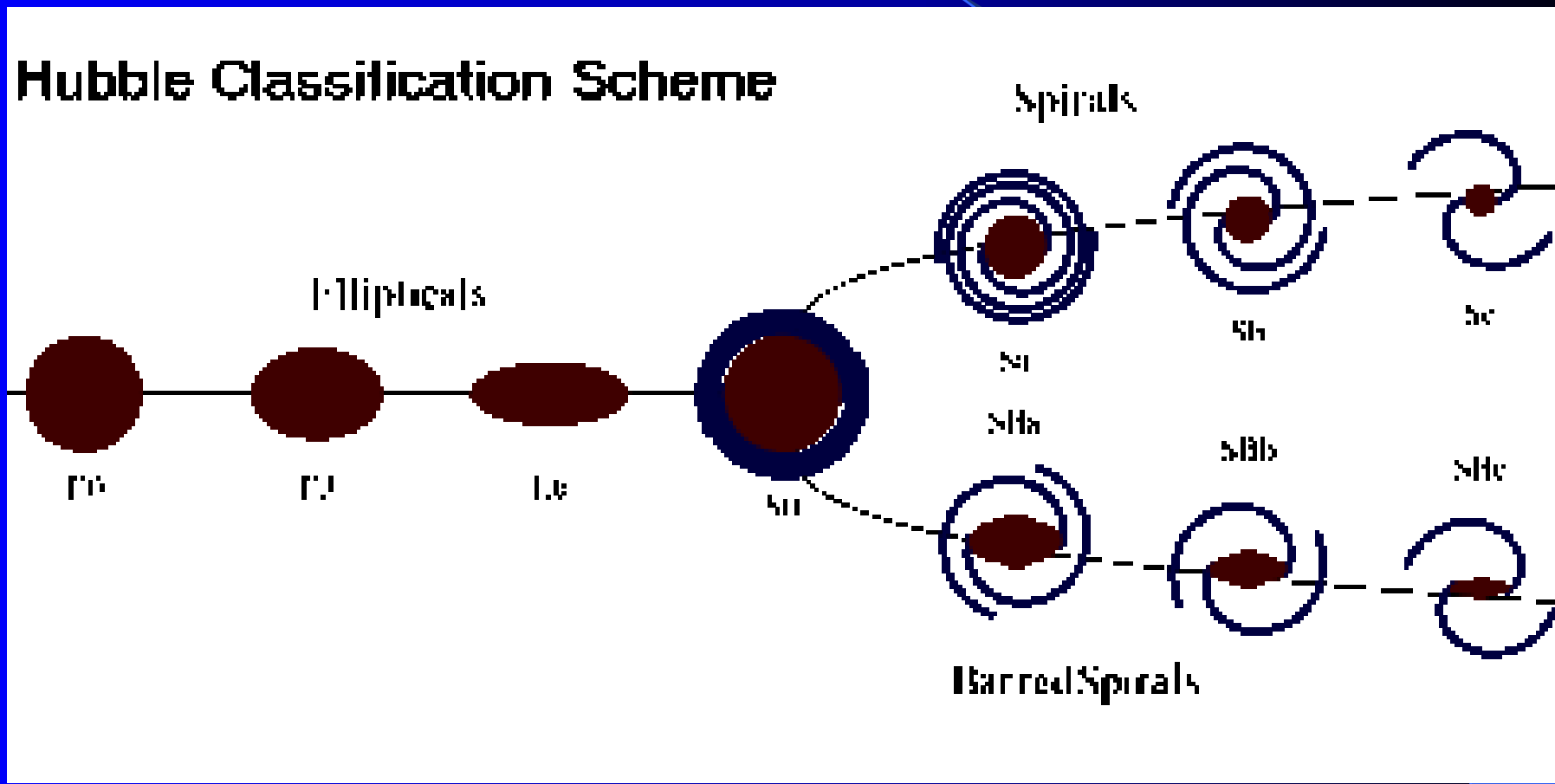
Pattern Speed in Barred Galaxies

José Alfonso López Aguerri (IAC)
Enrico Maria Corsini (Padua)
Victor P. Debattista (Washington)

What is a barred galaxy?



