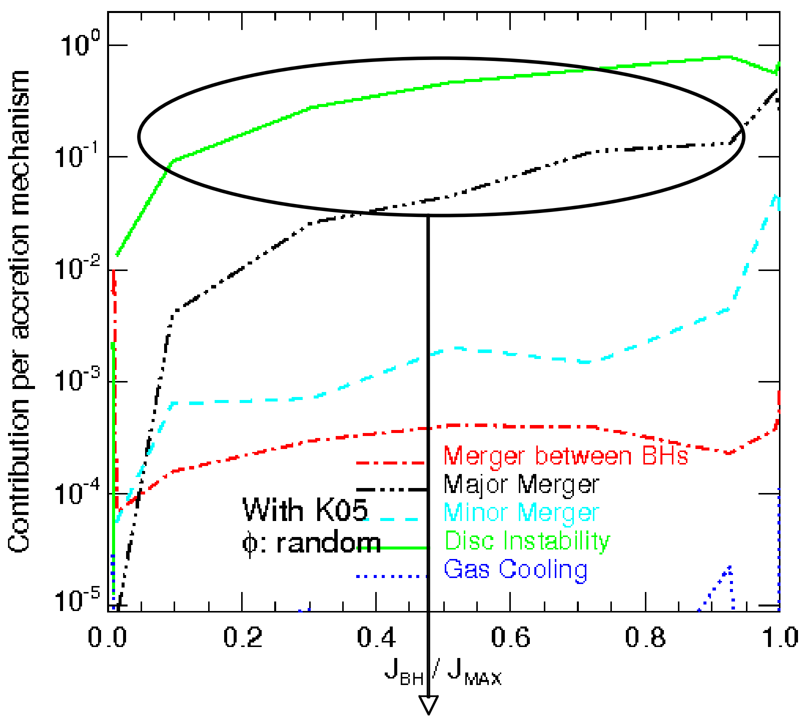


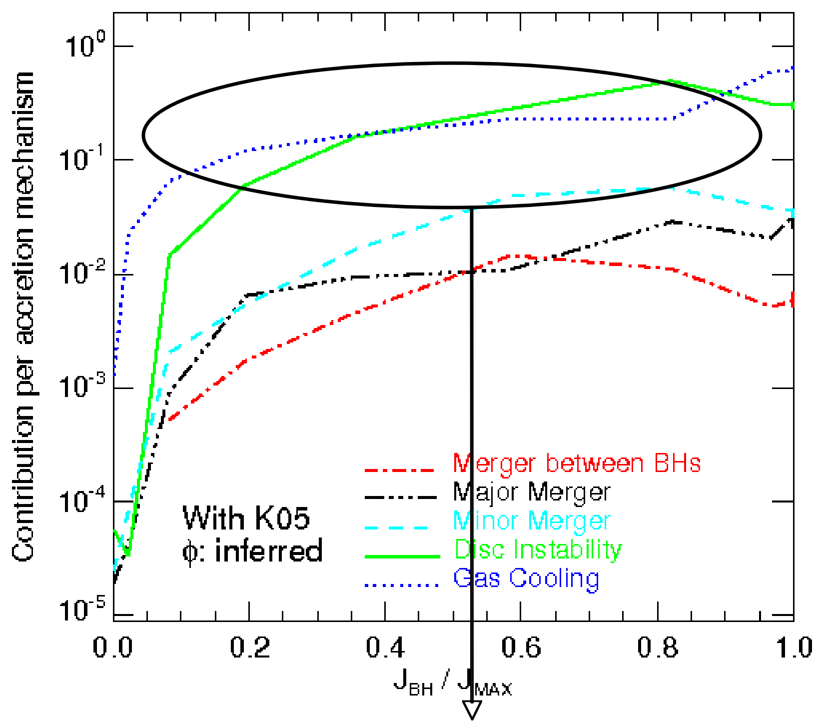
Simulations

1. The effect on the BH spin growth as inferred from the model

→ One of the main advantages in use a SAM is to **follow the baryon physics** and to distinguish between different phenomena in the galaxy SFH

