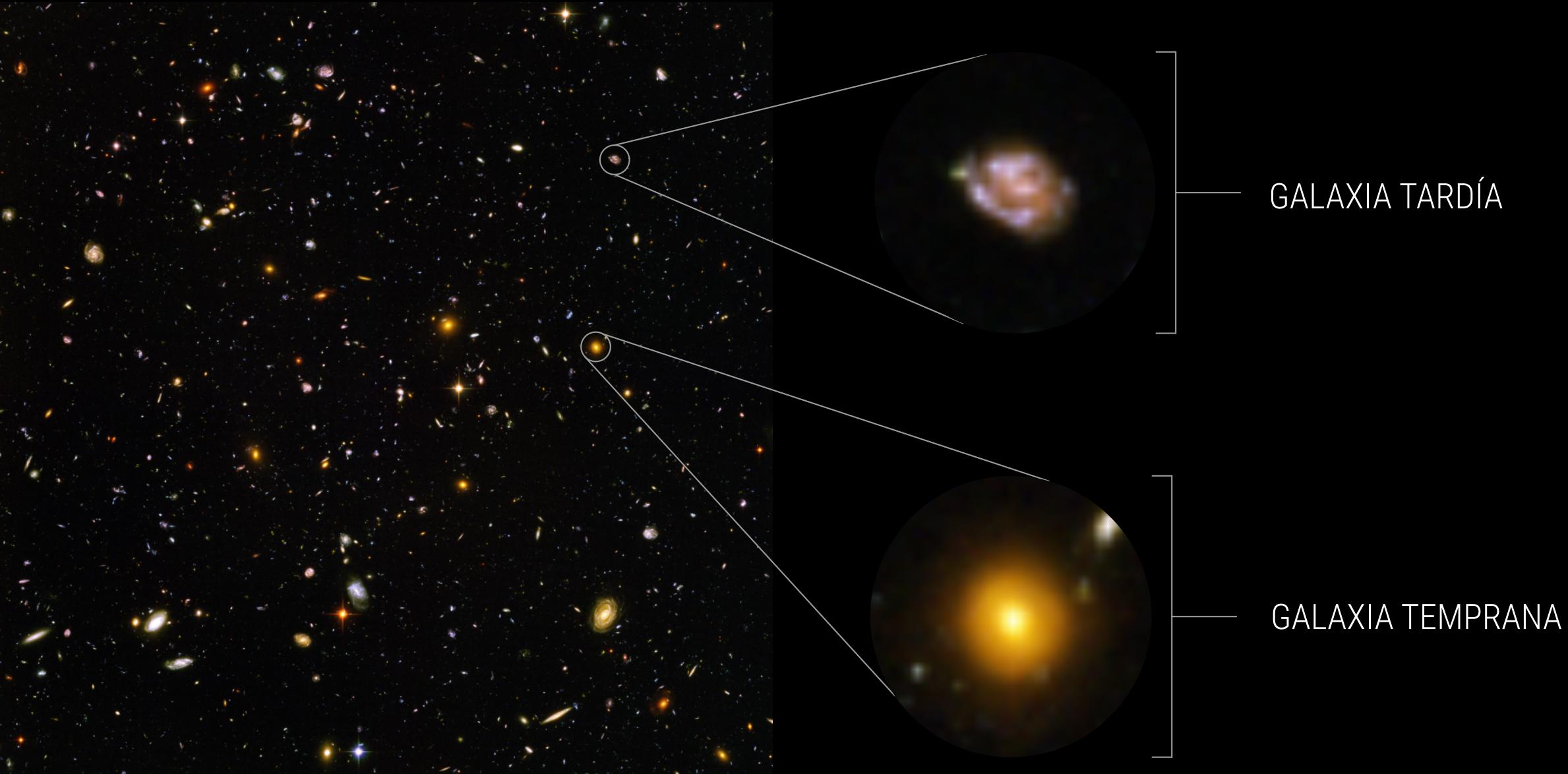


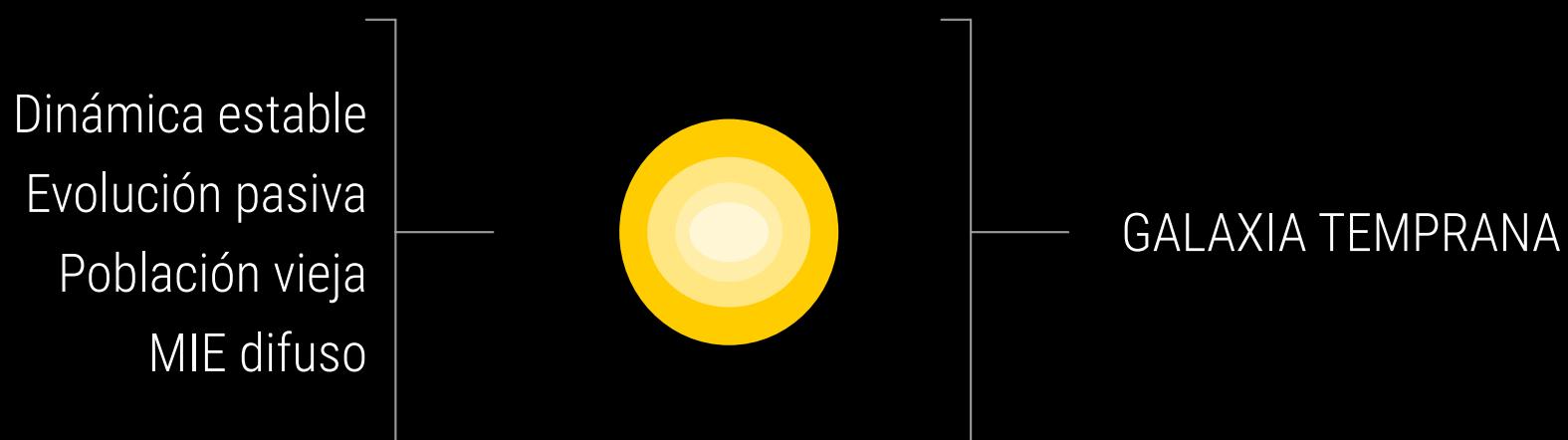
EL CICLO DE MASA BARIÓNICA EN LAS GALAXIAS

Por
Alfredo J. Mejía

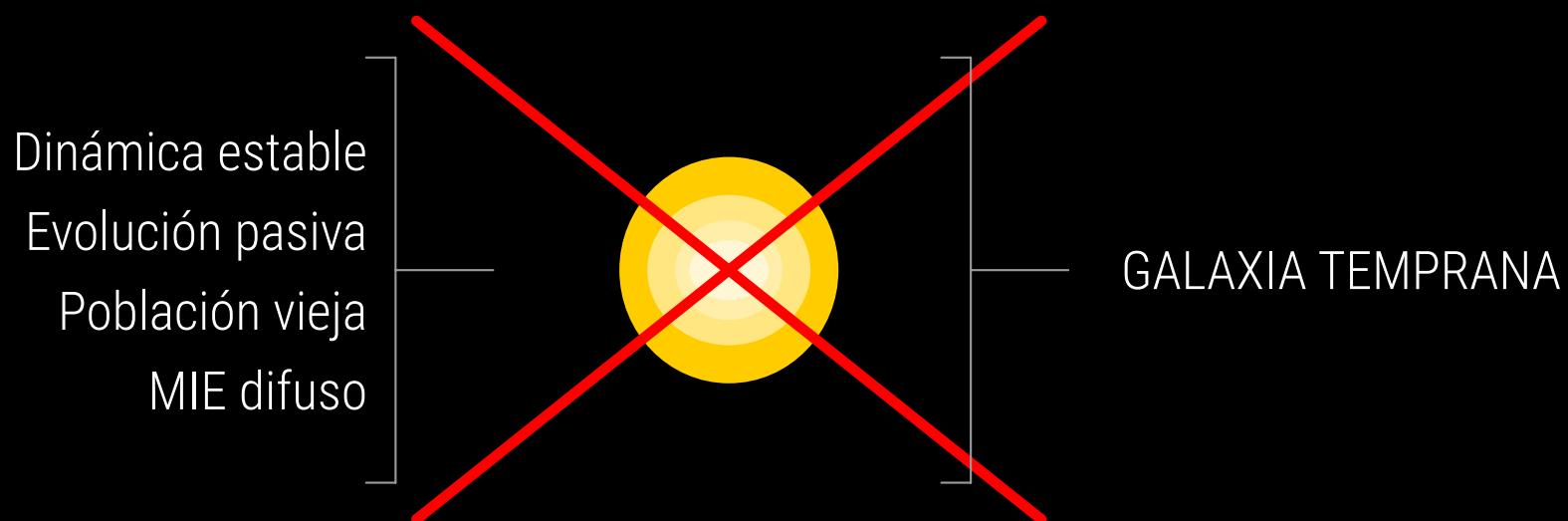
MOTIVACIÓN



MOTIVACIÓN



MOTIVACIÓN



MOTIVACIÓN

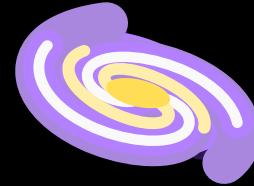
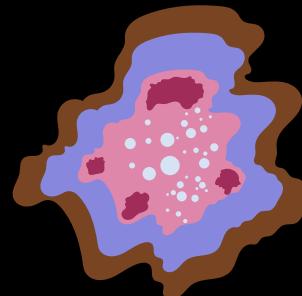
Dinámica inestable
Formación estelar
Población mixta
MIE multi-fase