Dynamic of a barred galaxy

- The presence of a bar structure in the disc of the galaxies strongly affects the dynamic of the disc.
- They are related with:
  - New orbits in the galactic discs
  - Transpot of material towards the galactic center
  - Feeding of the centers of spiral galaxies

Resonances in barred galaxies

- The presence of resonancies in barred galaxies are one of the most important characteristics that govern the dynamic of the galaxies.
- They are related with: Bar length (Contopoulos 1981), Location of rings (Buta & Crocker 1993), shape of dust lanes (Athanassoula 1992).
- The present of the resonancies are related with the pattern speed of the bar.
- The resonance condition is:

$$\Omega_p = \Omega - \frac{n}{m}\kappa$$

  - Particle close an orbit in “n” rotations and “m” radial oscilations; n=0 CR, (n=1,m=2) ILR, (n=-1,m=2) OLR

The Coratation Resonance

- The CR determines the presence or not of the other resonancies in the galaxy
- The CR fix an upper limit for the length of the bar: x1 orbits are stable untill the CR (Contopoulos 1980)
- We can characterized the bar by:

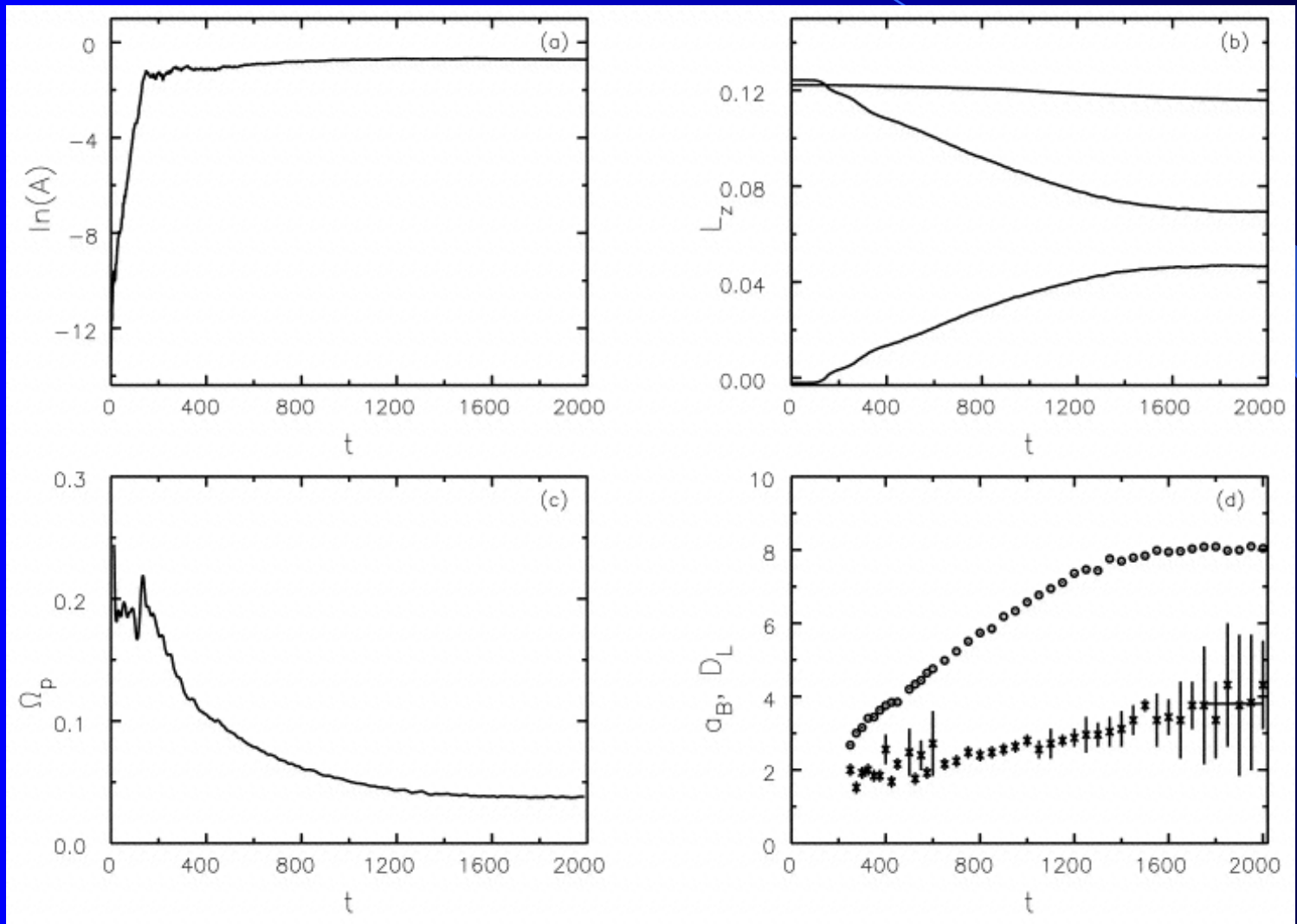
$$R = \frac{D_L}{a_b}$$

  - Numerical simulations: R=1-1.2 (Athanassoula 1992)
  - R>1.7-1.8 slow bars
  - R~1-1.4 fast bars

Corotation and Dark Matter

- It has been proved that a rotating bar transfer some of its rotation to the dark matter halo by dinamical friction (Sellwood 1980; Tremaine & Weinberg 1984).
- The angular momentum transferred to the halo slow down the rotation of the bar (Debattista & Sellwood 1998, 2000)
- Fast bars implies maximun disc solution, slow bars implies dark matter domination in the central parts of the galaxies.