Lagos, Padilla & Cora (2009a)





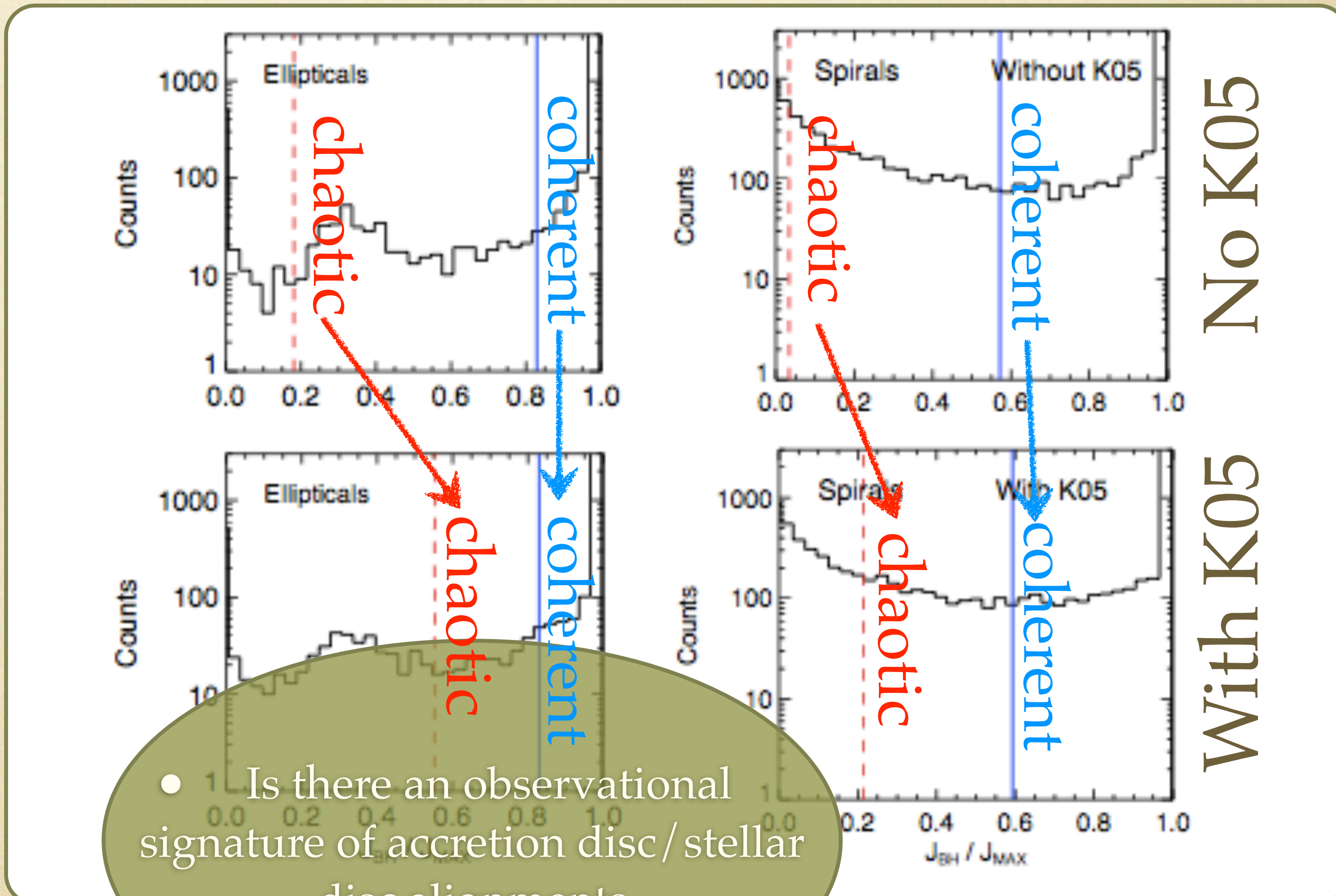
same mechanisms that produce the main BH growth