GALAXIA TARDÍA

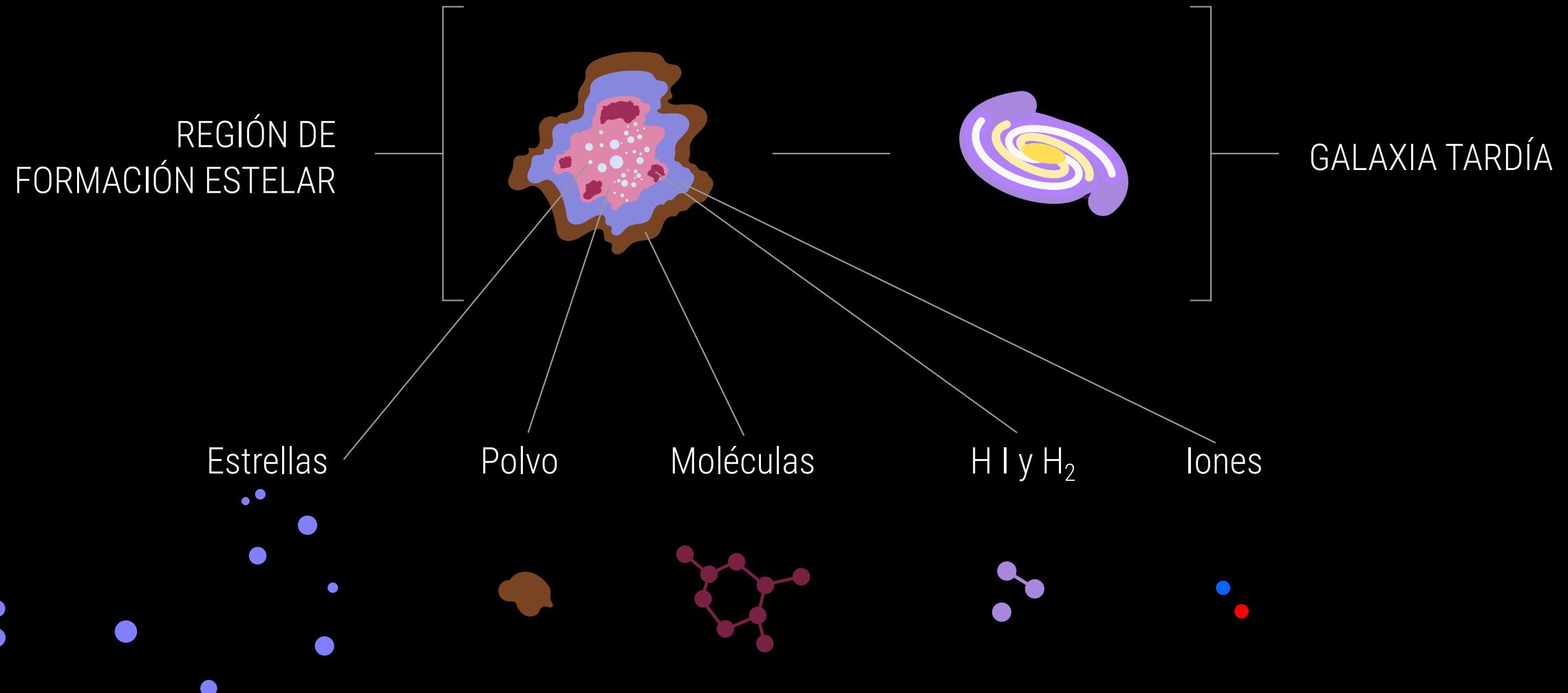
MOTIVACIÓN

REGIÓN DE
FORMACIÓN ESTELAR

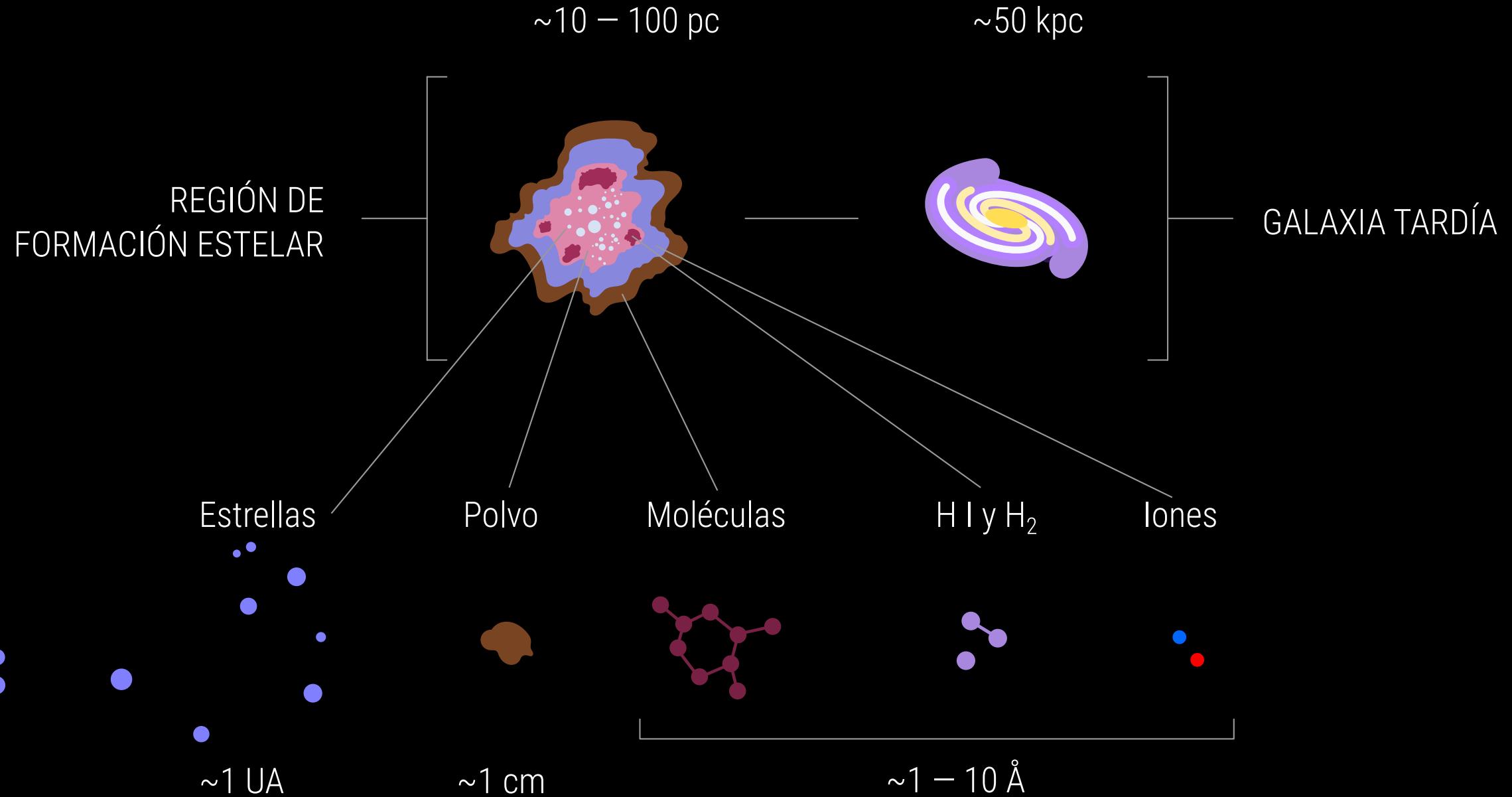


GALAXIA TARDÍA

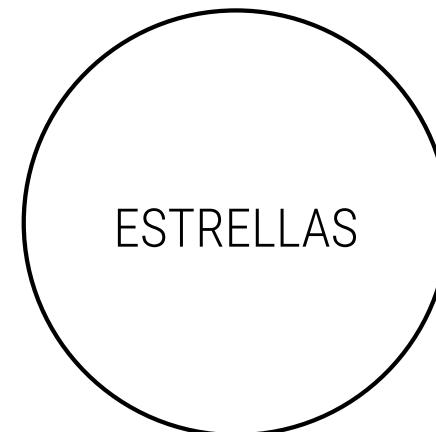
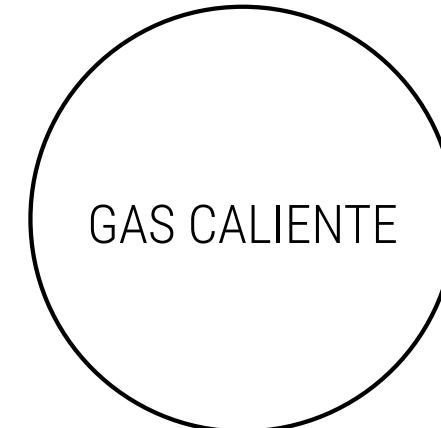
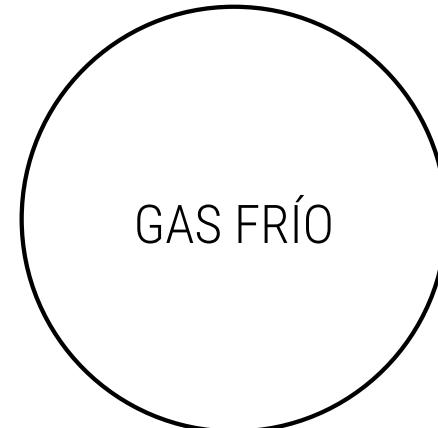
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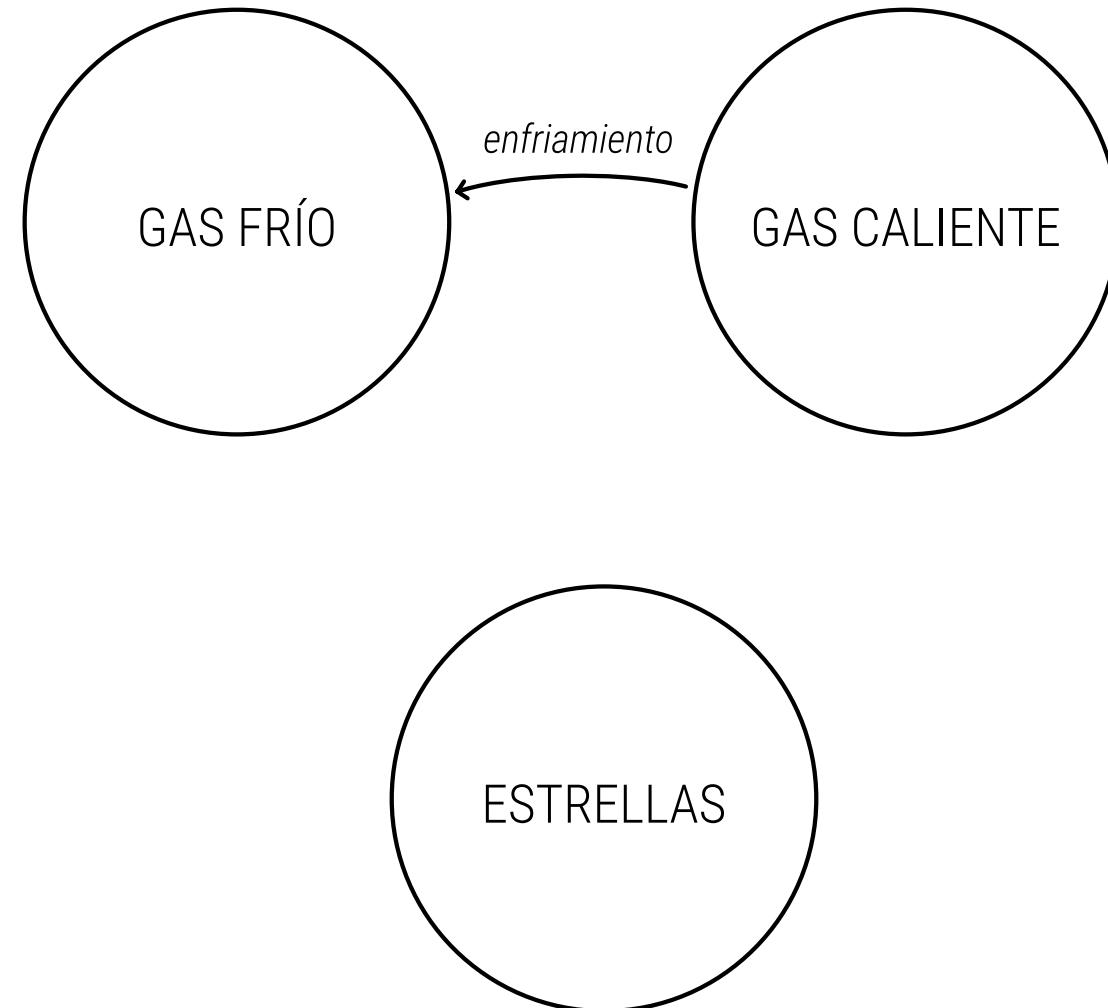
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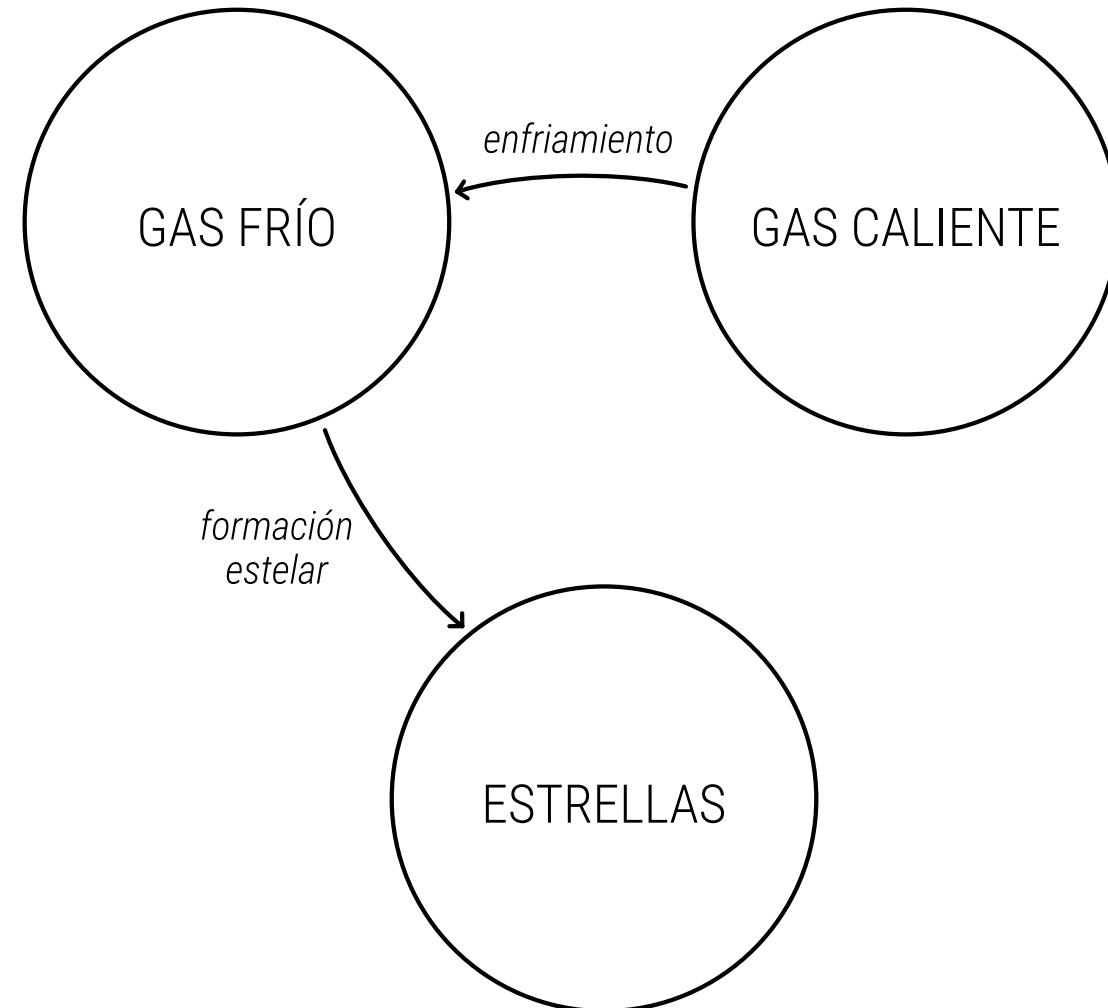
CONSIDERACIONES TEÓRICAS