Ω_p and Dark matter



Debattista & Sellwood (200

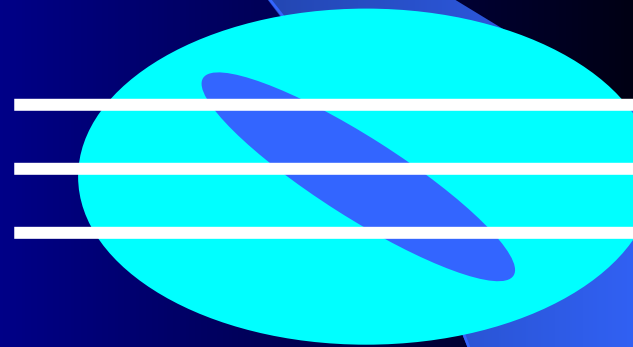
Meassuring the Corotation Radius

- It is difficult to determine observationally the corotation radius in a barred galaxy.
- Many observational methods:
  - Minimum of Star formation at CR: Beckman & Cepa (1990); Aguerri et al (2001)
  - Hydrodinamical models: matching the main structures of the galaxy (Laine 1996; England et al 1990; Hunter et al. 1989; Aguerri et al 2001) or simulations of gas flows (Lindblad et al 1996; Weiner et al 2001)
  - Model independent: Tremaine & Weinberg (1984)

Tremaine & Weinberg method

- The TW method is contained in:

$$\Omega_p \sin(i) = \frac{\int_{-\infty}^{\infty} \Sigma(x) V_{LOS}(x) dx}{\int_{-\infty}^{\infty} \Sigma(x) x dx} \equiv \frac{\upsilon}{\aleph}$$