self-interacting processes

1. The effect on the BH spin growth as inferred from the model

With coherent model, K05 introduces little effects

In chaotic model, K05 is needed to obtain large a*

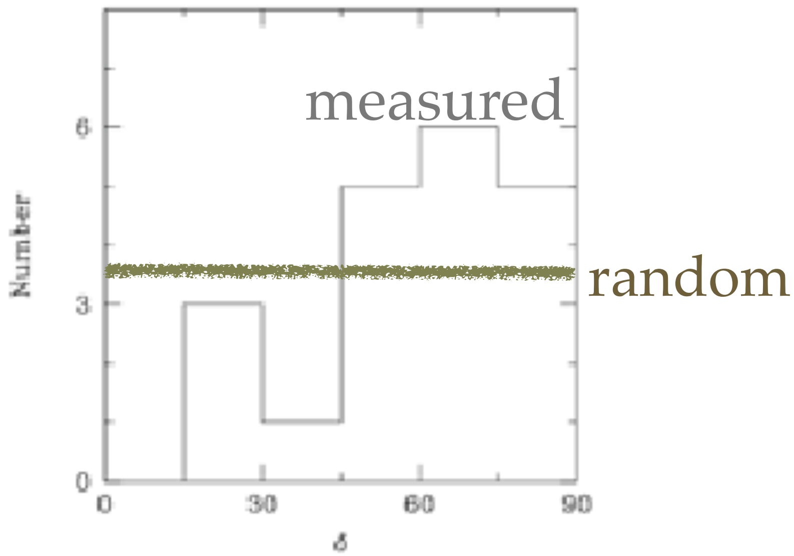


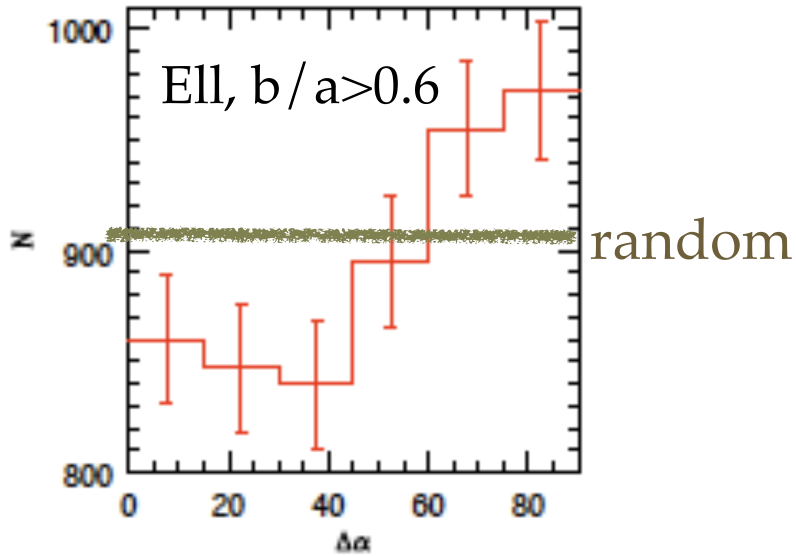
- Is there an observational signature of accretion disc/stellar disc alignments

Simulations

2. Measurable effect?: Observational results on alignments between stars and sub-pc region

Observations





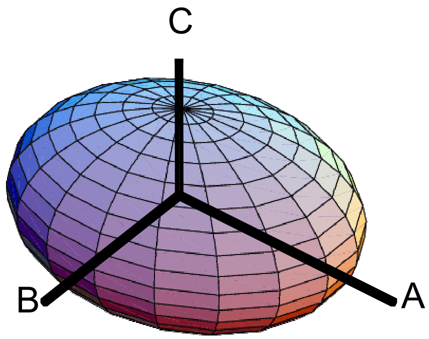
Schmitt et al (2002), measuring the difference in position angle for the dust disc and radio jets of 20 radio galaxies.

Possible concern: low number statistics, projection effects.

