GALAXIES IFS
Double-bars
gas
StellarPopulations
AGN Kinematics
BARS
Long-slit Spectroscopy
CALIFA

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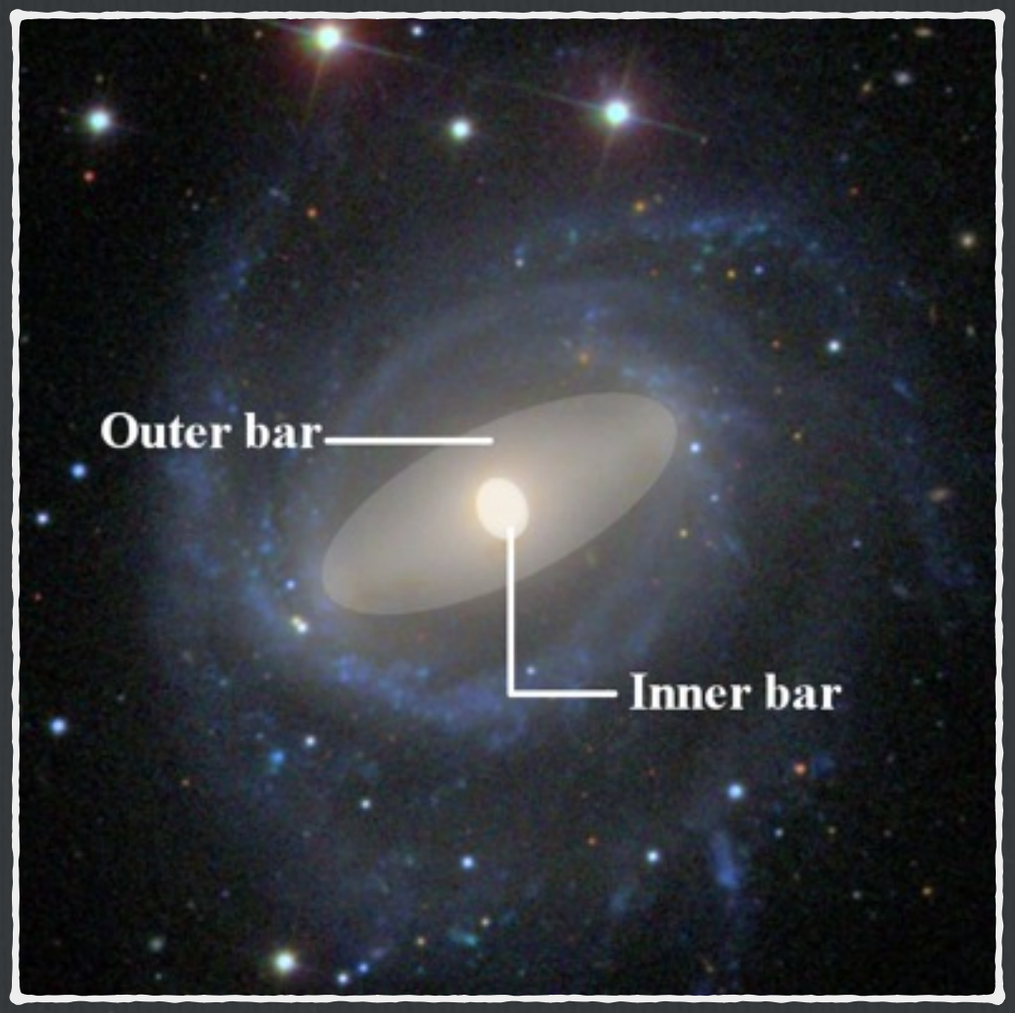
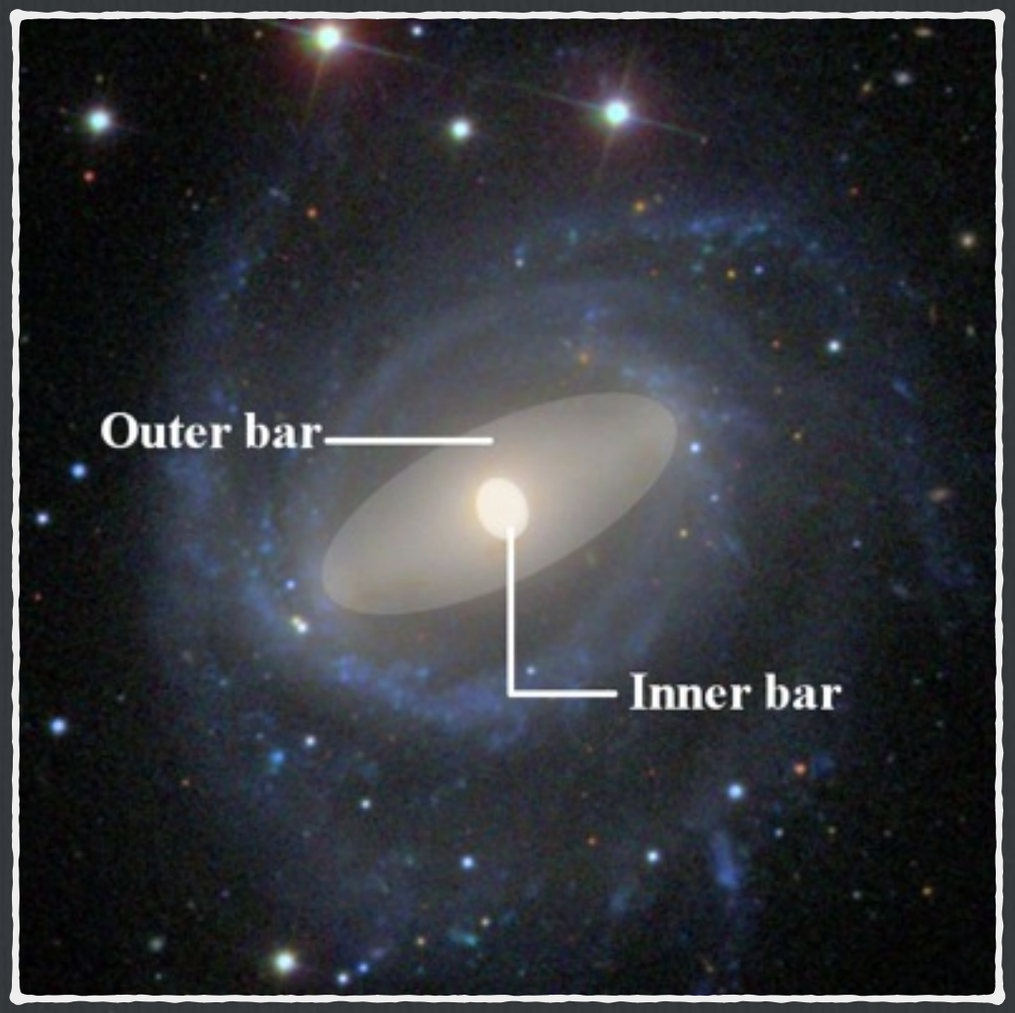
RASPUTIN - October 14, 2014

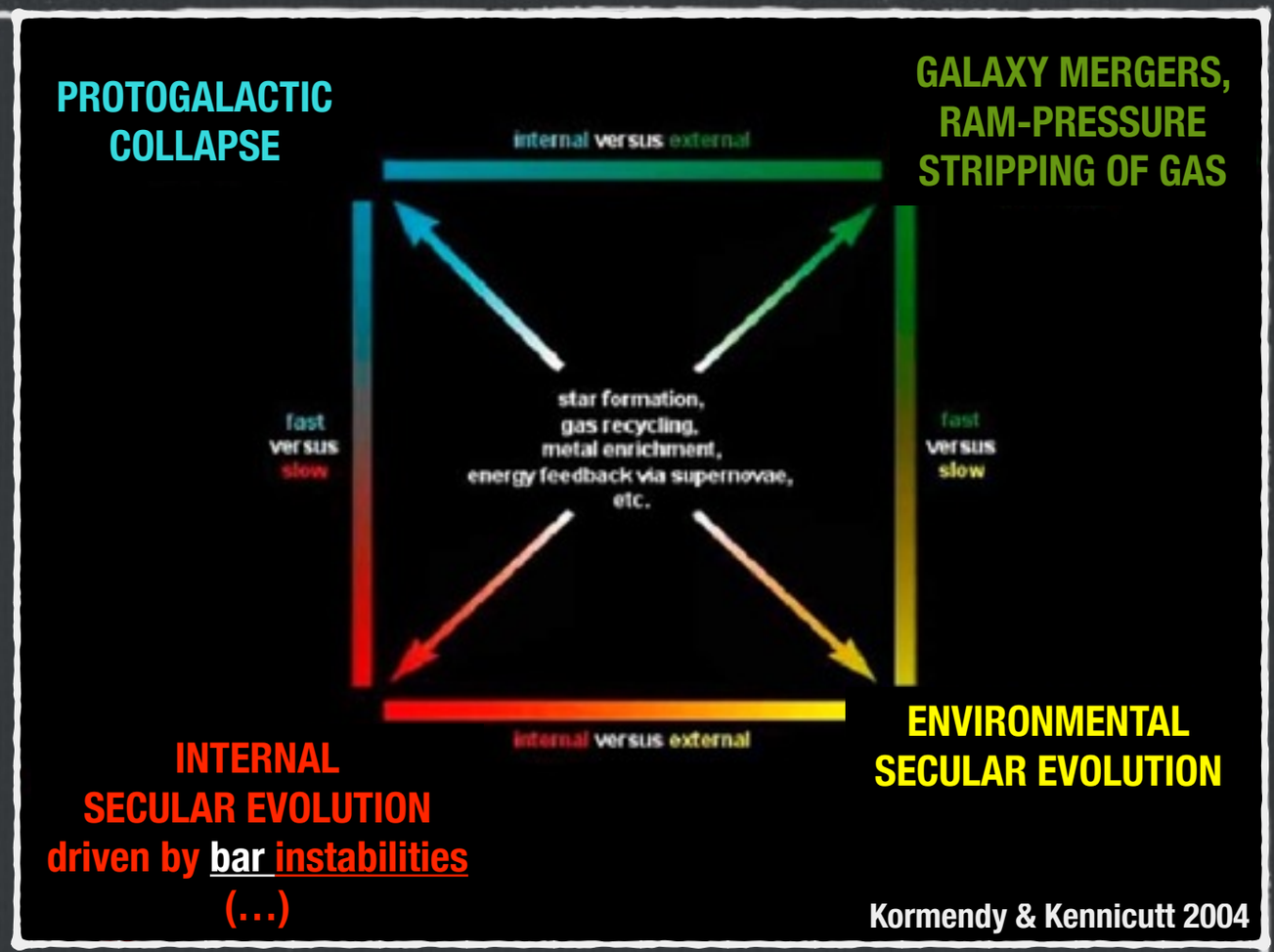
Double-barred galaxies: why are they interesting?