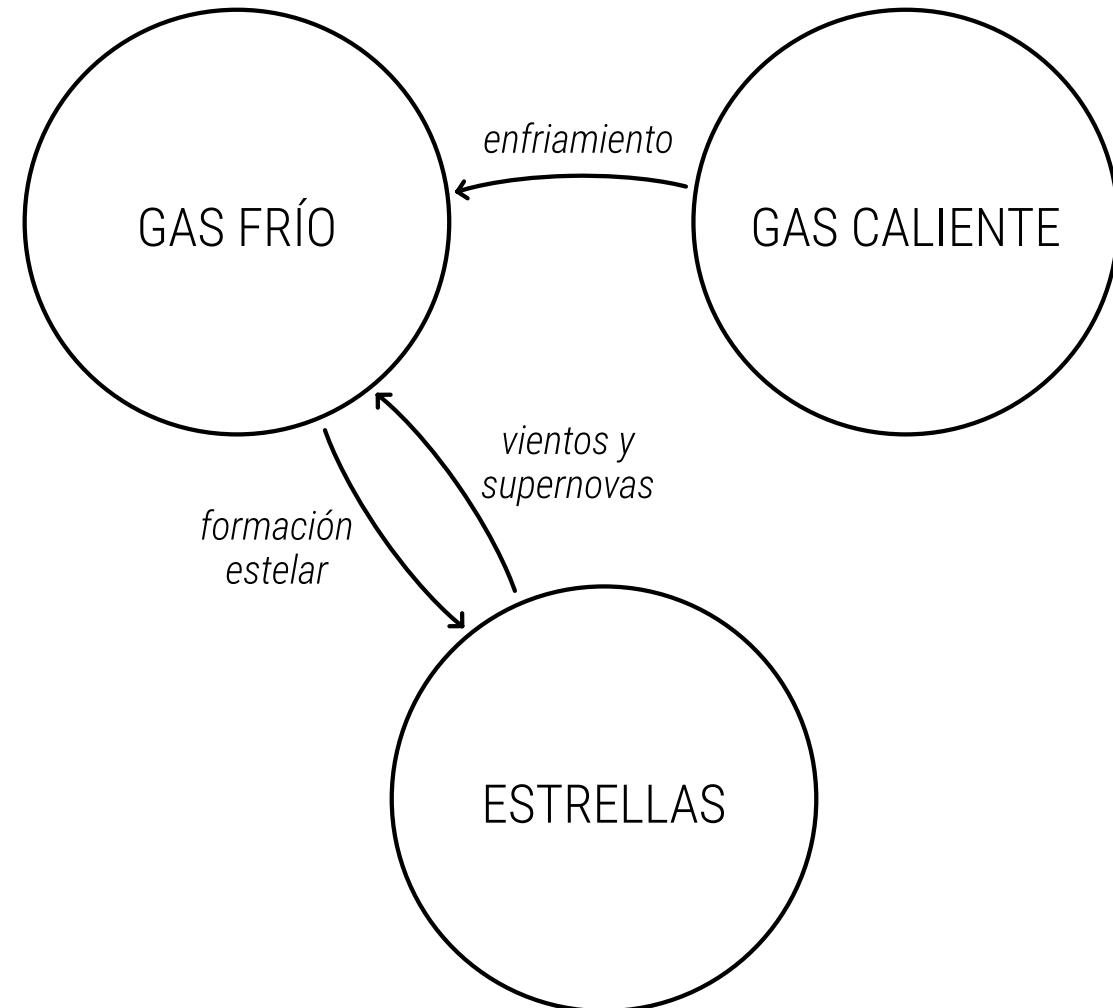
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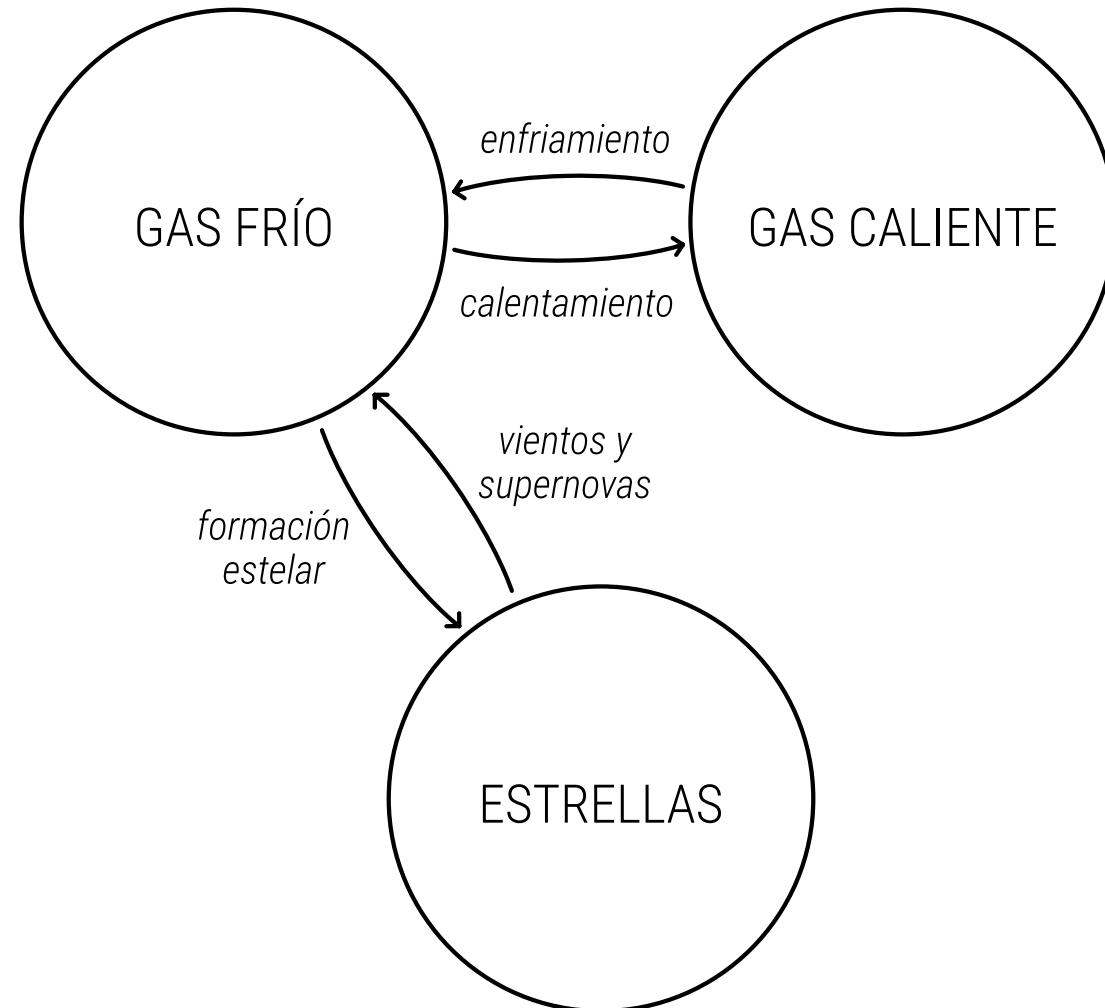
CONSIDERACIONES TEÓRICAS



CONSIDERACIONES TEÓRICAS



CONSIDERACIONES TEÓRICAS



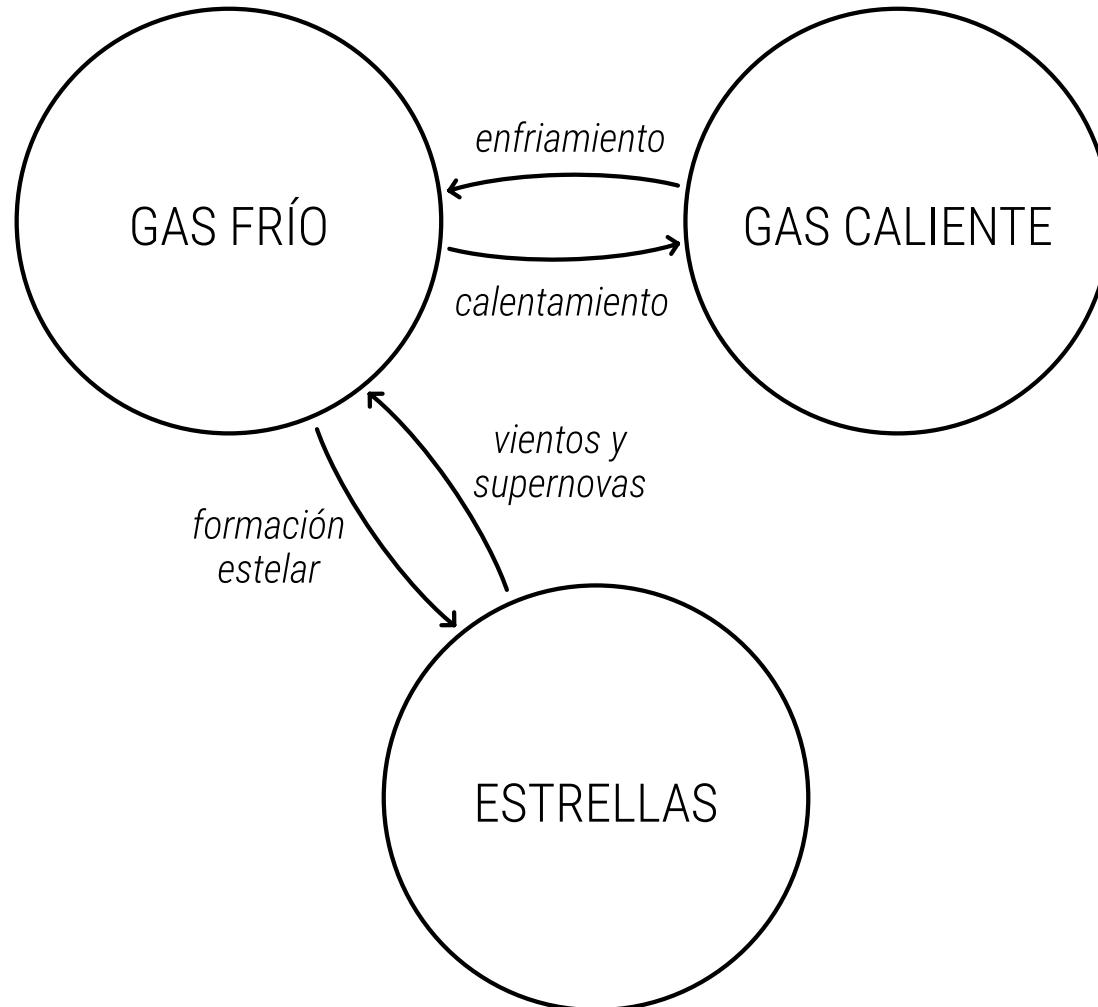
CONSIDERACIONES TEÓRICAS

Escalas temporales:

$$\tau_{\text{enf}} \propto 1/\Lambda(\rho_{\text{cal}}, T_{\text{cal}}, Z_{\text{cal}})$$

$$\tau_{\text{din}} \propto M_{\text{frio}}/\Psi$$

$$\tau_* \propto 1/F(m_*, Z_*)$$



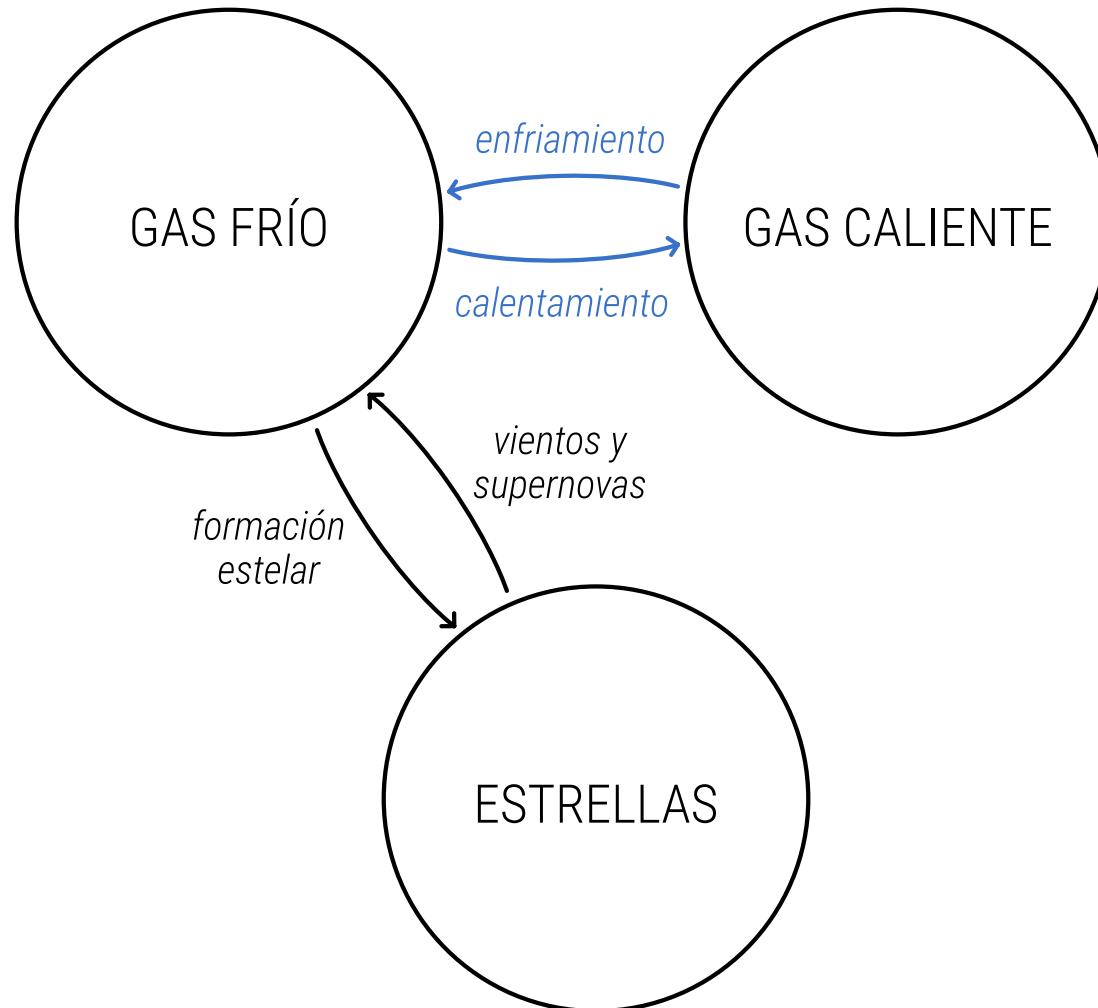
CONSIDERACIONES TEÓRICAS

Escalas temporales:

$$\tau_{\text{enf}} \propto 1/\Lambda(\rho_{\text{cal}}, T_{\text{cal}}, Z_{\text{cal}})$$

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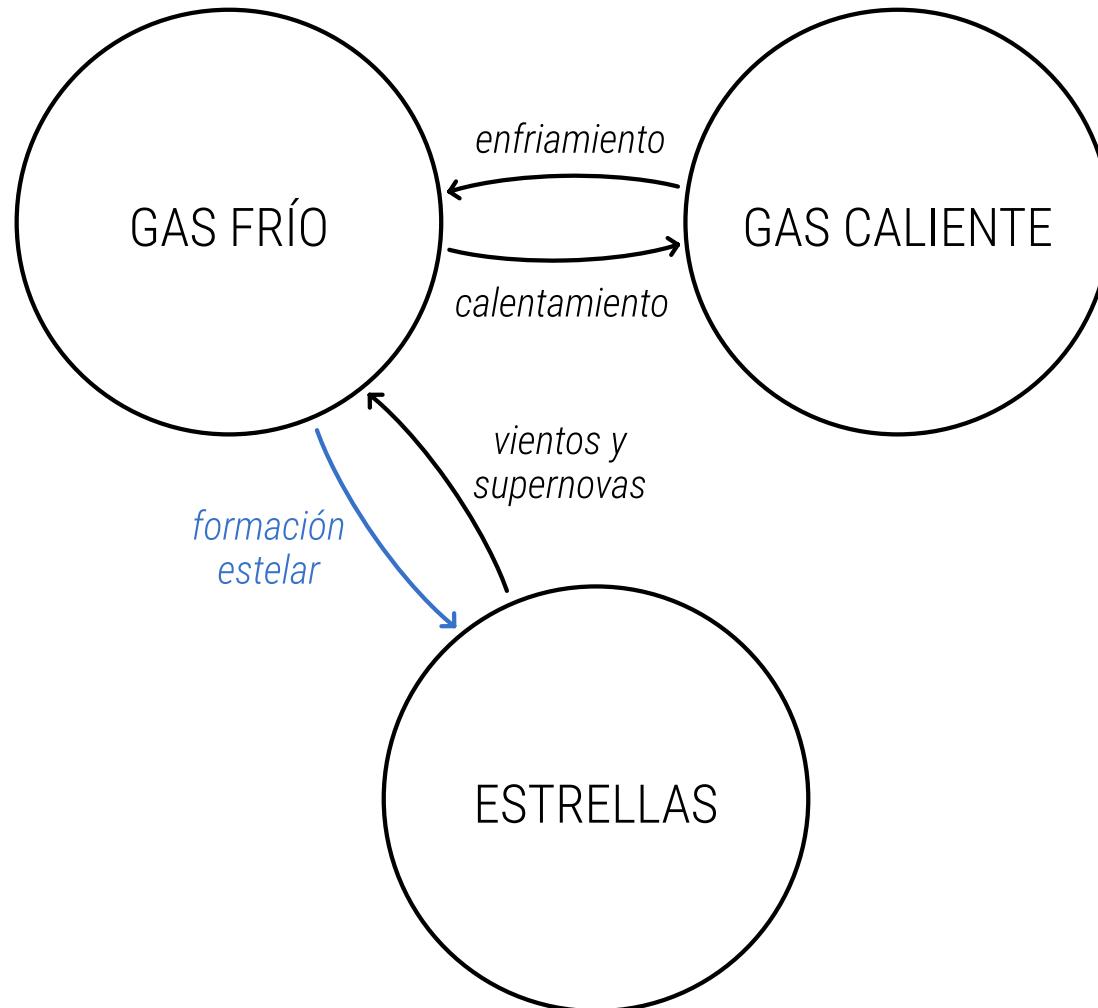
CONSIDERACIONES TEÓRICAS

Escalas temporales:

$$\tau_{\text{enf}} \propto 1/\Lambda(\rho_{\text{cal}}, T_{\text{cal}}, Z_{\text{cal}})$$

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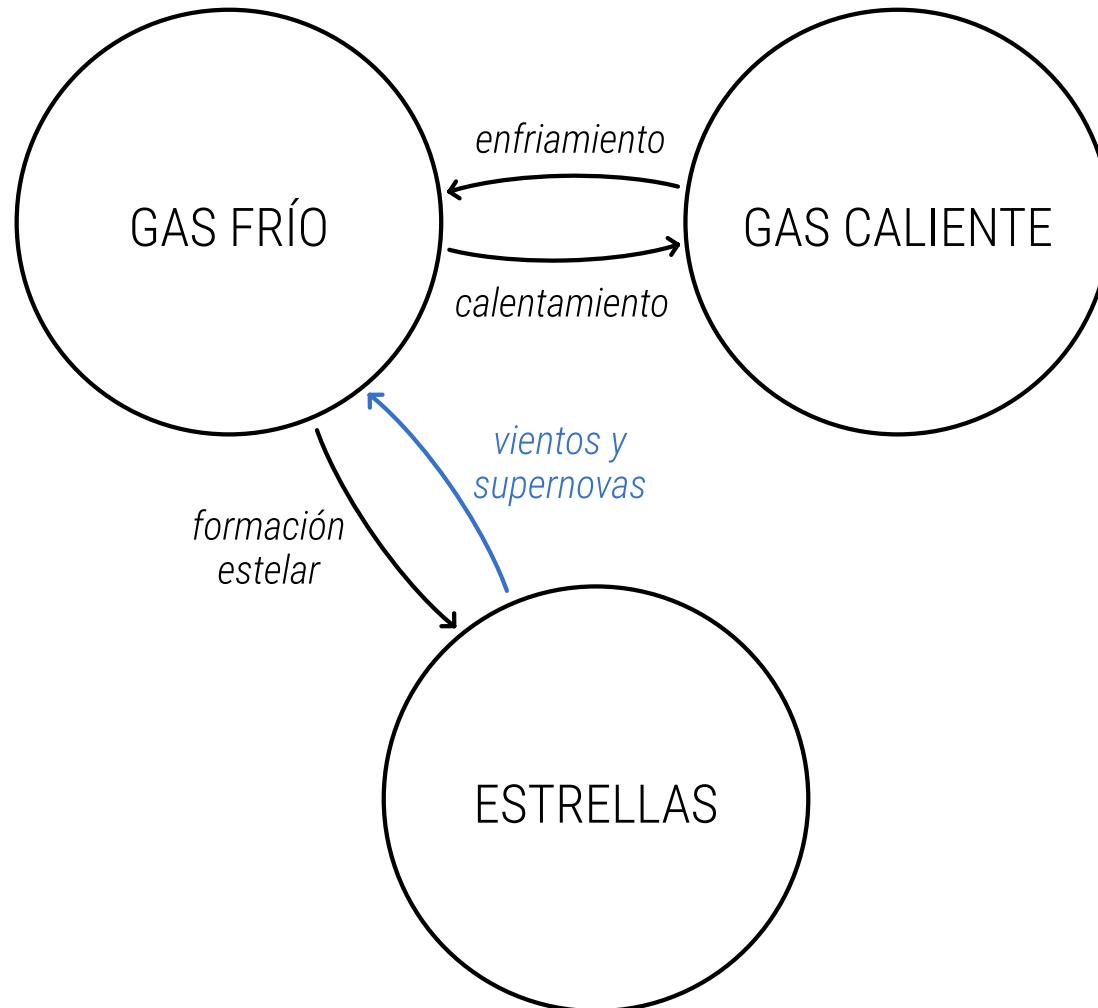
CONSIDERACIONES TEÓRICAS