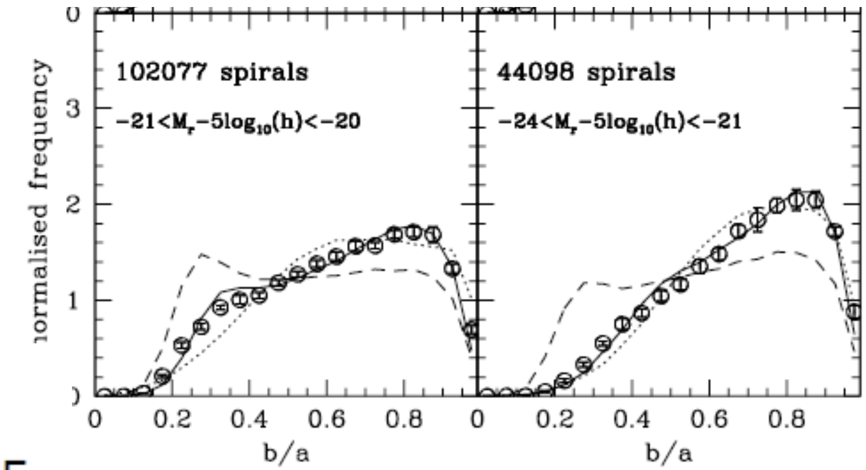
Battye & Browne (2009), measuring the difference in position angle for the optical and radio images of 14,300 galaxies.

Possible concern: sample selection, projection effects.

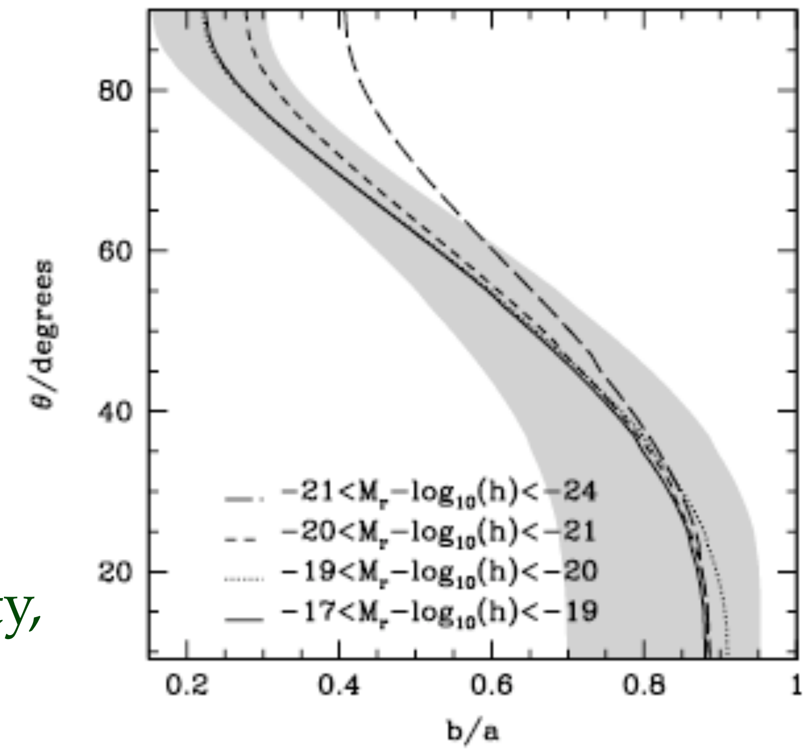
Tool #2: Shapes and orientations



Population → $\log_{10}(1-B/A)$ → μ, σ
→ 1-C/B → γ, σ_γ
→ Median extinction (spirals) → E_0