- Kormendy, 1979, 1982, ApJ, Double bar in NGC3945
- Shlosman, Frank, and Begelman, 1989, 1990, Nature, Fuelling of AGN
- Pfenniger and Norman, 1990, ApJ, Simulations and secular evolution
- Friedli and Martinet, 1993, A&A, Simulations of double bars
- Wozniak et al. 1995, A&AS, Search for double bars
- Jungwiert, Combes, and Axon, 1997, A&AS, Search for double bars
- Maciejewski and Sparke, 1997 (ApJ), 2000 (MNRAS), Orbital configuration
- Erwin and Sparke, 1999 (ApJ), 2002 (AJ), 2003 (ApJ), Search for double bars
- Erwin, Vega Beltrán, and Beckman, 2001, ApSSS, Double bar in NGC4340
- Moiseev, 2001, BSAO, Kinematics of double bars
- Heller, Shlosman, and Englmaier, 2001, Simulations of double bars
- Emsellem et al. 2001, A&A, Kinematics of double bars
- Shlosman and Heller, 2002, ApJ, Simulations and dust
- Laine et al. 2002, ApJ, Double bars and AGNs
- Petitpas and Wilson, 2002, 2003, 2004, ApJ, Molecular gas in double bars
- El-Zant and Shlosman, 2003, ApJ, Simulations of double bars
- Corsini, Debattista, and Aguerri, 2003, Pattern speed of a double bar
- Erwin, 2004, A&A, Catalogue of double-barred galaxies
- Lisker et al. 2006, MNRAS, Double bars at high z
- Debattista and Shen, 2007, ApJ, Simulations of double bars
- Maciejewski and Athanassoula, 2007, 2008, MNRAS, Orbital configuration
- de Lorenzo-Cáceres et al. 2008, ApJ, Kinematics of double bars
- Shen and Debattista, 2009, ApJ, Simulations of double bars
- Maciejewski and Small, 2010, ApJ, Orbital configuration
- de Lorenzo-Cáceres et al. 2012, MNRAS, Double bar in NGC357
- de Lorenzo-Cáceres et al., 2013, MNRAS, Stellar populations
- Saha and Maciejewski, 2013, Simulations of double bars
- Font et al. 2014, MNRAS, Pattern speed from gas

Double-barred galaxies: why are they interesting?





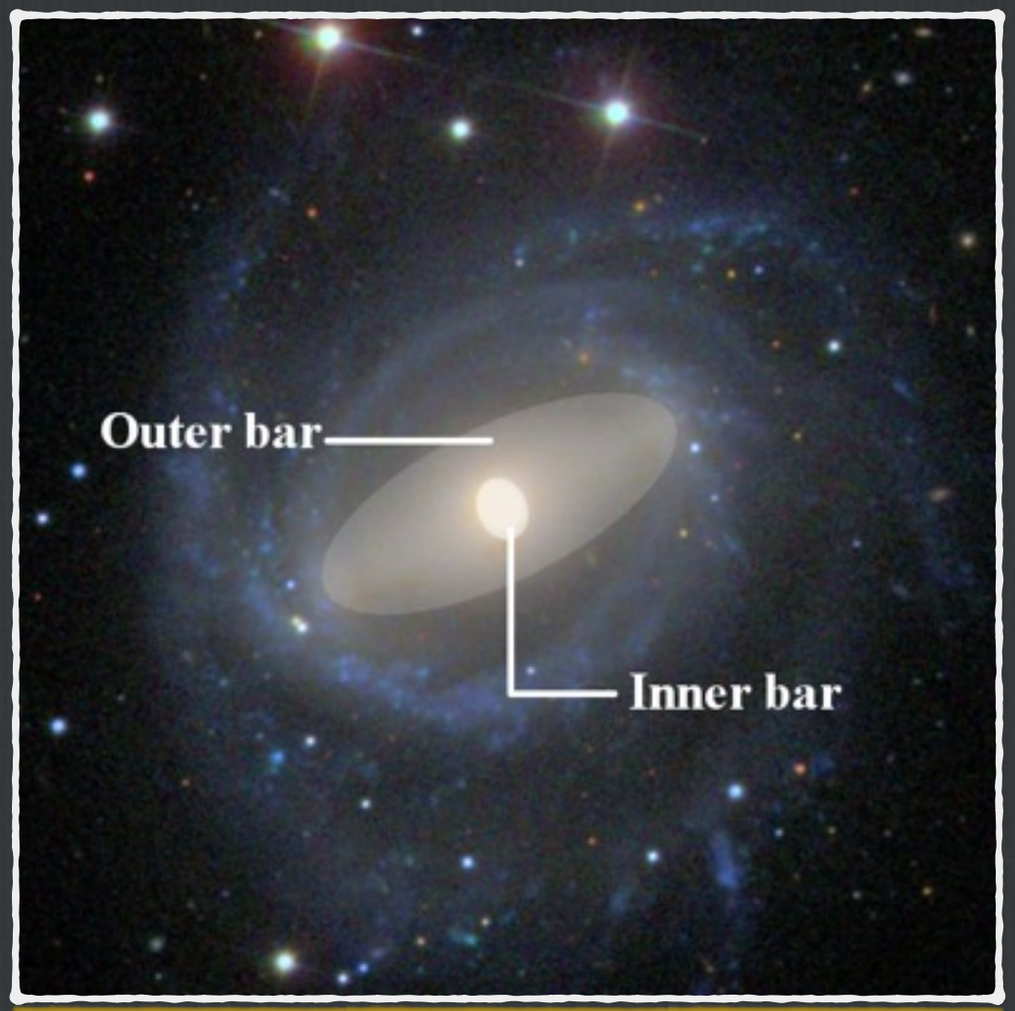
Double bars might…

- ★ **promote internal secular evolution**
- ★ **feed AGN** (Shlosman et al. 1989, 1990, but see also Ho et al. 1997, Márquez et al. 2000)

At least 30% of barred galaxies are double-barred (e.g., Laine et al. 2002, Erwin 2004, Laurikainen et al. 2011)

Double bars found till z~.15 (Lisker et al. 2006)

Double-barred galaxies: why are they interesting?

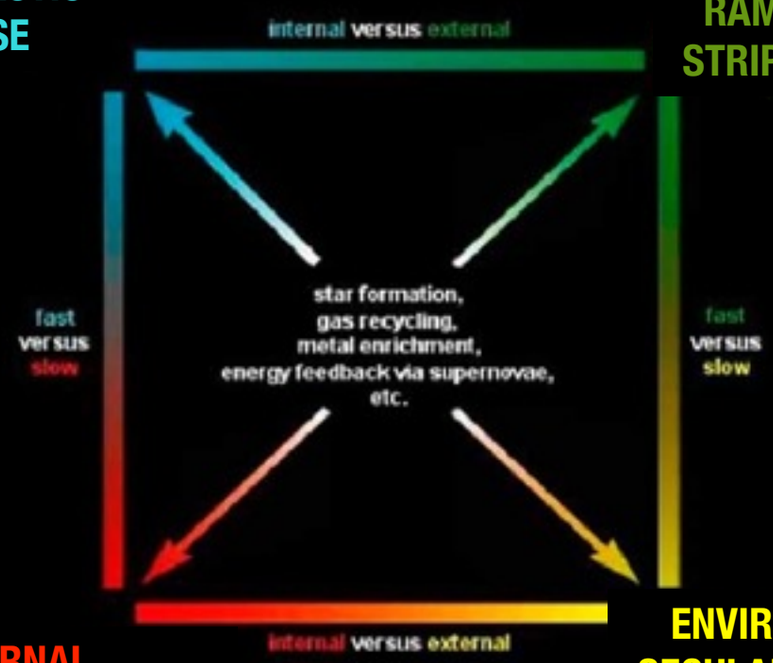


Many open questions:

- how do they form?
- Observational characterisation of double bars (photometry, kinematics, stellar populations)

PROTOGALACTIC COLLAPSE

GALAXY MERGERS, RAM-PRESSURE STRIPPING OF GAS



INTERNAL SECULAR EVOLUTION driven by bar instabilities (…)

ENVIRONMENTAL SECULAR EVOLUTION

Kormendy & Kennicutt 2004

Double bars might…

- ★ promote internal sec… …tion
- ★ feed AGN … et al. 1989, 1990, but … et al. 1997, Márquez et al. 2000)

Theoretically possible, no observacional evidence!!!