Escalas temporales:

$$\tau_{\text{enf}} \propto 1/\Lambda(\rho_{\text{cal}}, T_{\text{cal}}, Z_{\text{cal}})$$

$$\tau_{\text{din}} \propto M_{\text{frio}}/\Psi$$

$$\tau_* \propto 1/F(m_*, Z_*)$$



CONSIDERACIONES TEÓRICAS

$$\dot{M}_{\text{frio}} = \dot{M}_{\text{enf}} - (1 - R - \beta)\Psi$$

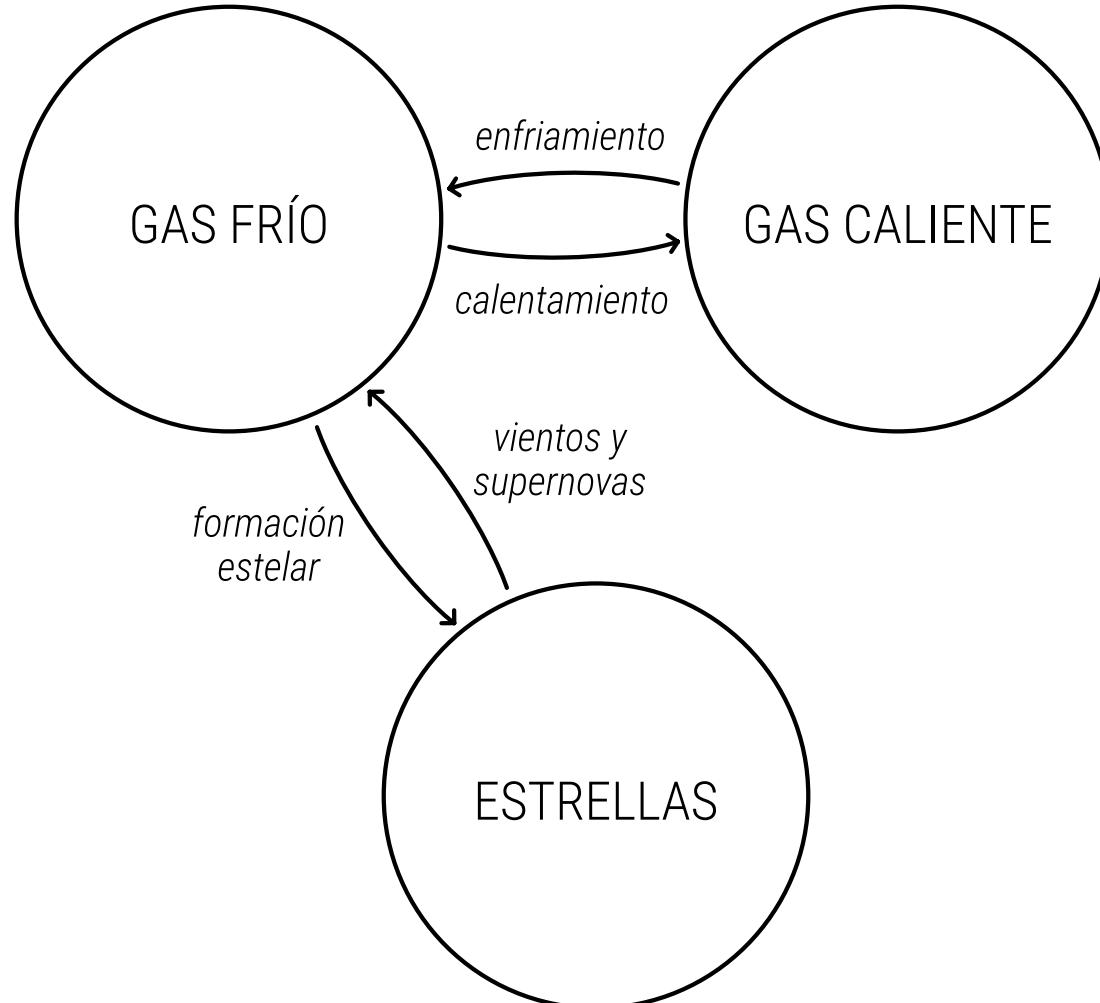
$$\dot{M}_{\text{cal}} = -\dot{M}_{\text{enf}} + \beta\Psi$$

Escalas temporales:

$$\tau_{\text{enf}} \propto 1/\Lambda(\rho_{\text{cal}}, T_{\text{cal}}, Z_{\text{cal}})$$

$$\tau_{\text{din}} \propto M_{\text{frio}}/\Psi$$

$$\tau_* \propto 1/F(m_*, Z_*)$$



$$\dot{M}_* = (1 - R)\Psi$$

CONSIDERACIONES TEÓRICAS

$$\dot{M}_{\text{frio}} = \dot{M}_{\text{enf}} - (1 - R - \beta)\Psi$$

$$\dot{M}_{\text{cal}} = -\dot{M}_{\text{enf}} + \beta\Psi$$

Escalas temporales:

$$\tau_{\text{enf}} \propto 1/\Lambda(\rho_{\text{cal}}, T_{\text{cal}}, Z_{\text{cal}})$$

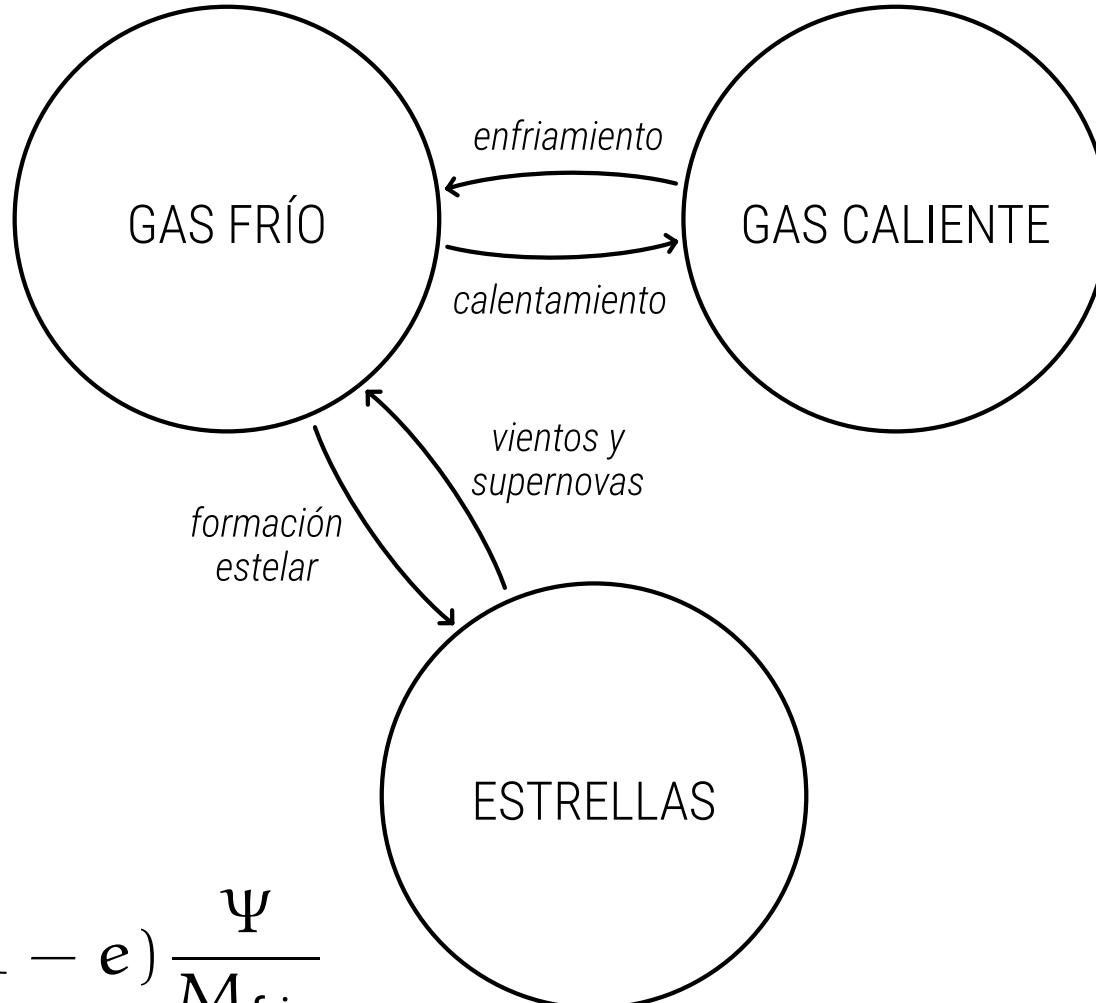
$$\tau_{\text{din}} \propto M_{\text{frio}}/\Psi$$

$$\tau_* \propto 1/F(m_*, Z_*)$$

Evolución química:

$$\dot{Z}_* = (1 - R) \frac{\Psi}{M_*} (Z_{\text{frio}} - Z_*)$$

$$\dot{Z}_{\text{frio}} = (Z_{\text{cal}} - Z_{\text{frio}}) \frac{\dot{M}_{\text{enf}}}{\dot{M}_{\text{frio}}} + p(1 - e) \frac{\Psi}{\dot{M}_{\text{frio}}}$$



$$\dot{M}_* = (1 - R)\Psi$$

CONSIDERACIONES TEÓRICAS

$$\dot{M}_{\text{frio}} = \dot{M}_{\text{enf}} - (1 - R - \beta)\Psi$$

$$\dot{M}_{\text{cal}} = -\dot{M}_{\text{enf}} + \beta\Psi$$

Escalas temporales:

$$\tau_{\text{enf}} \propto 1/\Lambda(\rho_{\text{cal}}, T_{\text{cal}}, Z_{\text{cal}})$$

$$\tau_{\text{din}} \propto M_{\text{frio}}/\Psi$$

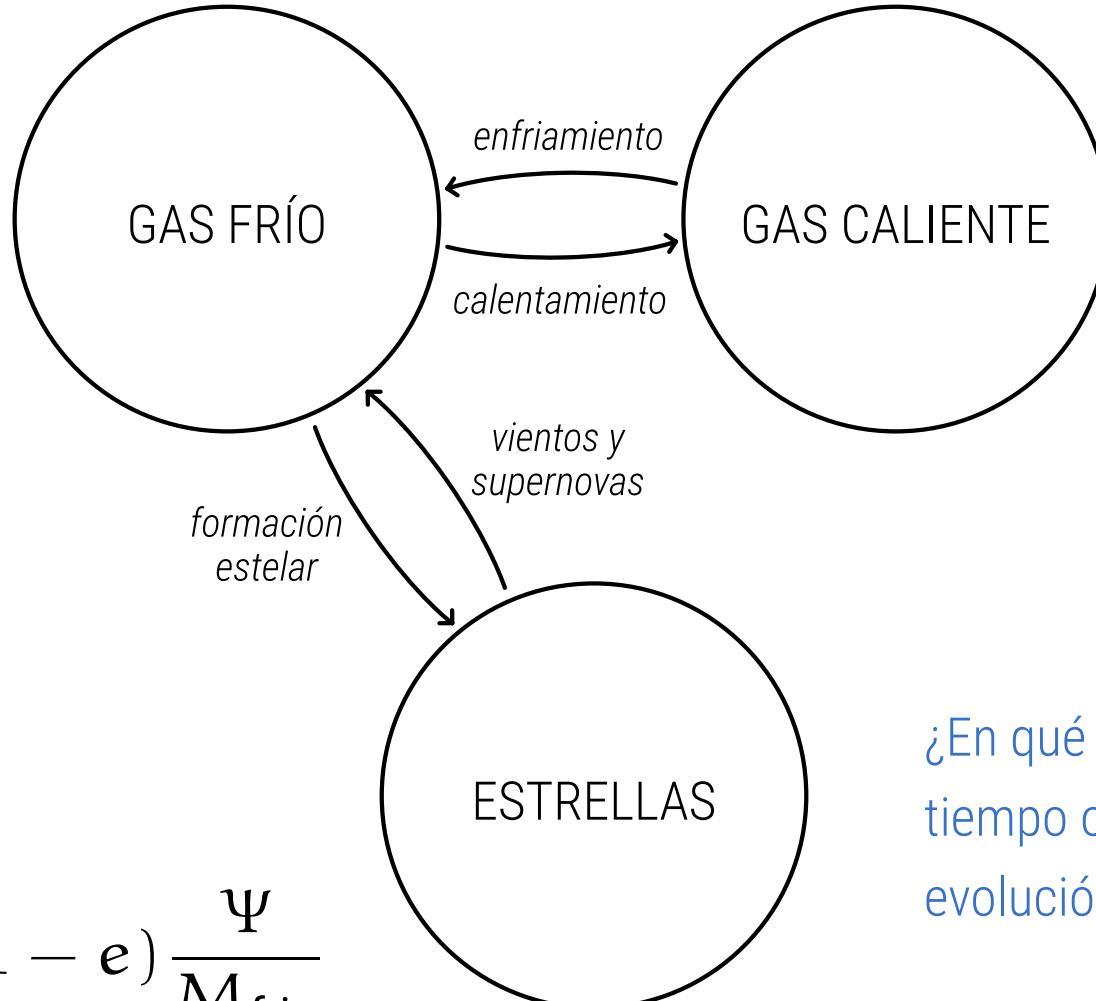
$$\tau_* \propto 1/F(m_*, Z_*)$$

Evolución química:

$$\dot{Z}_* = (1 - R) \frac{\Psi}{M_*} (Z_{\text{frio}} - Z_*)$$

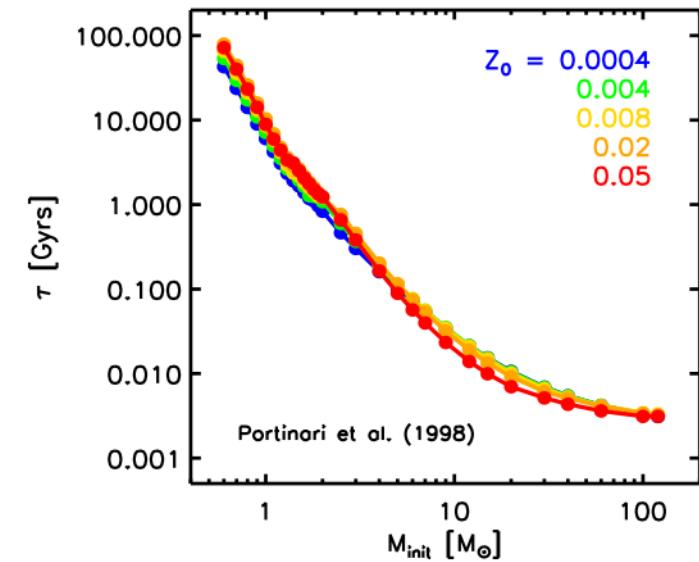
$$\dot{Z}_{\text{frio}} = (Z_{\text{cal}} - Z_{\text{frio}}) \frac{\dot{M}_{\text{enf}}}{\dot{M}_{\text{frio}}} + p(1 - e) \frac{\Psi}{\dot{M}_{\text{frio}}}$$

$$\dot{M}_* = (1 - R)\Psi$$

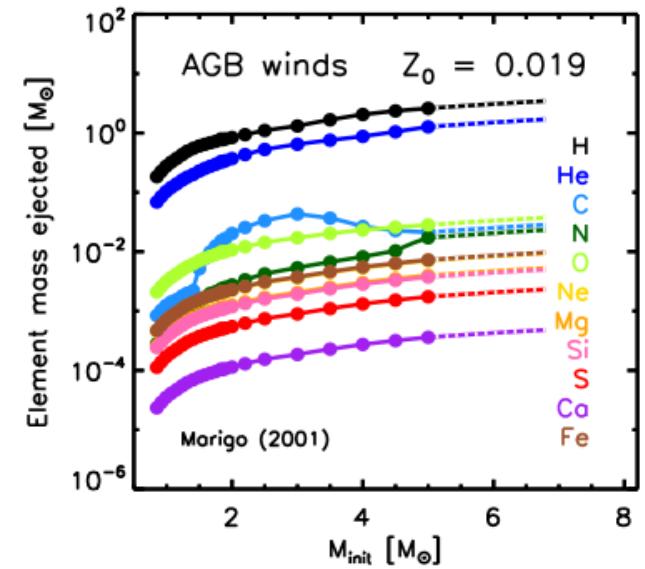
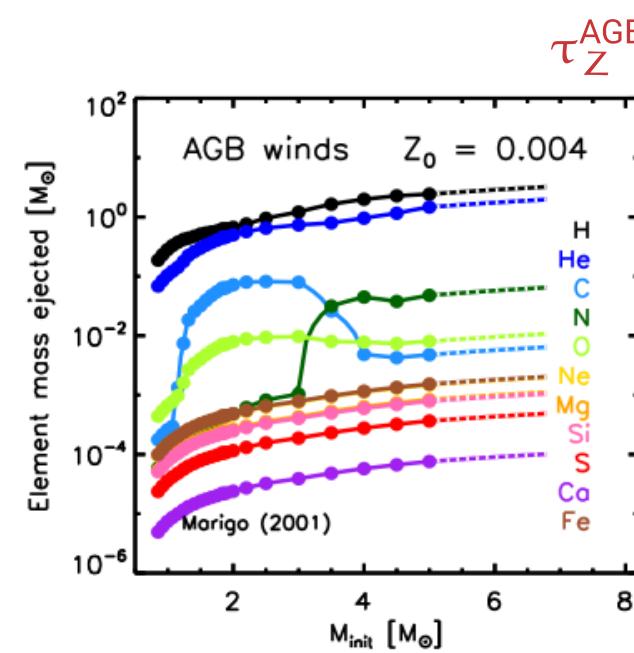
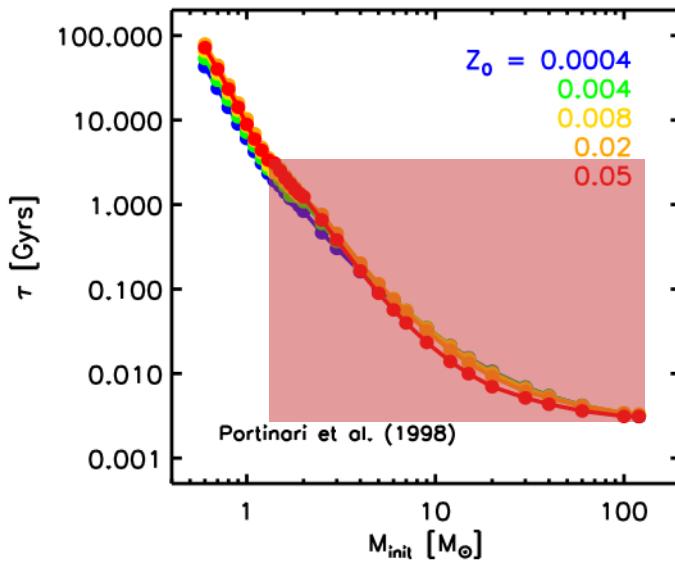


¿En qué escala de tiempo ocurre la evolución química?

CONSIDERACIONES TEÓRICAS

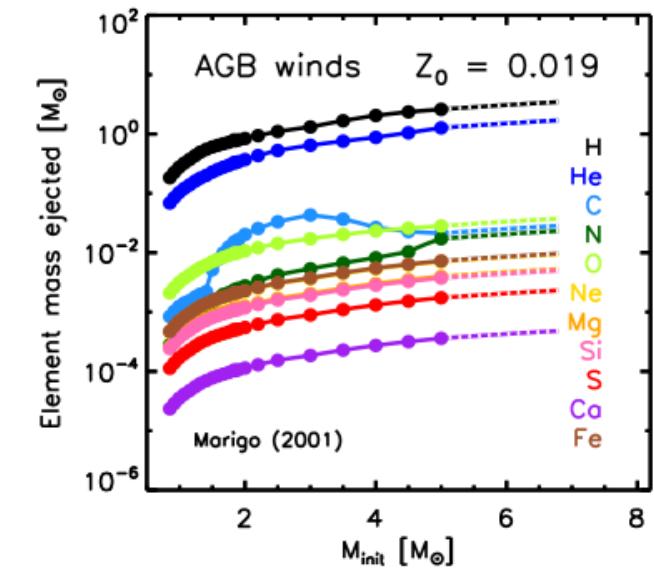
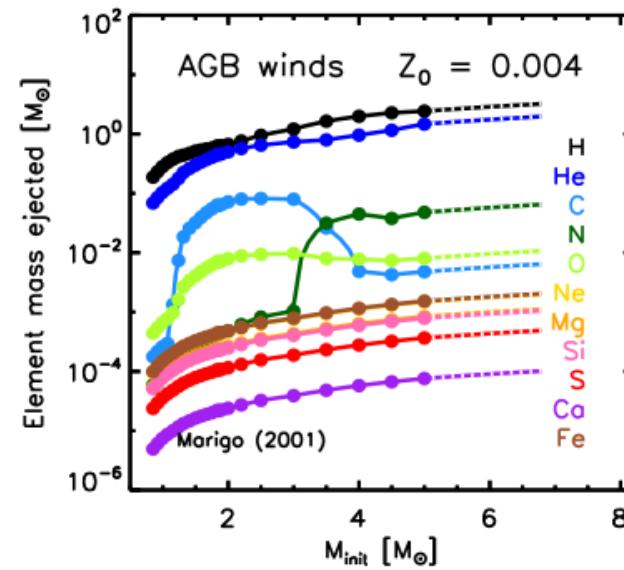
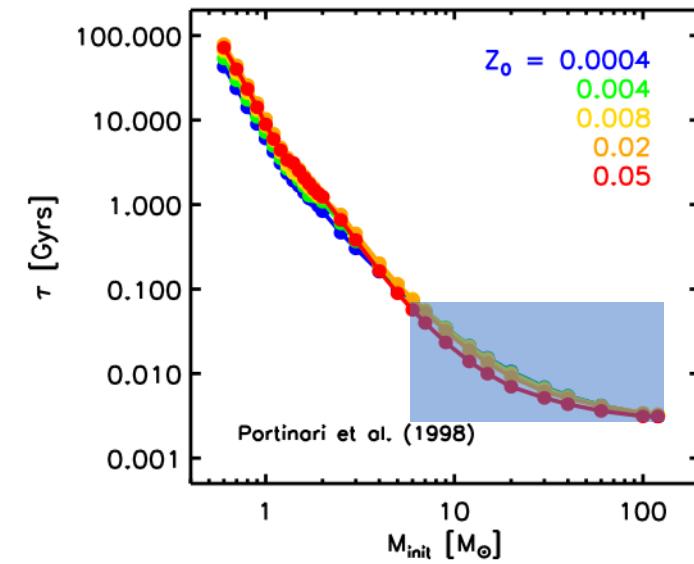


CONSIDERACIONES TEÓRICAS

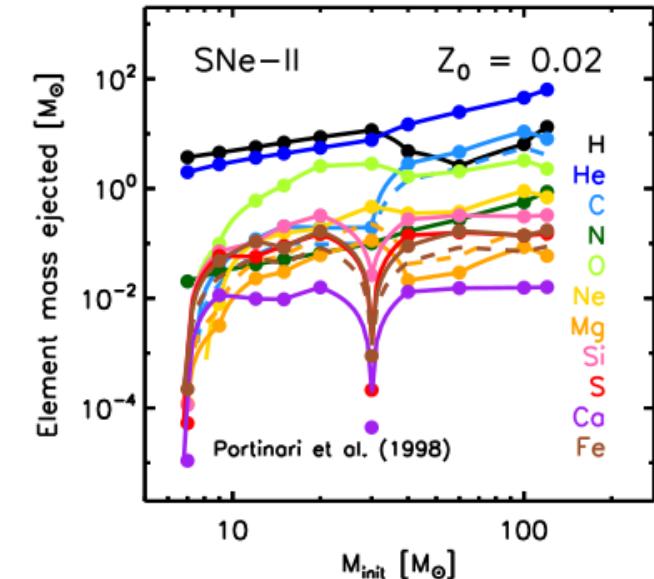
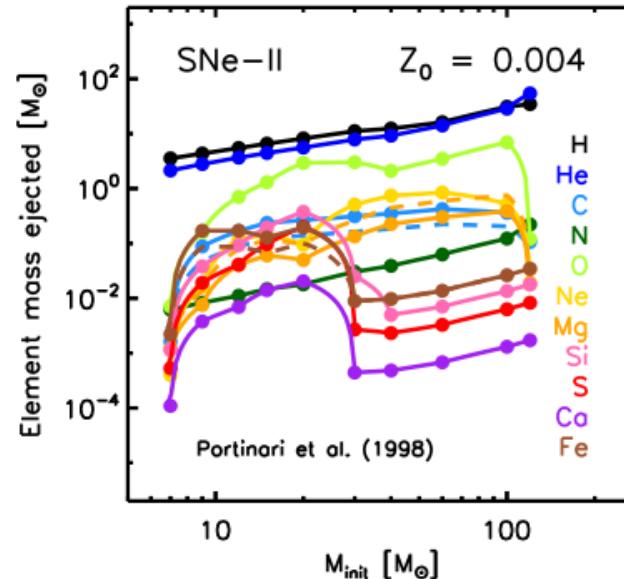