Distribution of inclination angles for a given b/a

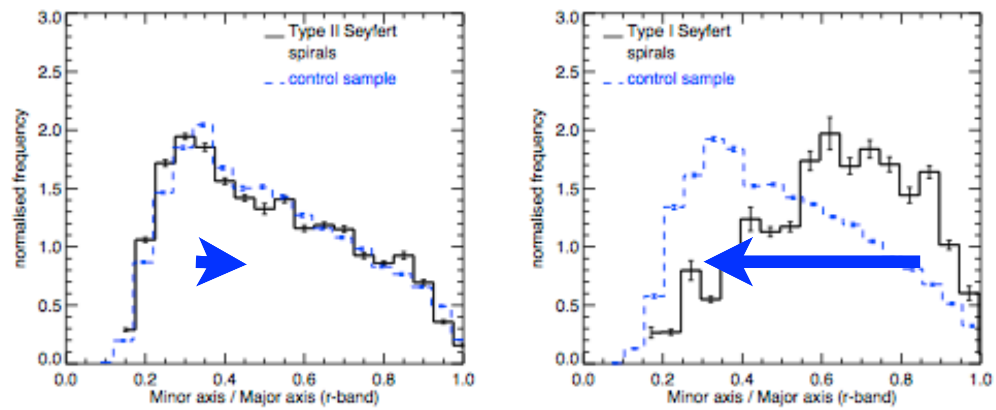


Shapes depend on (i) Luminosity, (ii) Color, (iii) Size

The kpc-pc connection

- After selecting control samples for AGN types I and II, by matching luminosities, colors, sizes, and concentrations (weighting by 1/Vmax), the distributions of b/a look like this:

Spirals only



Seyfert II　　Seyfert I

black solid: AGN

blue dashed: Control (non-AGN) provide AGN host intrinsic shapes

Unified model ok: hosts of types I and II are similar

Sample	E_0	μ	σ	γ	σ_γ	P_{MAX}
Type I Ell	0.0	-1.2 ± 0.3	2.2 ± 0.1	0.45 ± 0.03	0.27 ± 0.05	0.82
Type II Ell	0.0	-1.2 ± 0.2	1.5 ± 0.3	0.42 ± 0.03	0.25 ± 0.01	0.61
Type I Spi	0.9 ± 0.1	-0.55 ± 0.2	2.3 ± 0.1	0.72 ± 0.01	0.04 ± 0.01	0.30
Type II Spi	0.8 ± 0.1	-0.95 ± 0.4	2.7 ± 0.3	0.75 ± 0.03	0.10 ± 0.03	0.66