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Double bars found till z~.15 (Lisker et al. 2006)

STELLAR POPULATION PROPERTIES OF DOUBLE-BARRED GALAXIES

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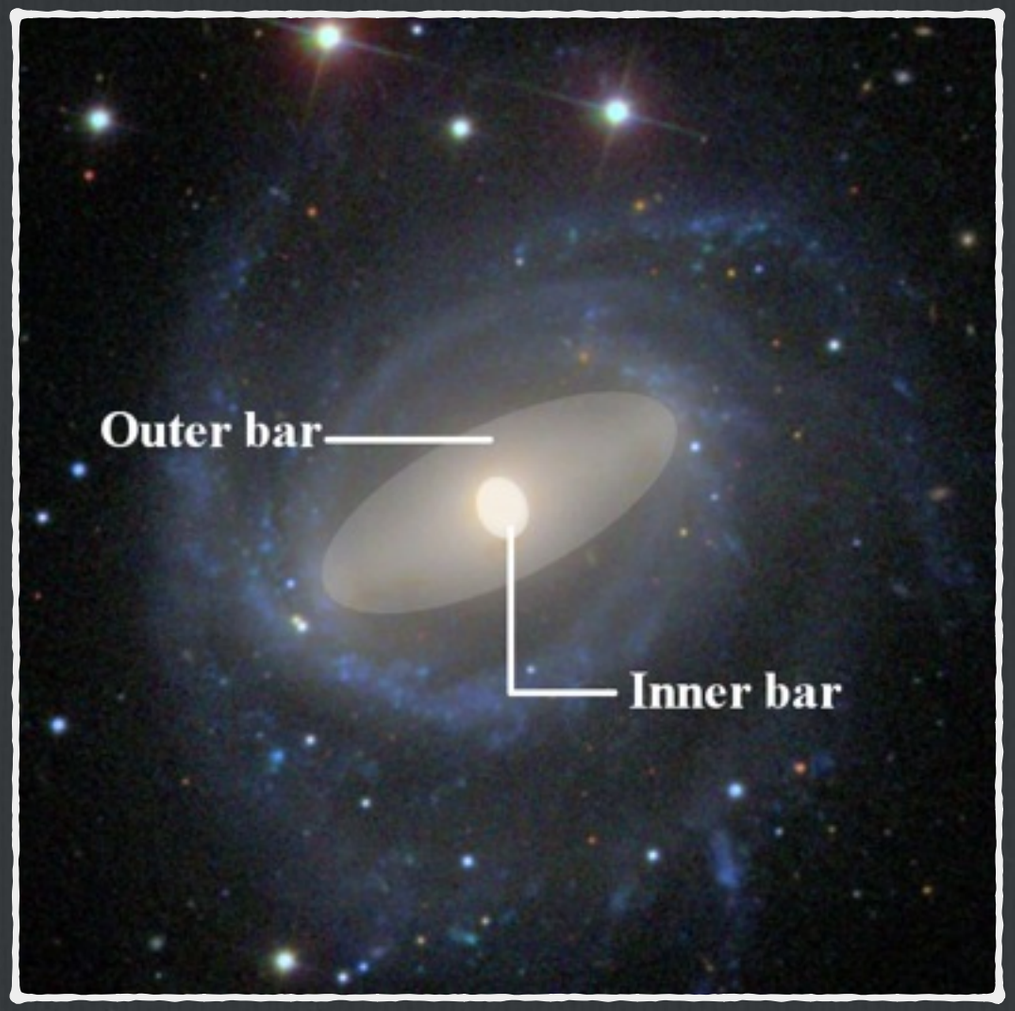
Jesús Falcón-Barroso (Instituto de Astrofísica de Canarias, Spain)
Victor P. Debattista (Univ. Central Lancashire, UK)
Enrico M. Corsini (Universitá di Padova, Italy)

Spectroscopic survey of double-barred galaxies



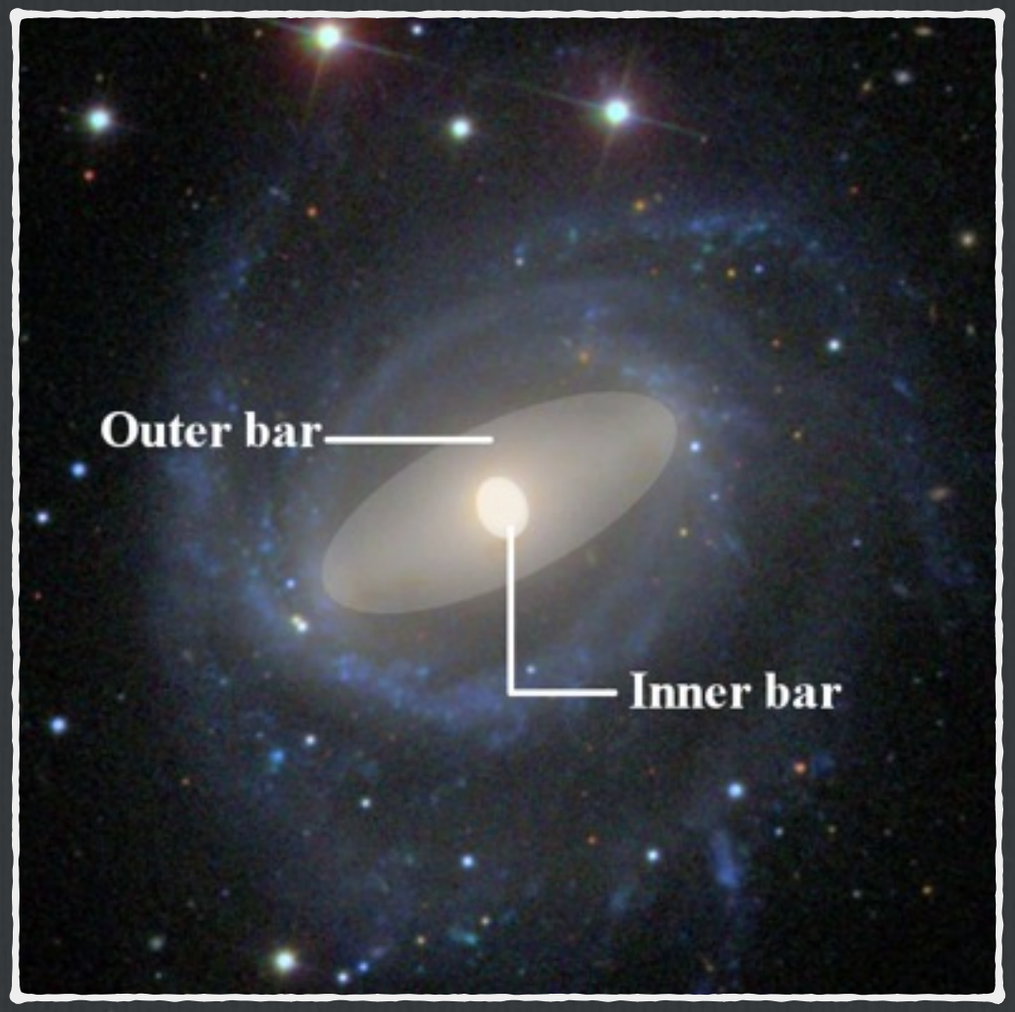
Long-slit and integral-field spectra for analysing the

- ★ **gas kinematics**
- ★ **stellar kinematics**
- ★ **mean ages and metallicities**
- ★ **star formation histories**

Spectra for 8 different double-barred galaxies (~16% of all the known double bars):

- ★ **4 galaxies observed with SAURON@WHT (IFU)**
- ★ **2 galaxies observed with OASIS@WHT (IFU)**
- ★ **1 galaxy observed with EMMI@NTT (long-slit)**
- ★ **5 galaxies observed with ISIS@WHT (long-slit)**

Spectroscopic survey of double-barred galaxies



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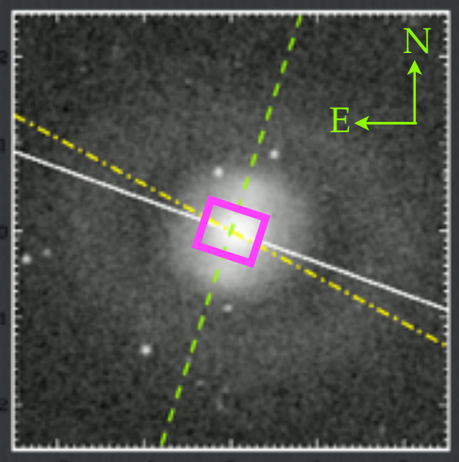
- ✓ **4 galaxies observed with SAURON@WHT (IFU)**
  de Lorenzo-Cáceres et al. 2008, 2013
- — **2 galaxies observed with OASIS@WHT (IFU)**
  Observations taken in August 2014
- ✓ **1 galaxy observed with EMMI@NTT (long-slit)**
  de Lorenzo-Cáceres et al. 2012
- **5 galaxies observed with ISIS@WHT (long-slit)**
  de Lorenzo-Cáceres et al. 2015a, stay tuned!