CONSIDERACIONES TEÓRICAS

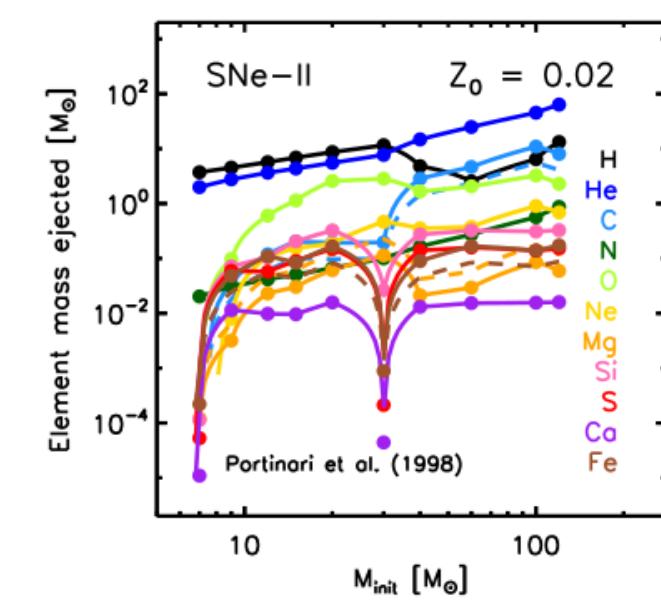
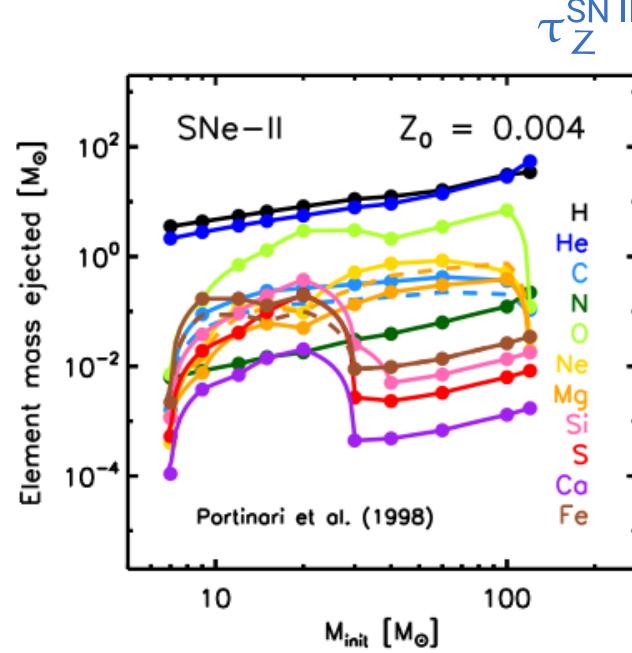
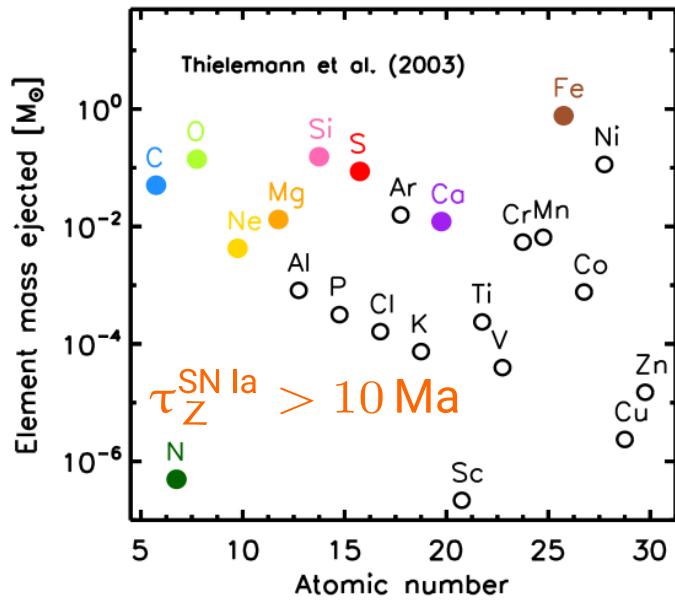
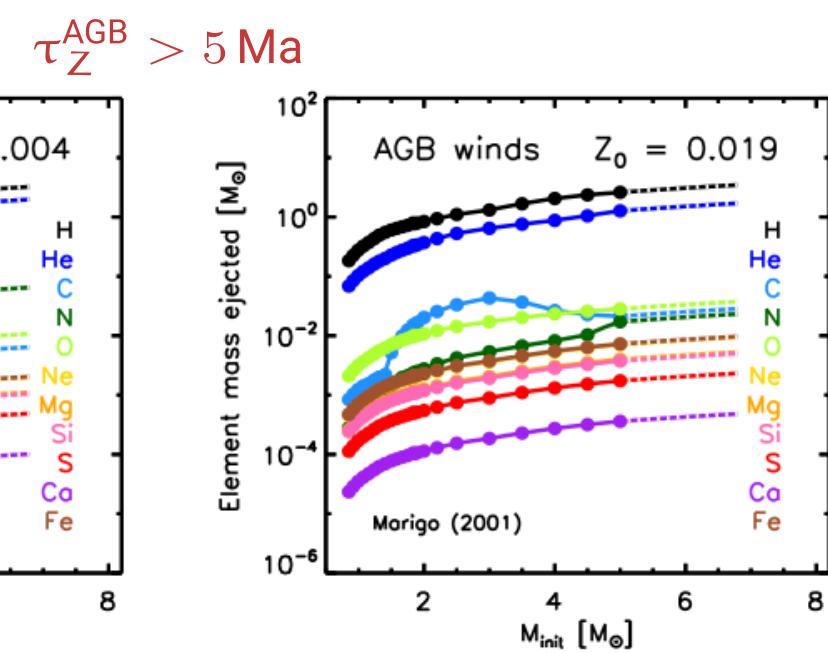
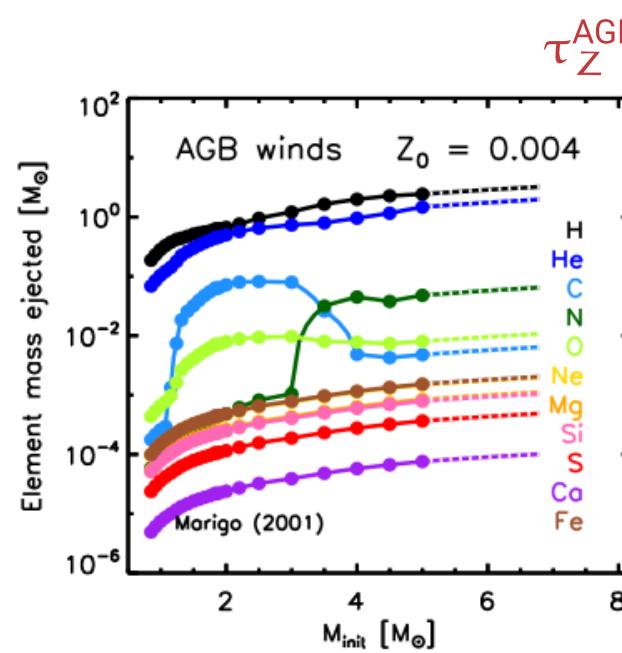
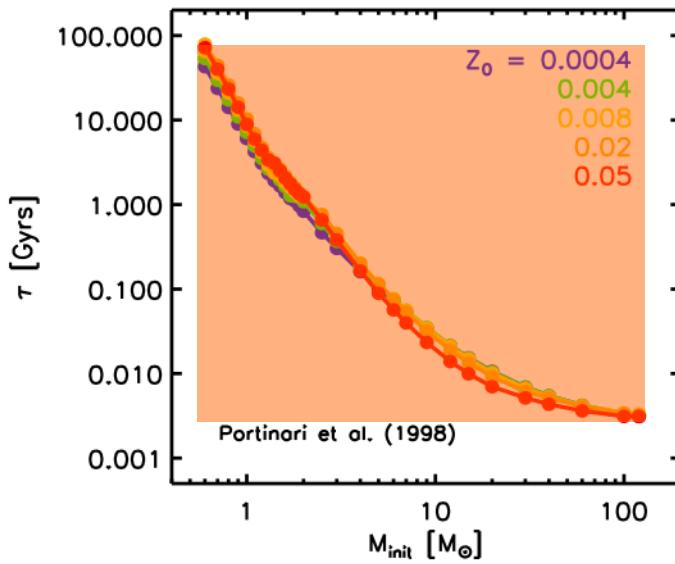
$\tau_Z^{\text{AGB}} > 5 \text{ Ma}$