Observations

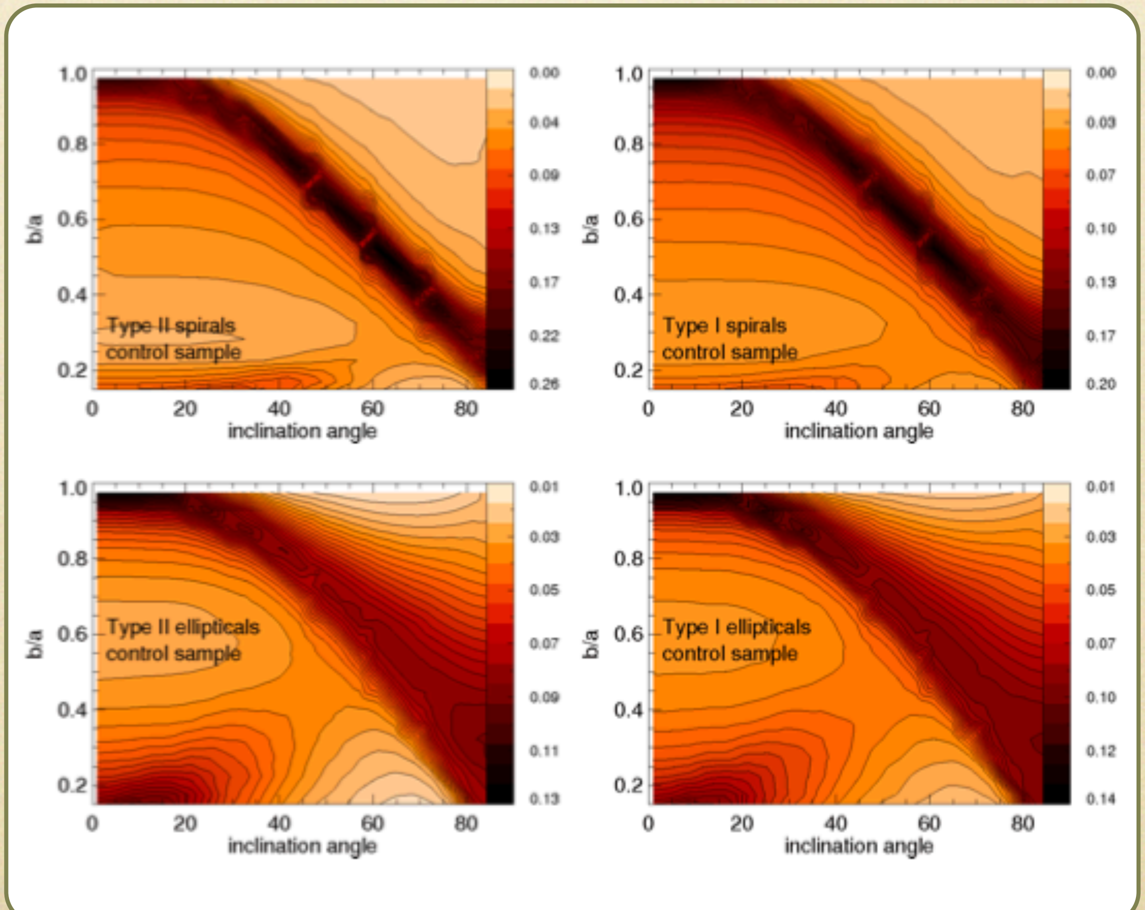
The kpc-pc connection

- After finding the intrinsic shapes of the control samples for Seyfert types I and II, the expected distributions of inclinations as a function of b/a are:

Observations

Spirals

Ellipticals



Ellipticals are rounder and only marginally usable to find inclination angles.

Seyfert II　　Seyfert I

The kpc-pc connection

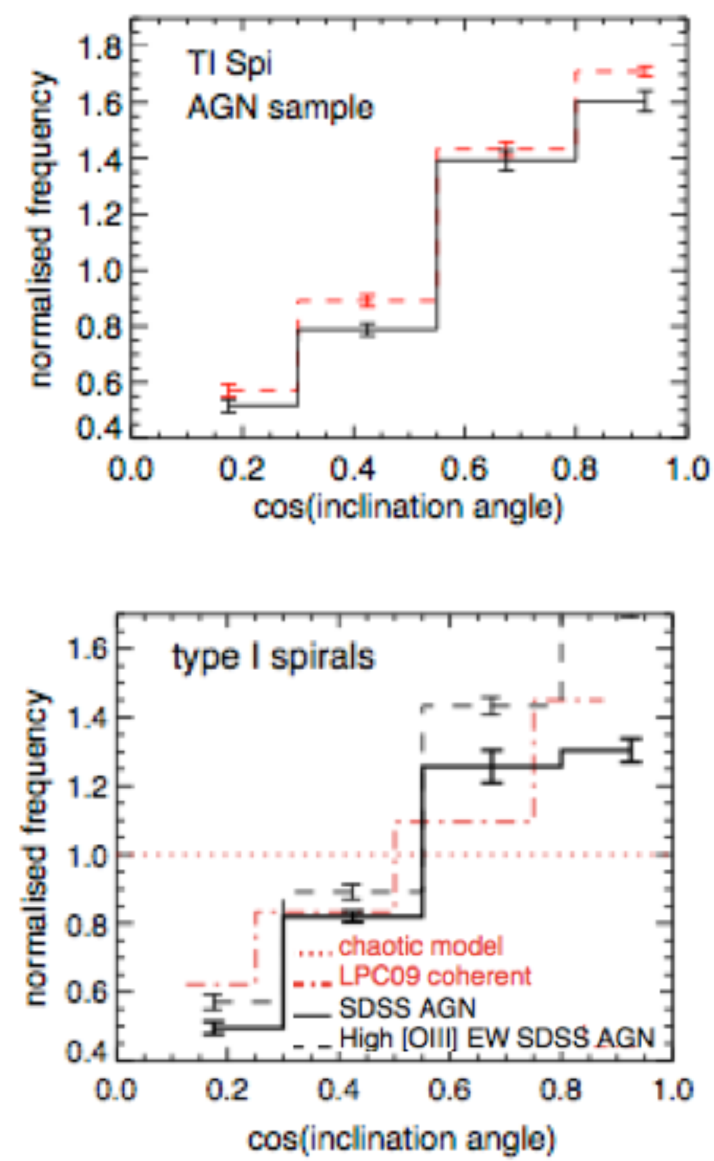
- Which implies

  distribution of inclination angle for AGN

  (high and low EWs)