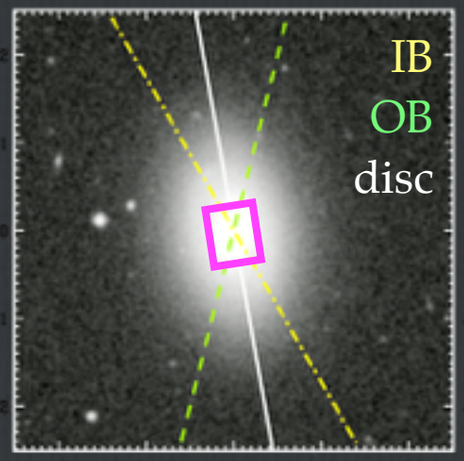
4 double bars observed with IFS

NGC2859



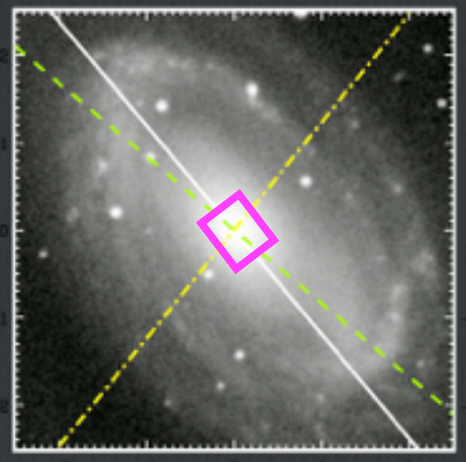
(R)SB(r)0+

NGC3941



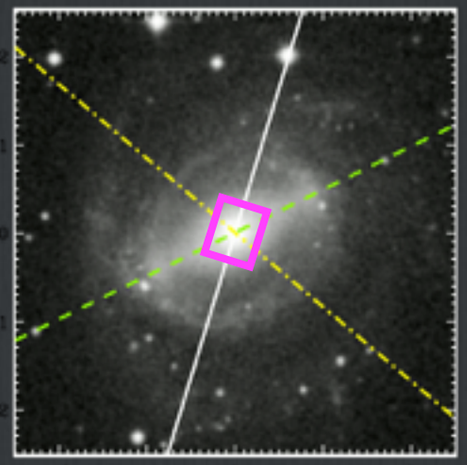
SB(s)00

NGC4725



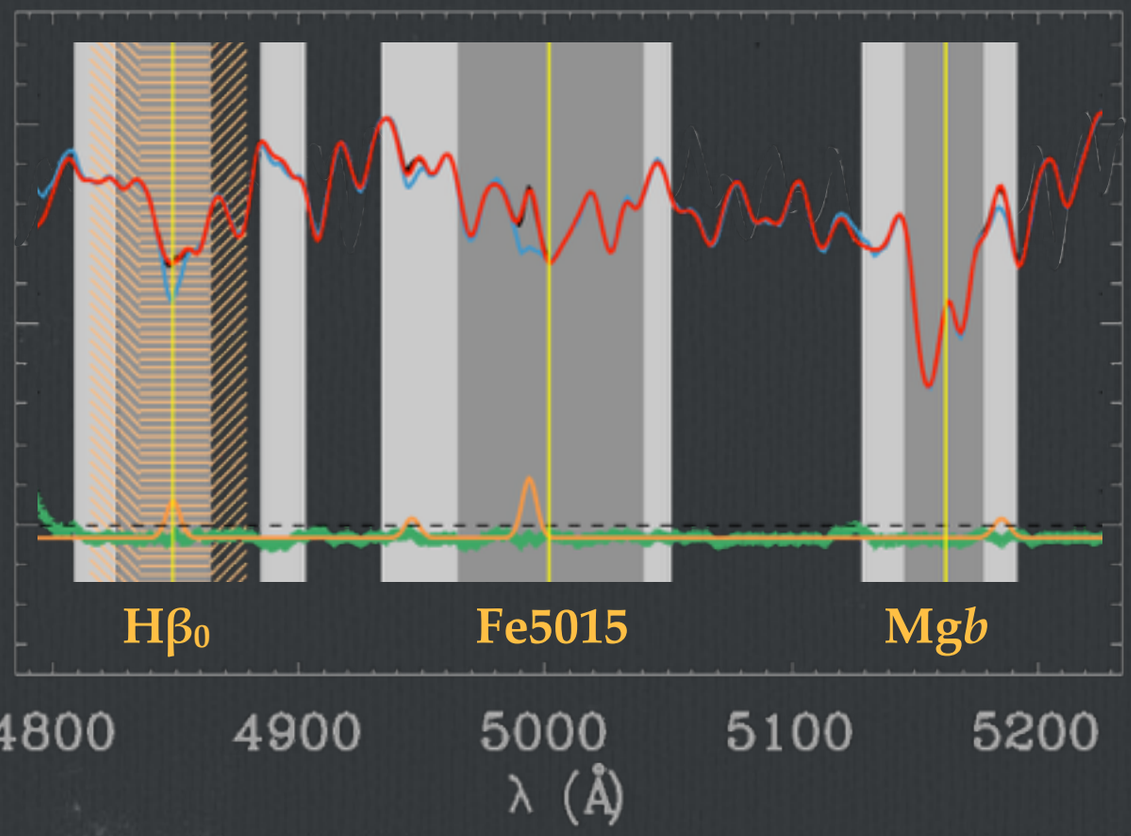
SAB(r)ab

NGC5850

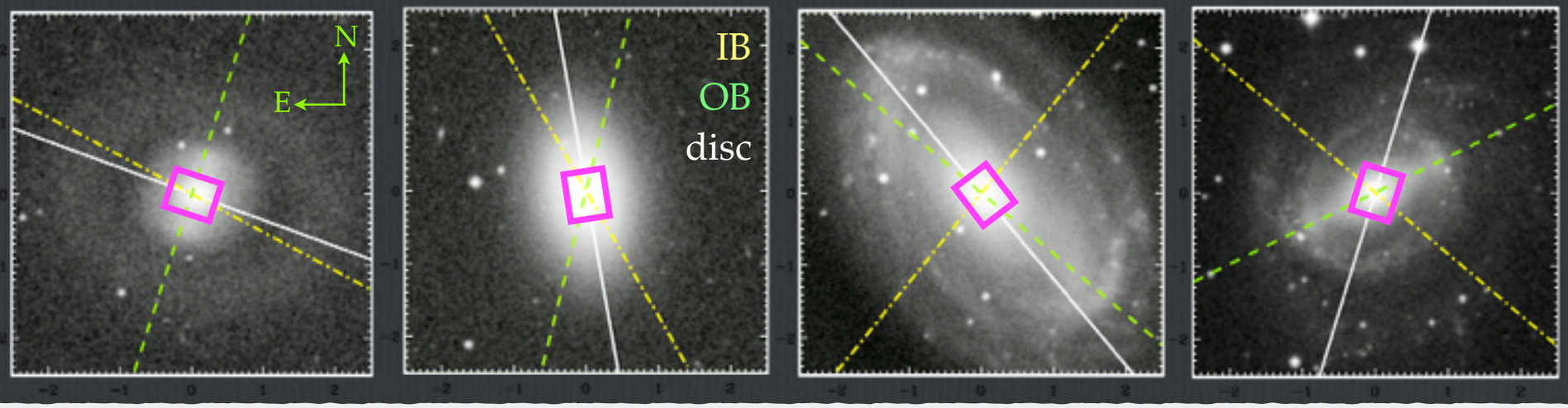


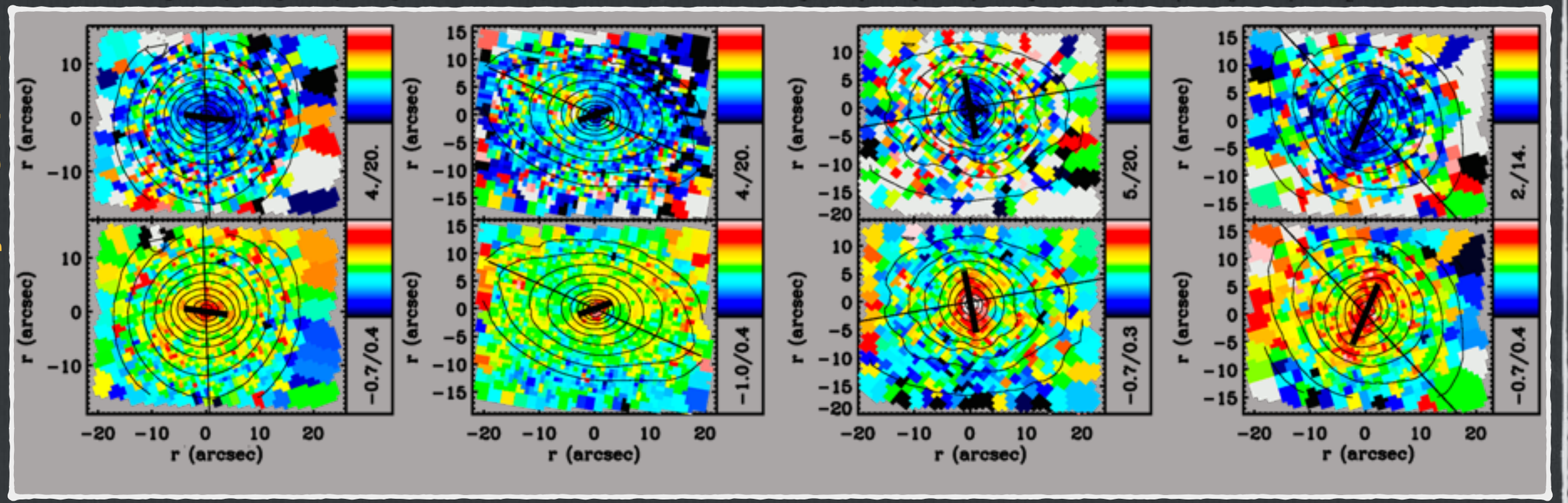
SB(r)b

SAURON central spectrum of NGC2859