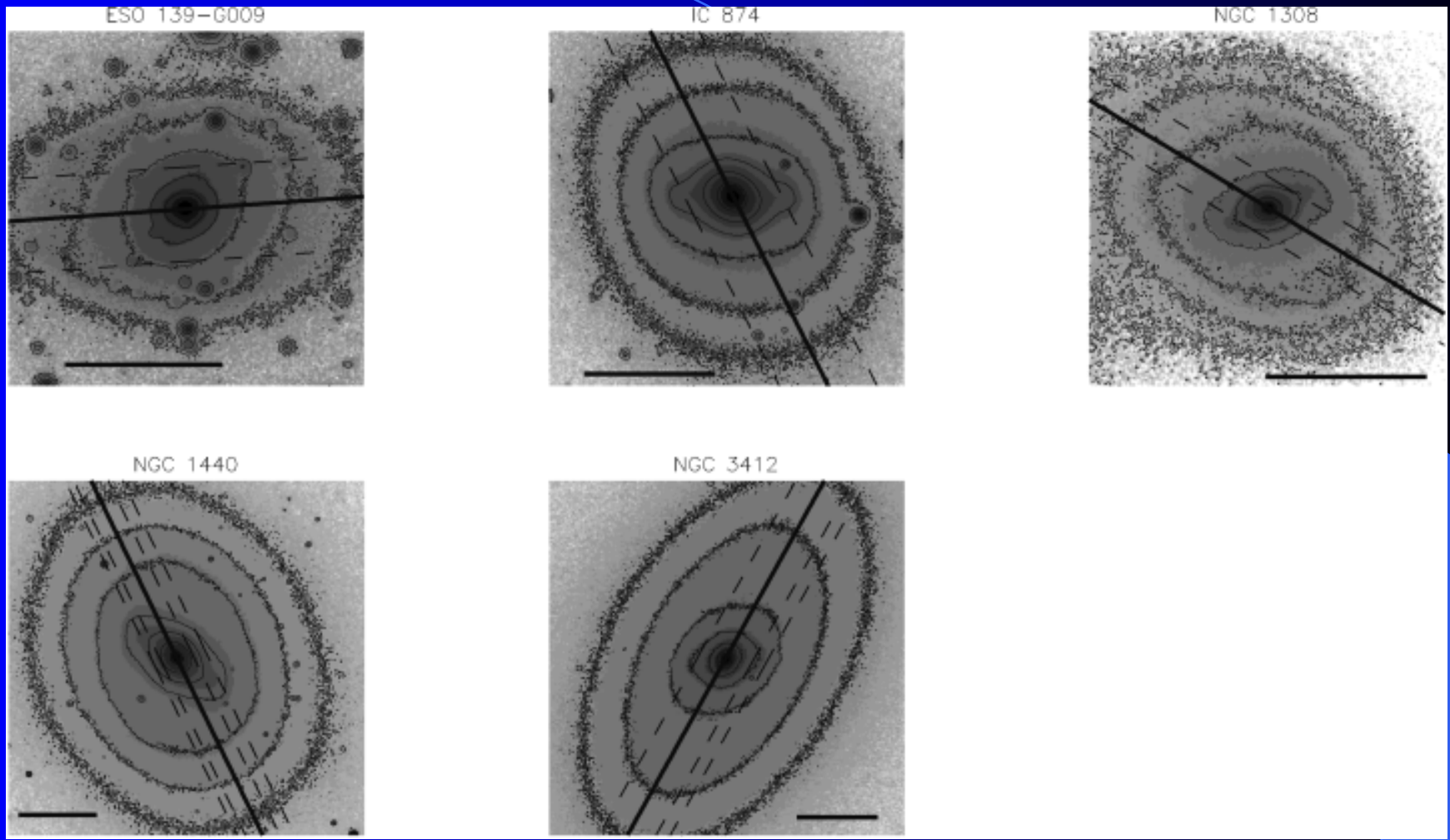


- In 2002 only 3 CR were measured by TW
  - NGC 936 (Kent 1987; Merrifield & Kuijken 1995)
  - NGC 4596 (Gerssen et al 1999)
  - NGC 7079 (Debattista & Williams 2001)

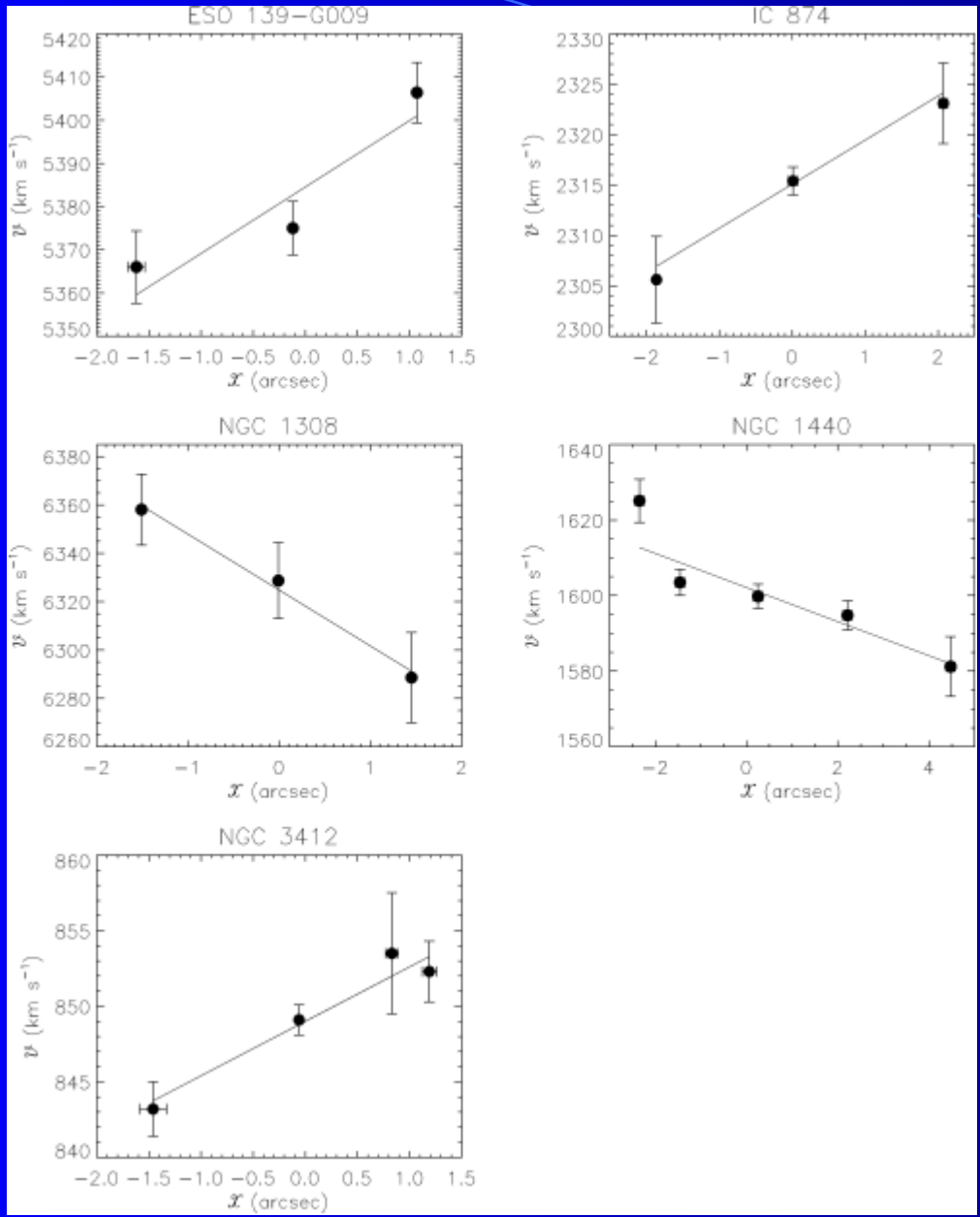
Our project

- We started a project for measuring pattern speed in a sample of early type galaxies.