Different biases in Seyfert types I and II (Goulding & Alexander 2009,2010, Juneau et al. 2011). 170 and 3.5 sigma detections.

- Setting the torus height to 40 degs in the SAM (red) compared to the SDSS (black):



dotted horizontal: random orientations

The kpc-pc connection

- The 1/Vmax weighted fraction of edge-on (viewing angle<C/B) galaxies is higher for high [OIII] EW, by ~20%:

Sample	Type II AGN spirals
All AGN in the sample	0.58
Low [OIII] EW	0.59
High [OIII] EW	0.70

- Consistent with estimate by Juneau et al. (2011) of 40±20% of missed AGNs by comparing to hard X-ray + [OIII]5007 detection.

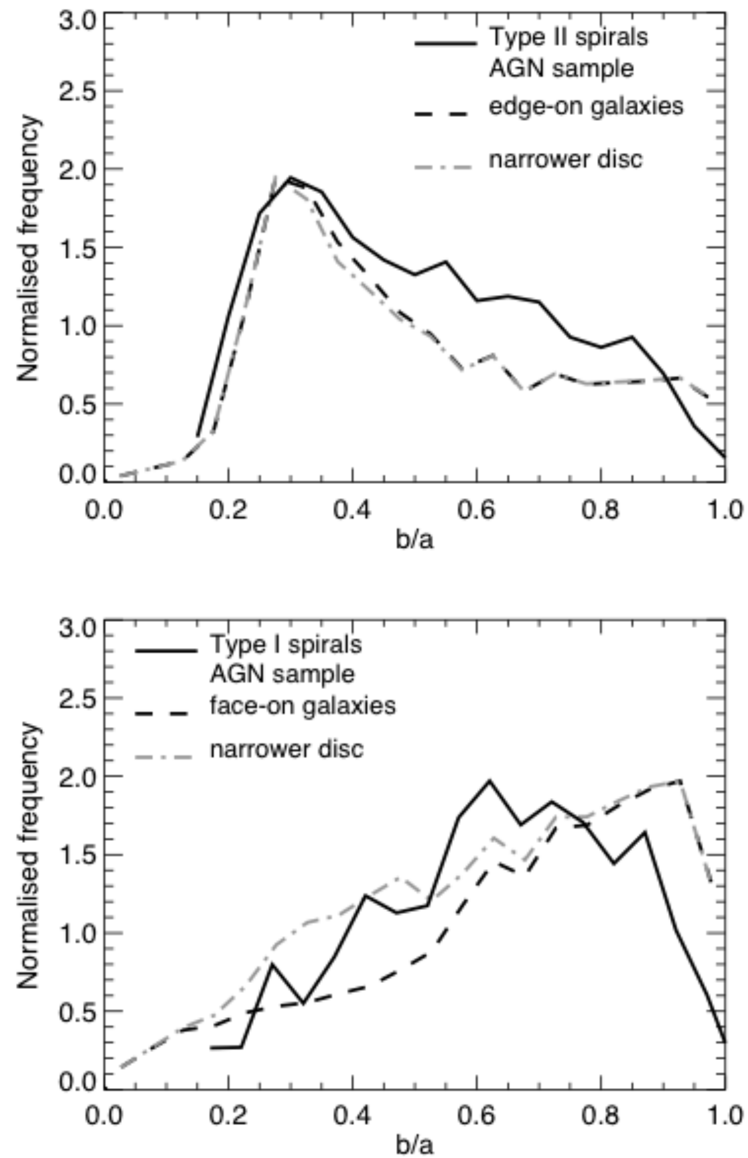
- Shape parameters of Type I and high [OIII] EW type II galaxies are consistent in favour of AGN unified model (significantly more so than without a limit on EW).