IBs are younger and more metal-rich than OBs





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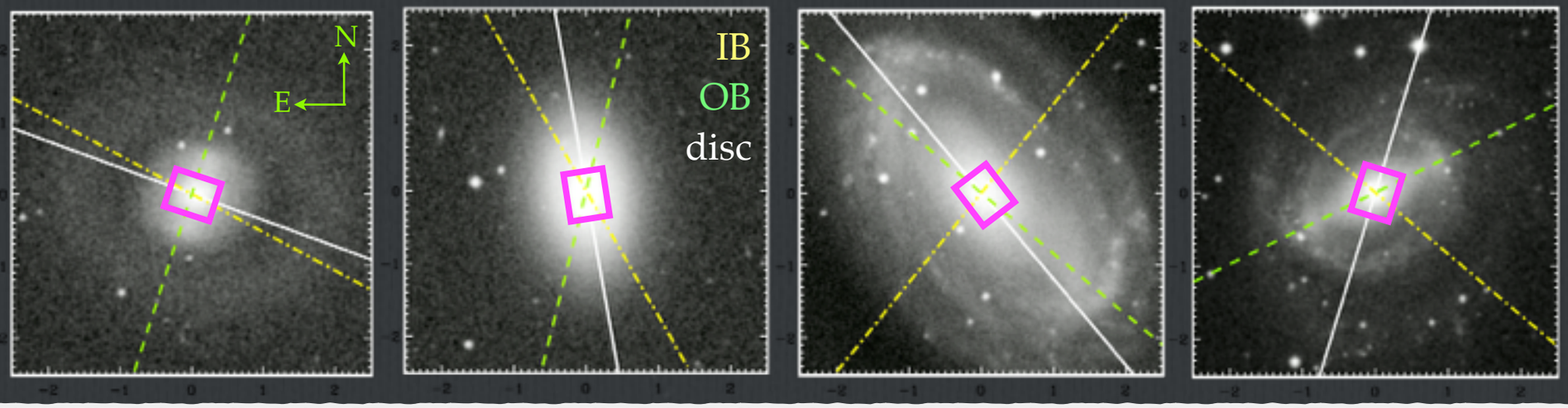

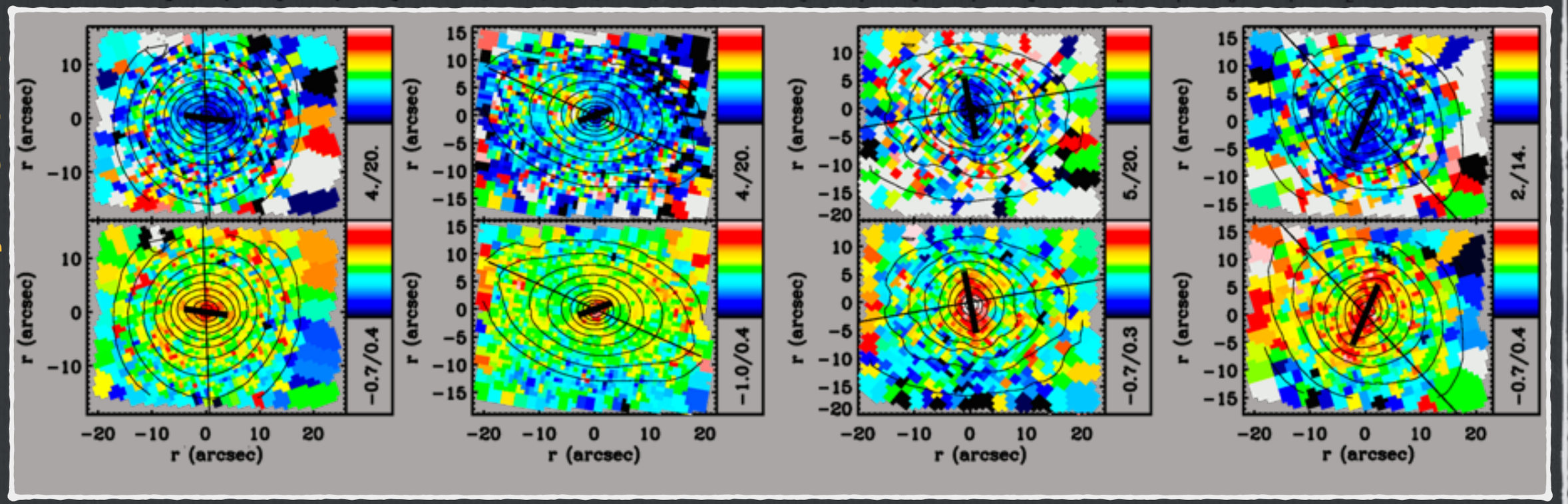

Possible formation scenarios

GAS-RICH (e.g., Friedli and Martinet 1993, Shlosman and Heller 2002; Rautiainen et al. 2002, Heller et al. 2001, 2007)

vs.

GAS-FREE (e.g., Debattista and Shen 2007; Saha and Mackejewski 2013)