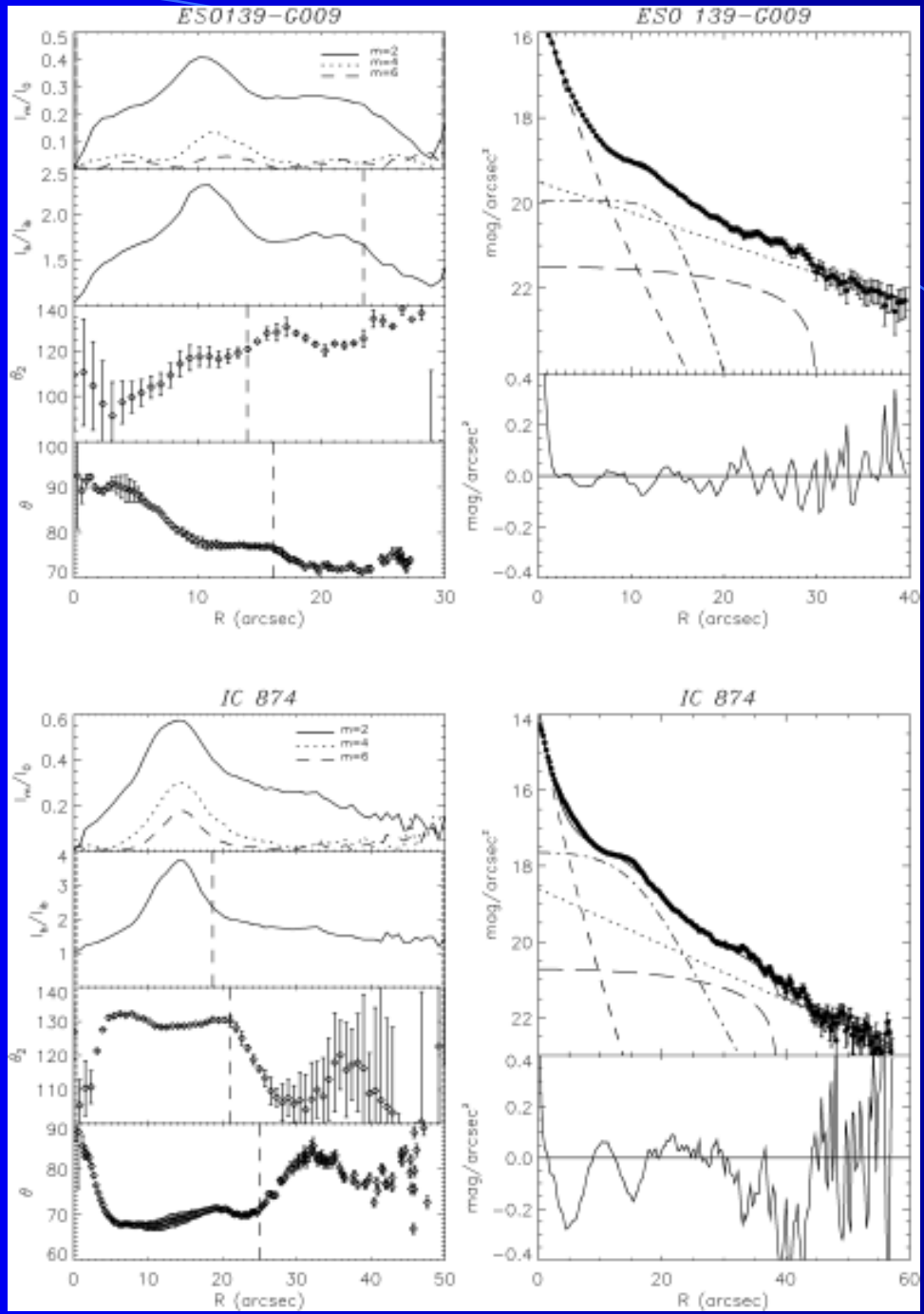
Galaxy	Photometry	Spectroscopy
NGC 1023	JKT	TNG
ESO 139	NTT	NTT
IC 874	NTT	NTT
NGC 1308	JKT	TNG
NGC 1440	Danish 1.5	NTT
NGC 3412	JKT	TNG
NGC 2950	JKT	TNG