The kpc-pc connection

- Effect from the dust in the disc?

resulting distributions of b/a when the dust in the disc is assumed to provide the absorption of broad lines.

not good matches to observed AGN host distributions.



Kpc to pc scales

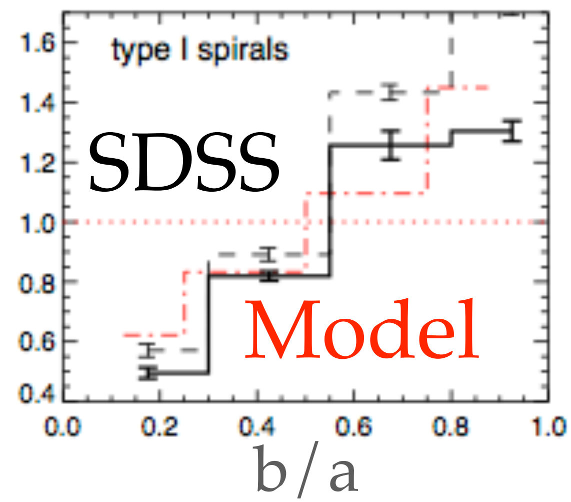
- Some memory of the angular momentum that came with the material that formed the torus.
- Possible inclination angle dependent systematic effects in identifying edge-on Seyfert II galaxies.
- Influence on process of growth of BH spins.

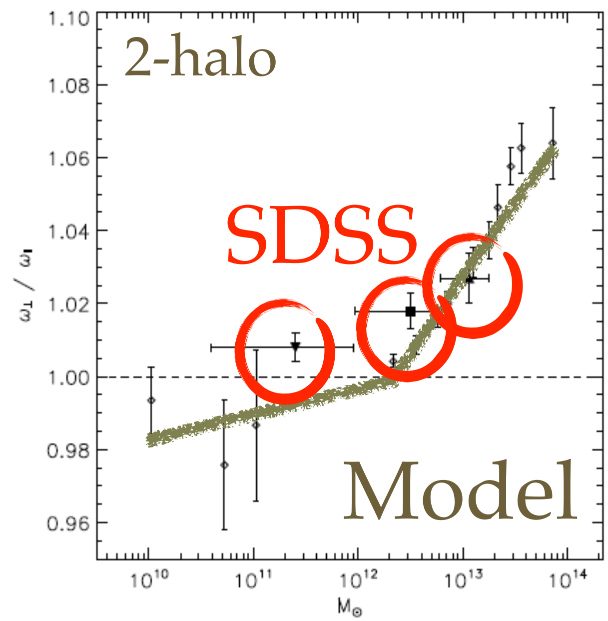
Summary

- Observations point to an alignment between the LSS and galaxy angular momenta. In turn, the angular momenta of the stellar and accretion discs show signs of alignment. Simulations indicate that the first effect comes from tidal torques.

- The second effect is studied using a new model where the material falling into the nucleus of galaxies either
(i) arrives with a randomly oriented angular momentum
(ii) or remembers the direction of the angular momentum of the source.

- Model (ii) produces a better agreement with the observations in the angle between the accretion disc and the stellar disc but preferentially for type I Seyferts.





Thank you

Numerical simulations: Ruiz, Padilla, Domínguez & Cora (2011, MNRAS, arXiv:1103.5074)
pc-kpc connection: Lagos, Padilla, Strauss, Cora & Hao (2011, MNRAS, 414, 2148)
Padilla & Strauss (2008, MNRAS, 388, 1321)
BH spin in the model: Lagos, Padilla & Cora (2009, MNRAS, 395, 625)
Mpc-kpc connection: Paz, Stasyszyn & Padilla (2008, MNRAS, 389, 1127)
Paz, Sgró, Merchán & Padilla (2011, MNRAS, 414, 2029)