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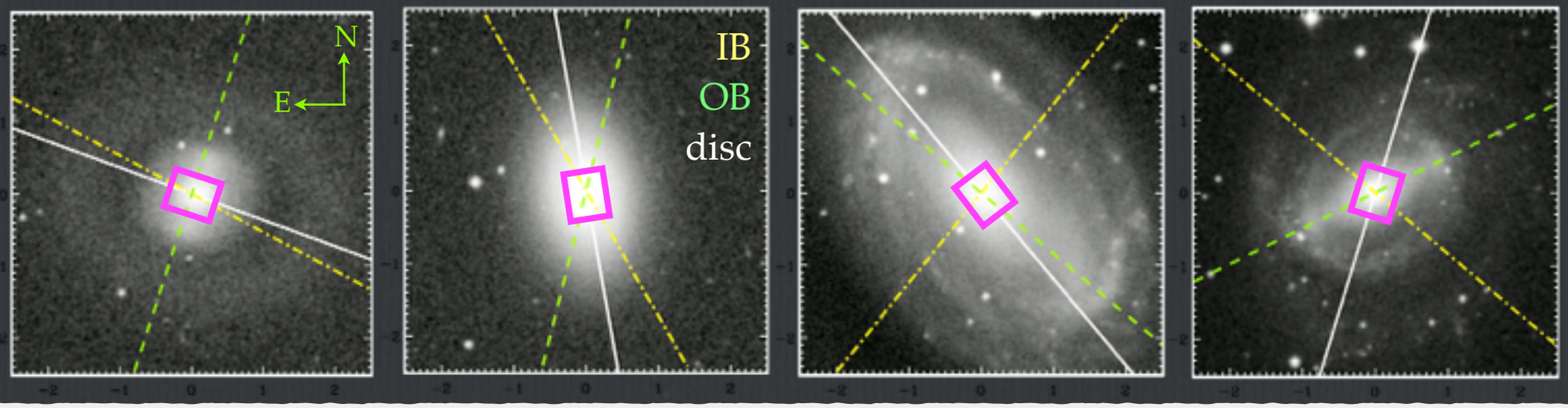
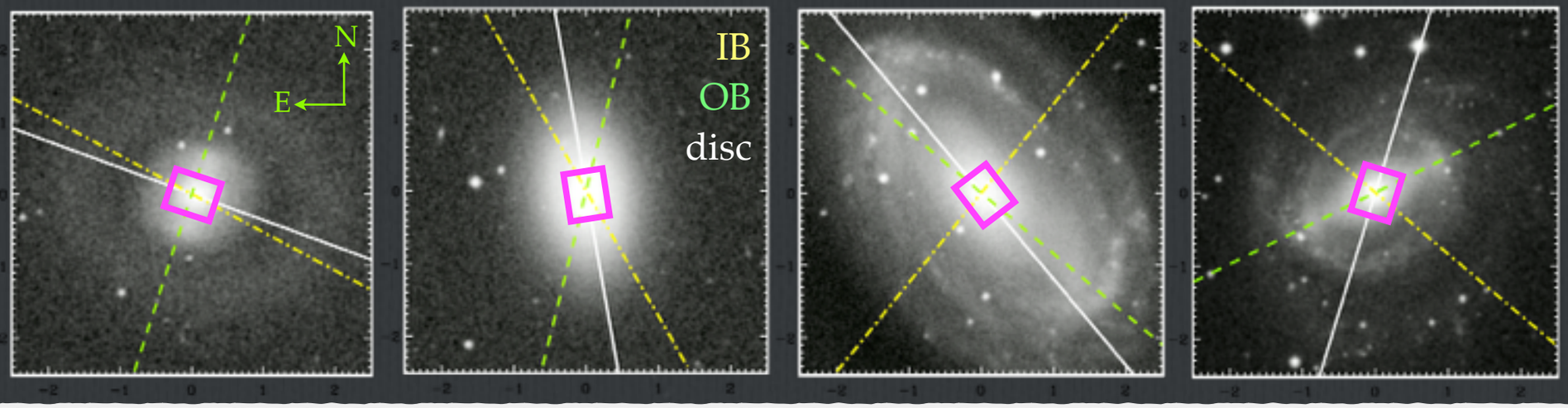
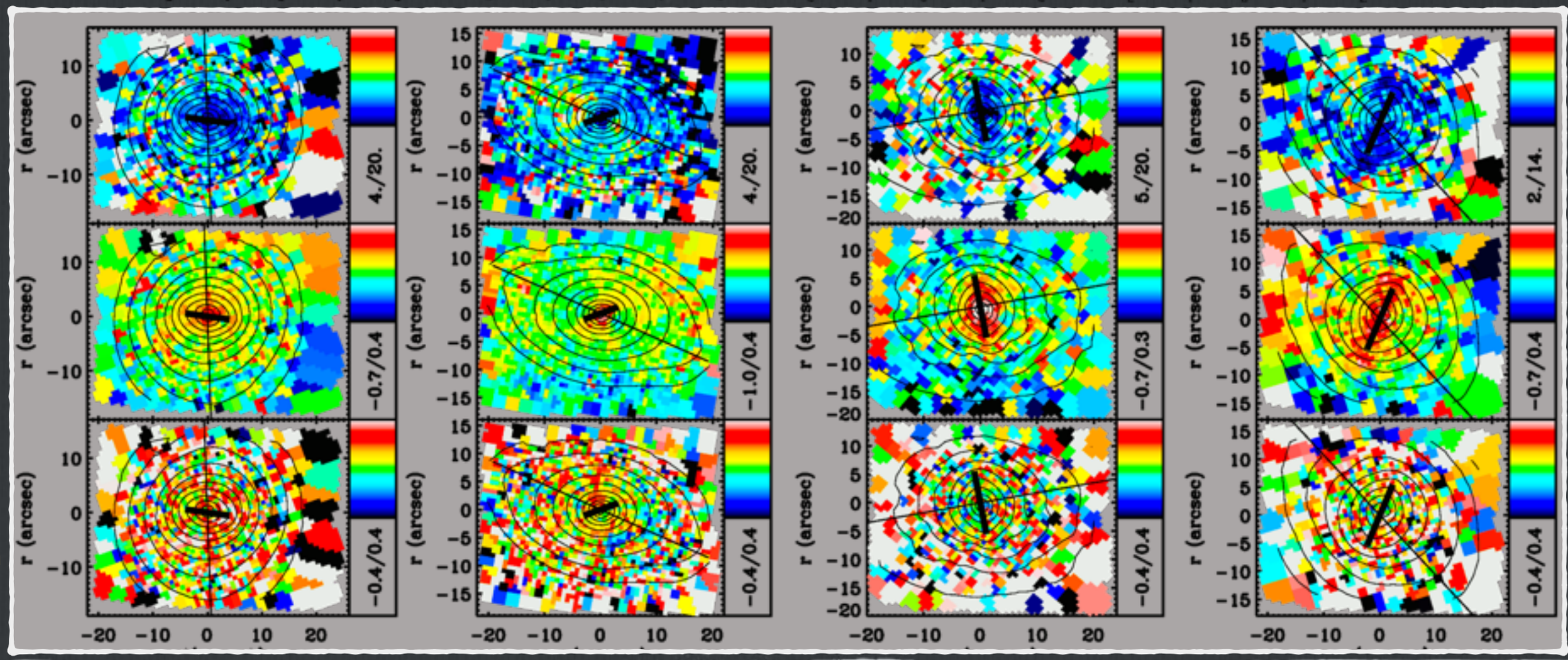


Any special effect on secular evolution due to the inner bar?

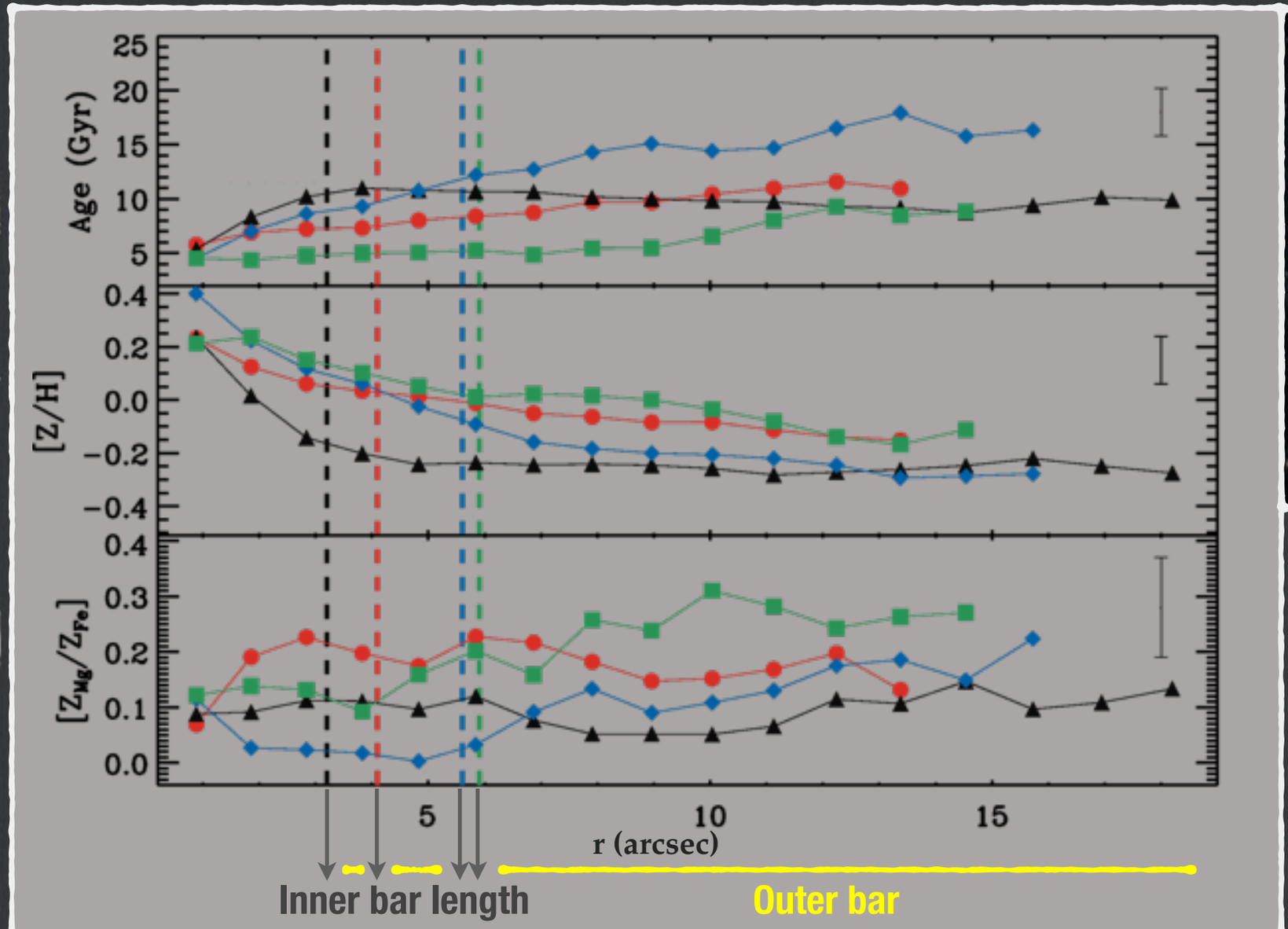
- ★No ongoing star formation
- ★No young structures

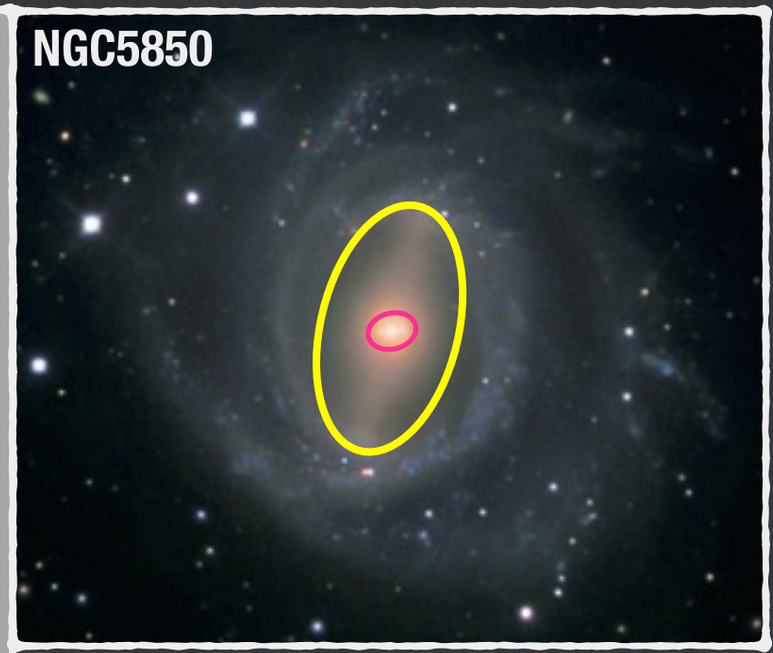
IBs are younger and more metal-rich than OBs