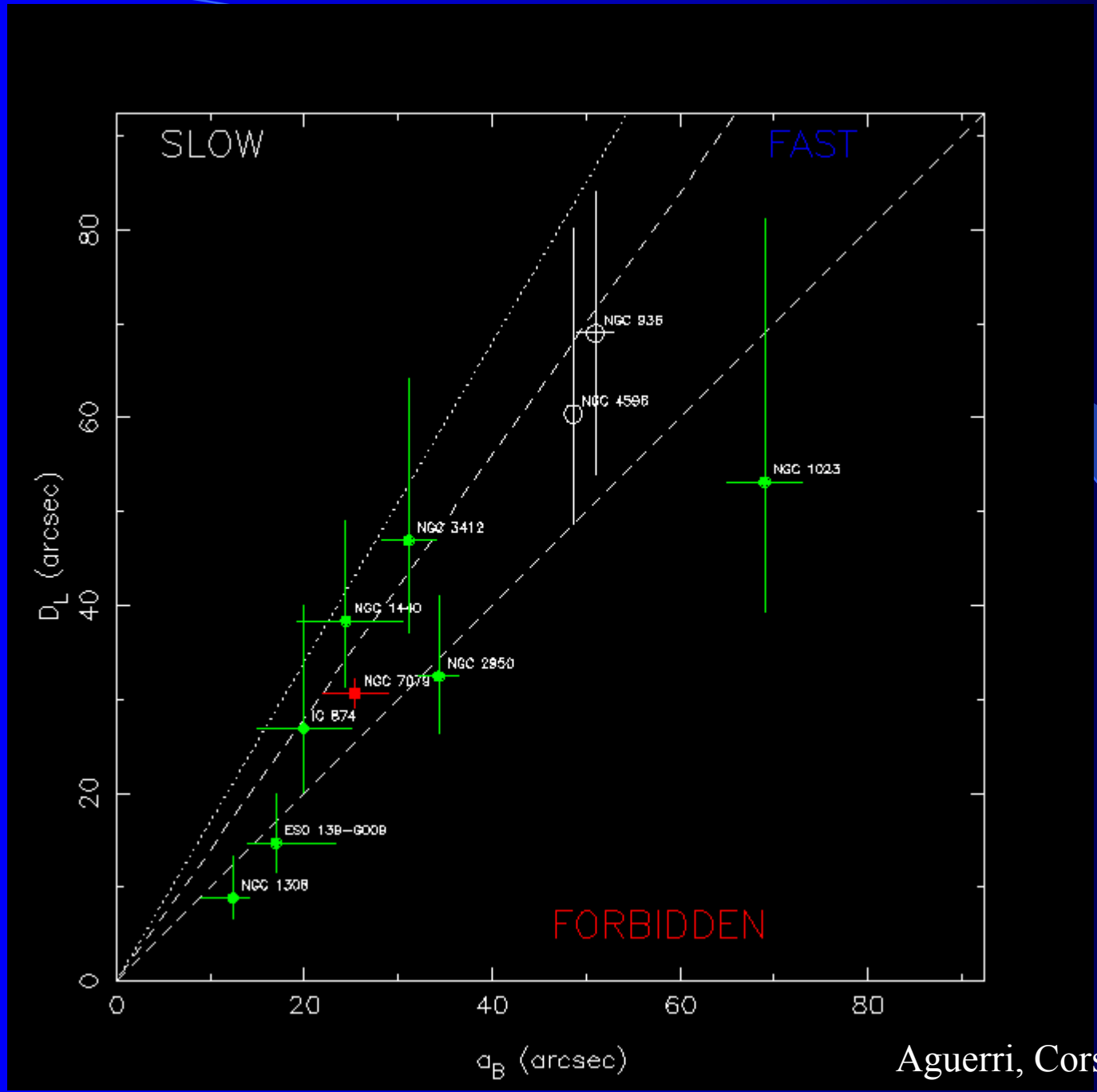
Aguerri, Corsini & Debattista 2003



Aguerri, Corsini & Debattita (2003)



Aguerri, Corsini & Debattita (2003)