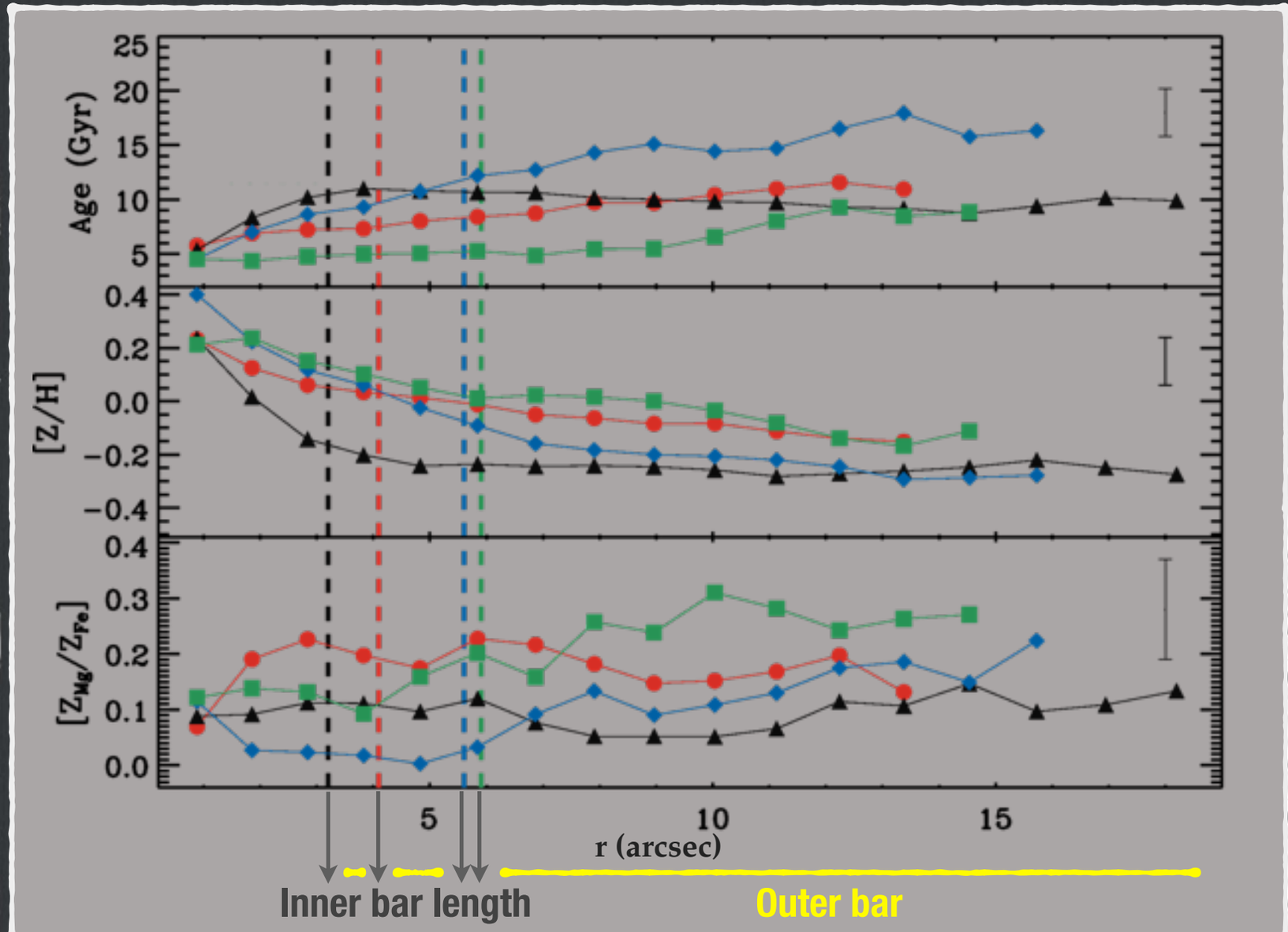
Positive age- and [α/Fe]-, negative [Z/H]-gradients

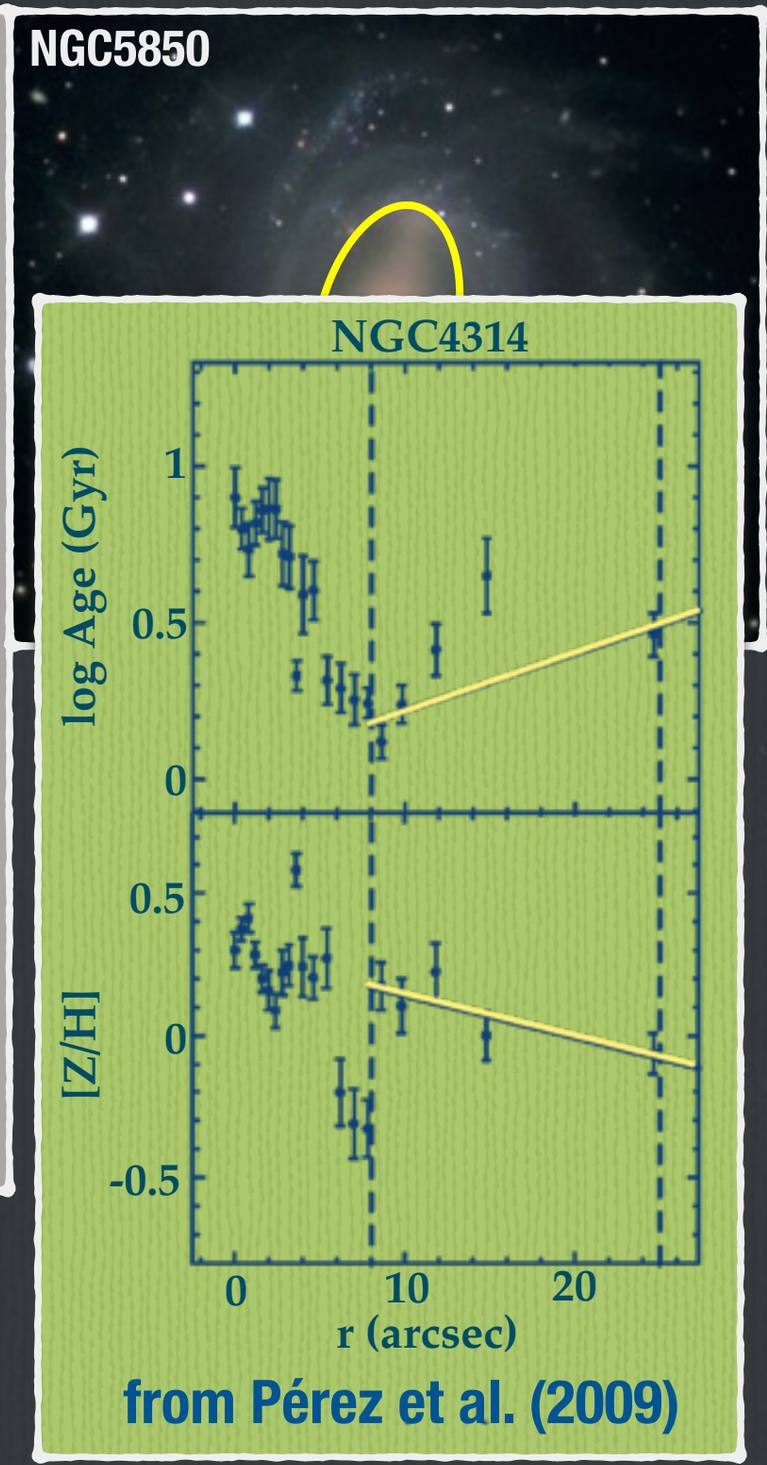




- ★ Inner bars are younger and more metal-rich than outer bars
- ★ No major differences between inner bars and bulges
- ★ Positive age gradients, negative [Z/H] gradients
- ★ Slightly lower [α/Fe] values for the very central regions

Positive age- and [α/Fe]-, negative [Z/H]-gradients





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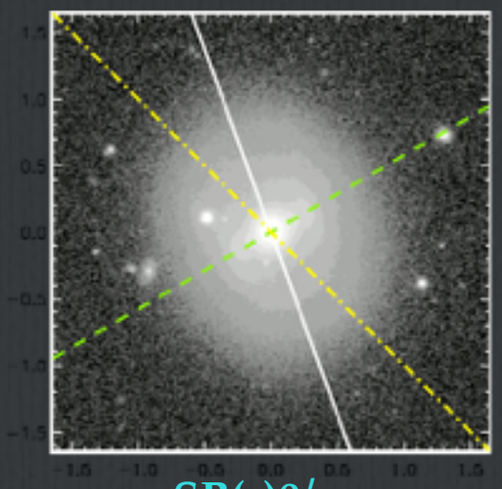
Results confirmed by long-slit data

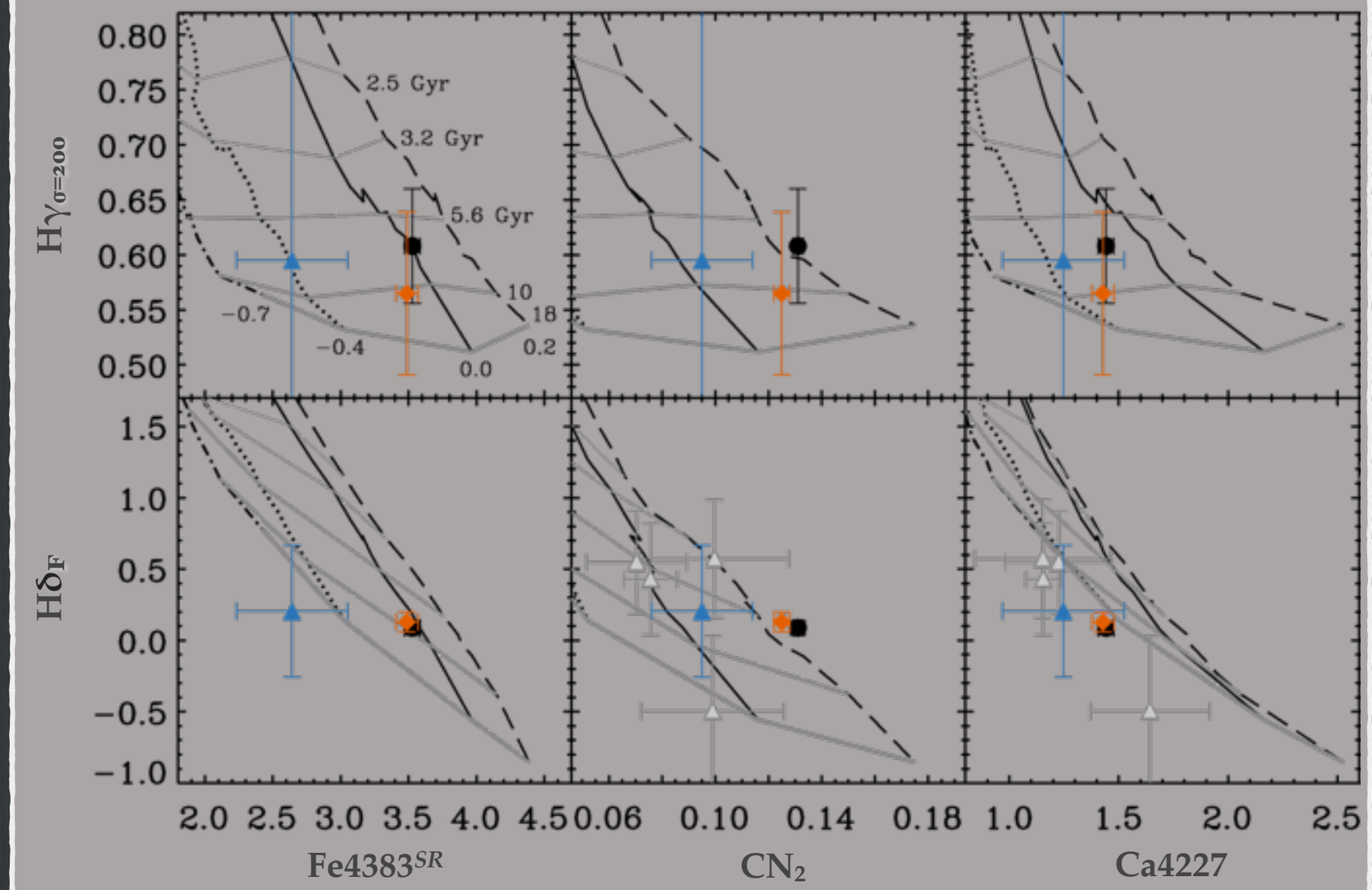
NGC357



SB(r)0/a

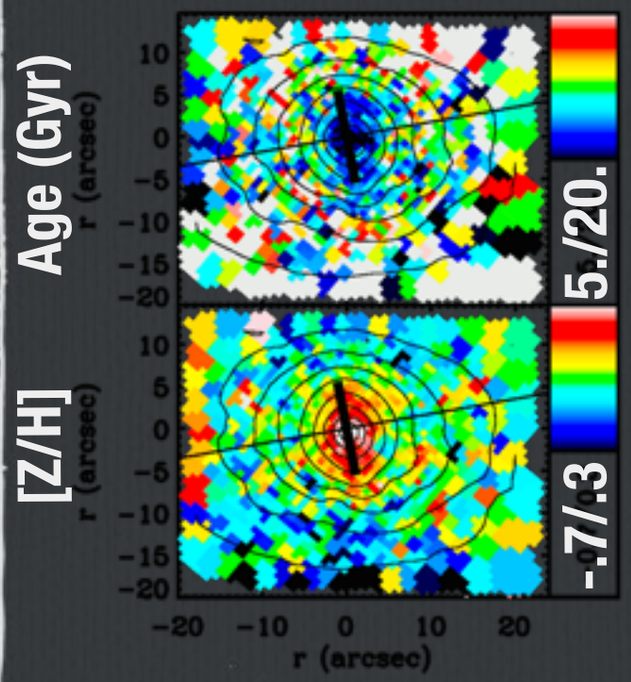
- Bulge
- Inner bar
- Outer bar
- Barred sample from Pérez et al. (2009)

SSP models from Vazdekis et al. (2010)



- ★ Inner regions are more metal-rich than the outer bar
- ★ No major differences between inner bar and bulge
- ★ Outer bar values in agreement with a comparison sample of inner bars
- ★ Lower [α/Fe] values for the inner regions

Summary, interpretation, and next steps



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- ★ Positive age gradients, negative [Z/H] gradients outwards
- ★ Slightly lower [α/Fe] values for the very central regions
- ★ No absolutely young structures

Interpretation:

- ★ Inner bar formed after the outer bar, probably in a gas-rich process (secular evolution)

  e.g., Rautiainen et al. (2002), Heller et al. (2007)
- ★ The secular evolution process due to the inner bar is mild

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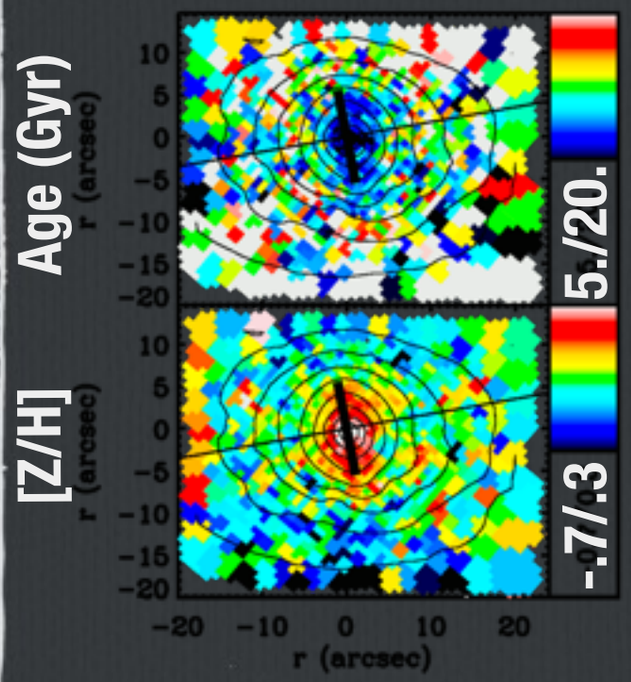

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To know more:

- ★ Link with the kinematics (classical vs. disc-like bulges):
  de Lorenzo-Cáceres et al. (2012, 2013)
- ★ Link with the photometry: de Lorenzo-Cáceres et al. (2015b)
- ★ Star formation histories: STECKMAP (Ocvirk et al. 2006), VESPA (Tojeiro et al. 2007), and STARLIGHT (Cid-Fernandes et al. 2005): de Lorenzo-Cáceres et al. (2015a)

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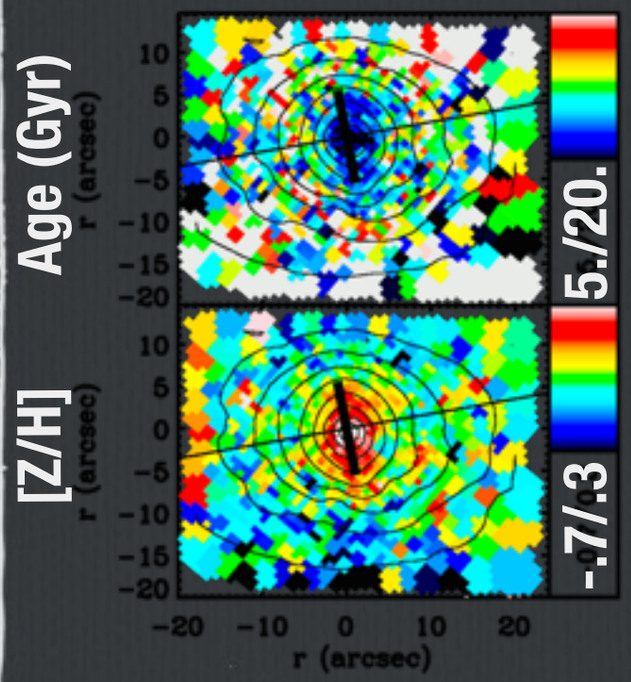

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Thank you… and stay tuned!!!

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