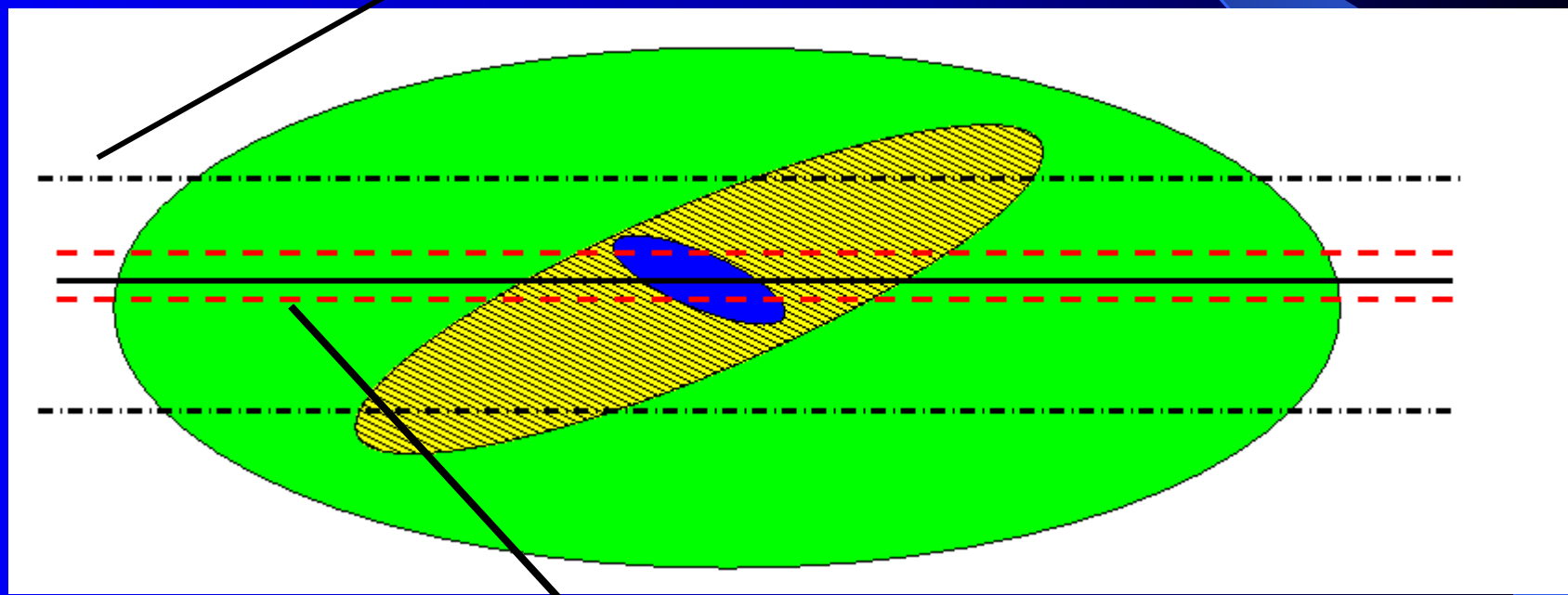
Aguerri, Corsini & Debattita (200

Double bar galaxies

- About 1/3 of barred galaxies have a secondary bar.
- They are mechanism for driving gas to small radii to feed the supermasive black hole powering AGN. The efficiency of this mechanisms depends on the ratio Ω_s / Ω_p
- Pure disk simulations shows that systems with $\Omega_s > \Omega_p$ can be formed and survived for more than a few rotation periods (Rautiainen et al 2002).

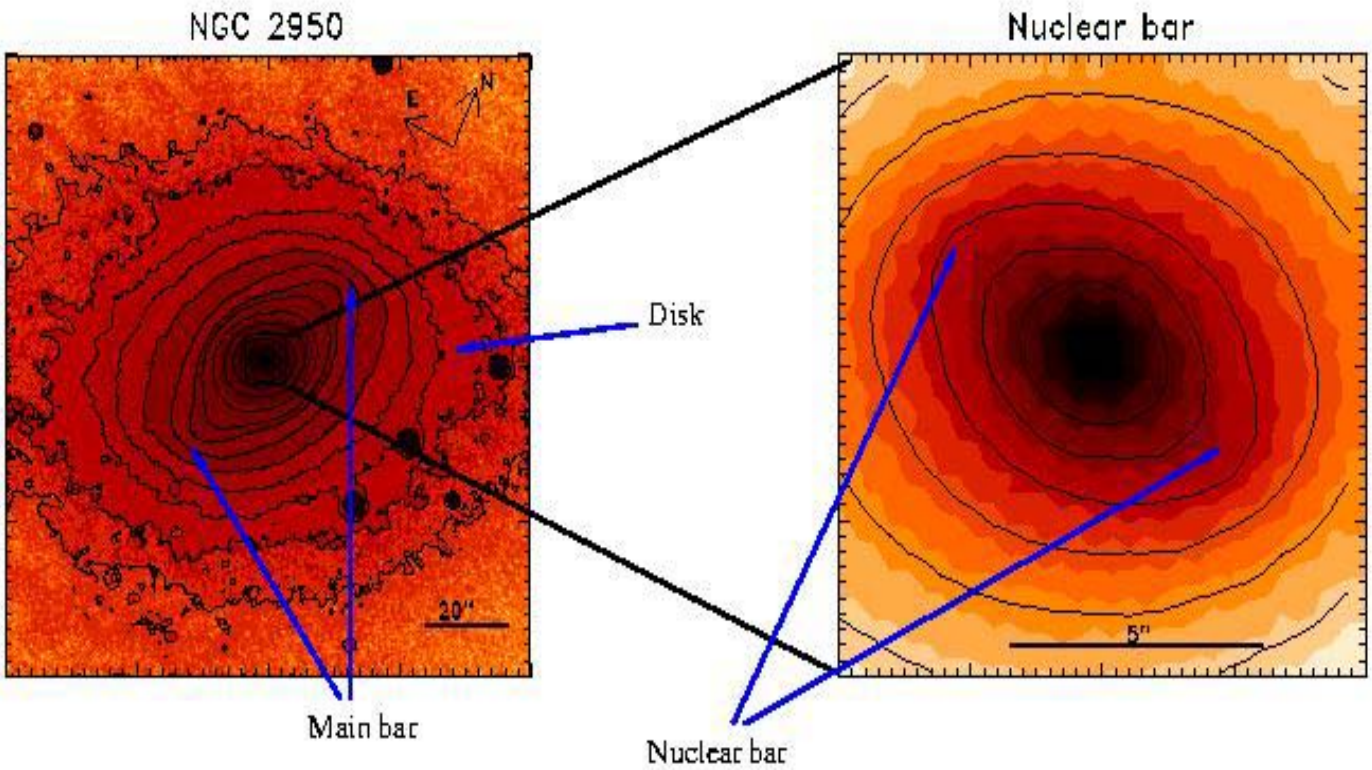
TW for double barred galaxies

$$\aleph \Omega_p \sin(i) = v$$



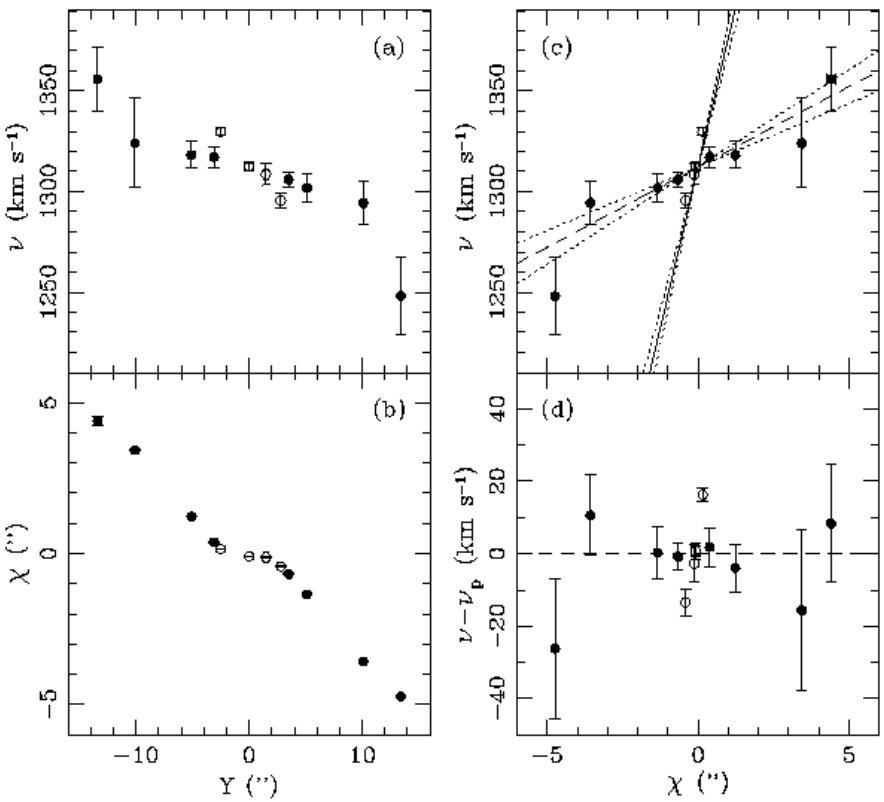
$$(\aleph_p \Omega_p + \aleph_s \Omega_s) \sin(i) = v$$

The case of NGC 2950



Corsini, Debattista & Aguerri (2003)

The case of NGC 2950



Corsini, Debattista & Aguerri (200

Conclusions

- All bars from the sample are compatible with fast rotators (Debattista, Corsini & Aguerri 2002; Aguerri, Debattista & Corsini 2003).
- The only double bar galaxy mesured so far shows a nuclear bar which rotates faster than the main bar (Corsini, Debattista & Aguerri 2003).

Future work

- We have already observations for 2 double galaxies more.
- We have observations for SAB galaxies
- Dwarf galaxies with bars
- Later types of galaxies.
- How efficient are the double bars mechanisms for feeding BH?: Stellar population studies.