$\tau_Z^{\text{SN II}} < 10 \text{ Ma}$



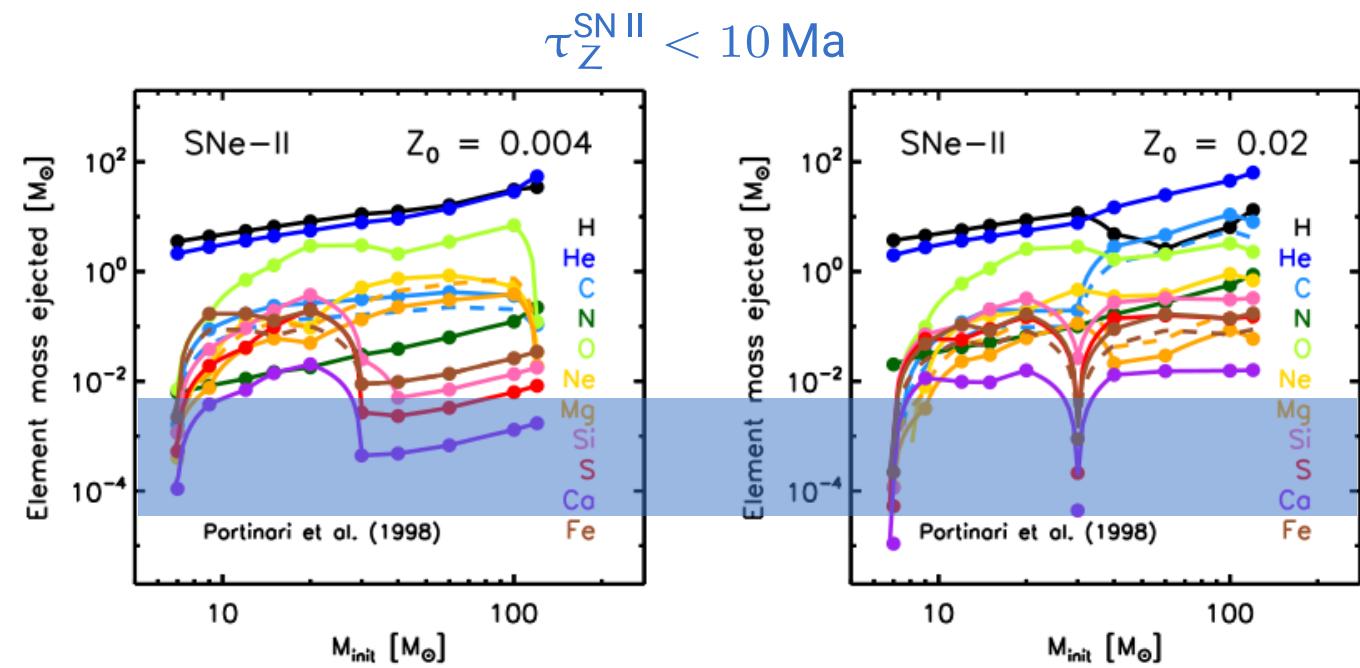
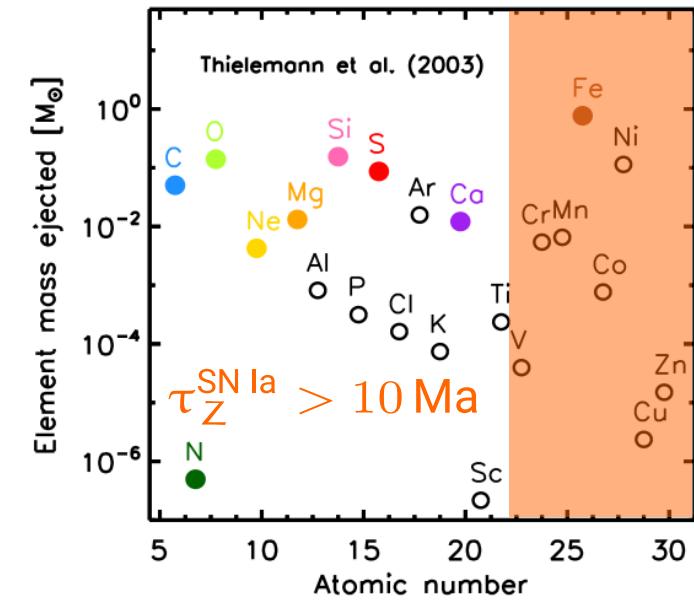
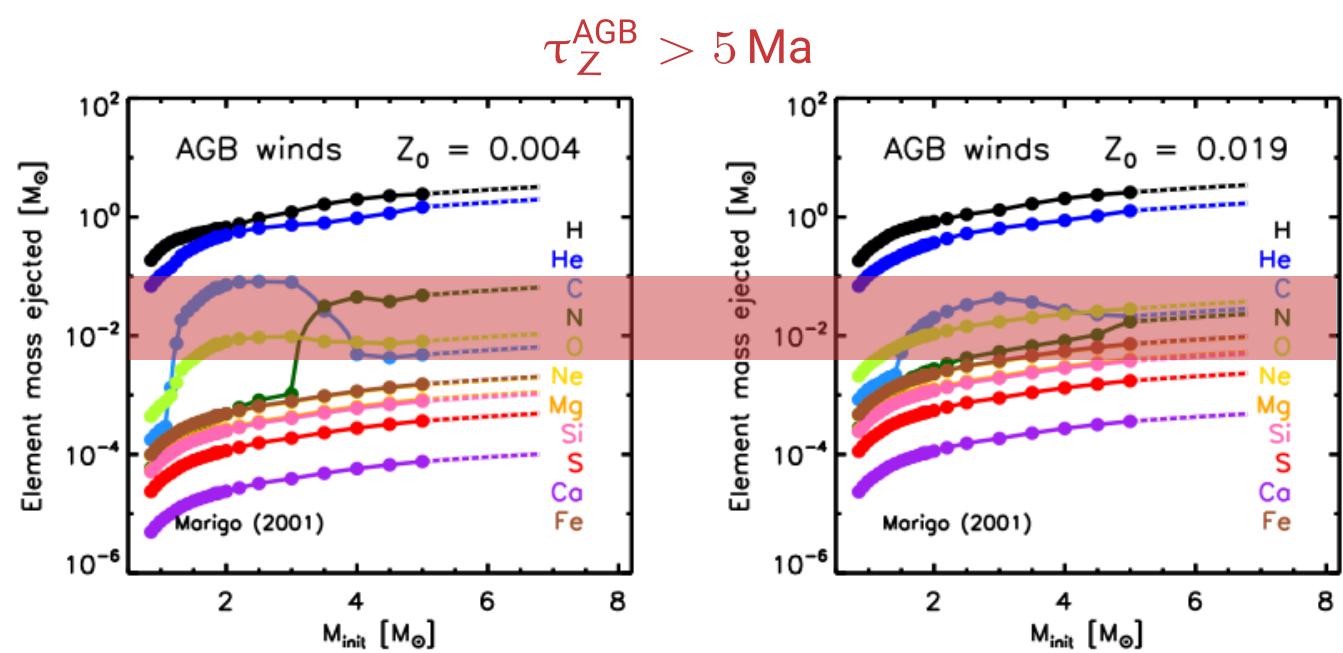
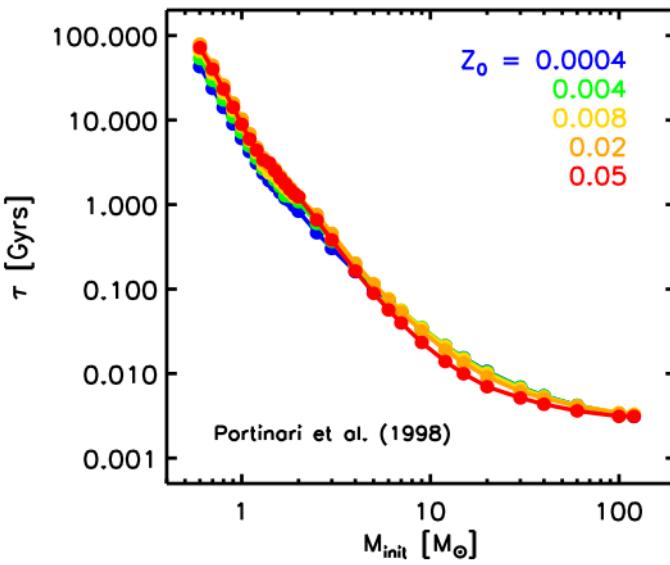
CONSIDERACIONES TEÓRICAS



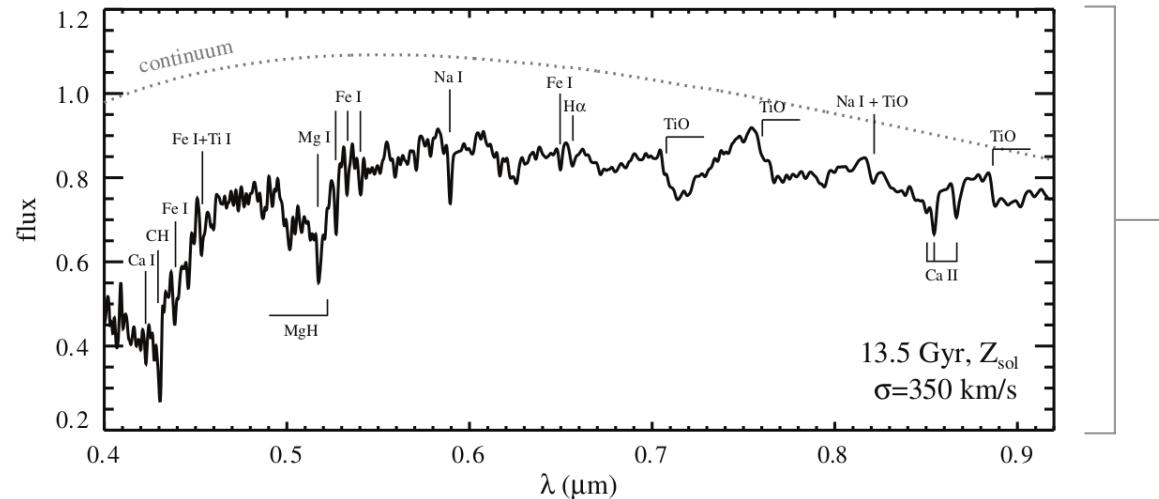
$\tau_{\text{Z}}^{\text{AGB}} > 5 \text{ Ma}$

$\tau_{\text{Z}}^{\text{SN II}} < 10 \text{ Ma}$

CONSIDERACIONES TEÓRICAS



CONSIDERACIONES OBSERVACIONALES

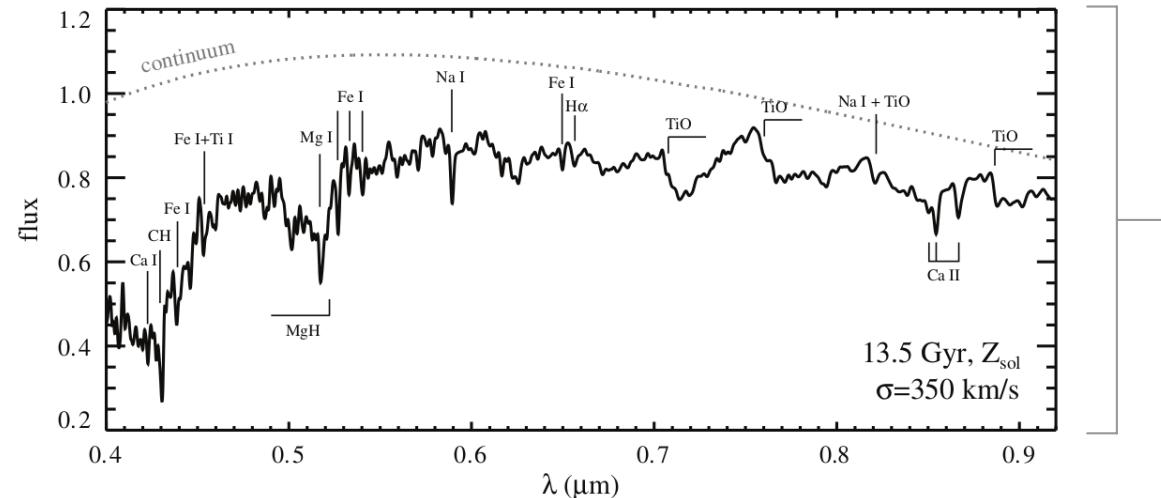


EMISIÓN ESTELAR

Masa estelar
Edad estelar
Metalicidad estelar

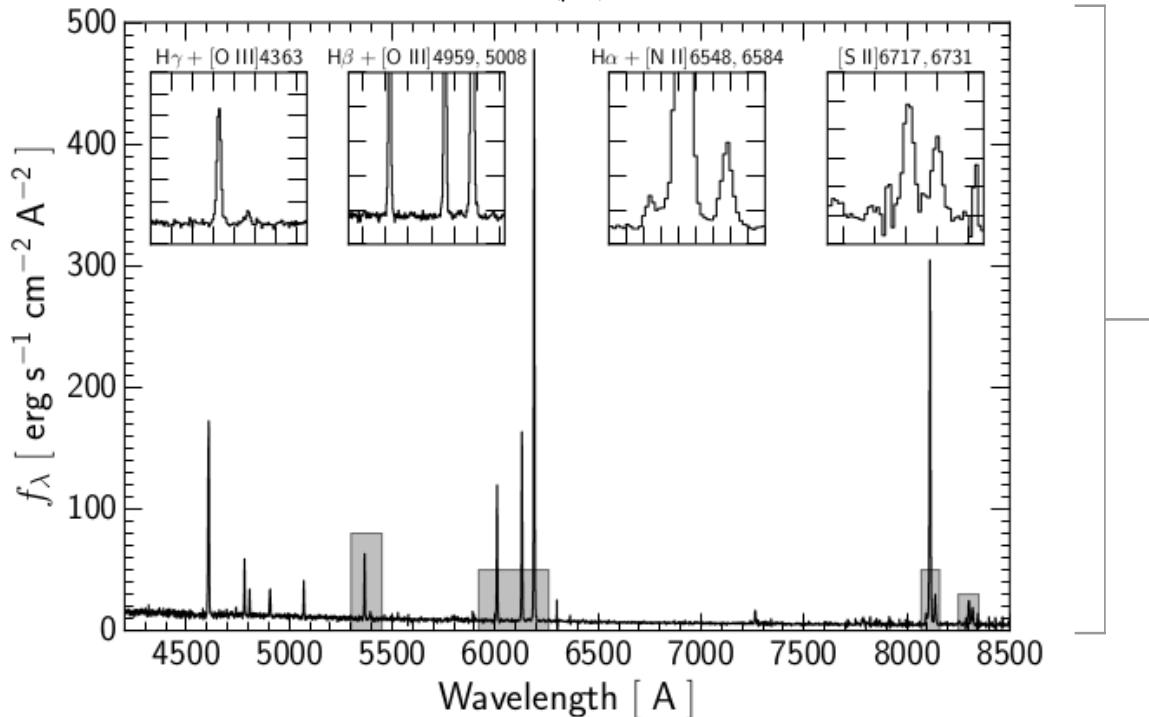
(Conroy+2014, Hayes+2016)

CONSIDERACIONES OBSERVACIONALES



EMISIÓN ESTELAR

Masa estelar
Edad estelar
Metalicidad estelar



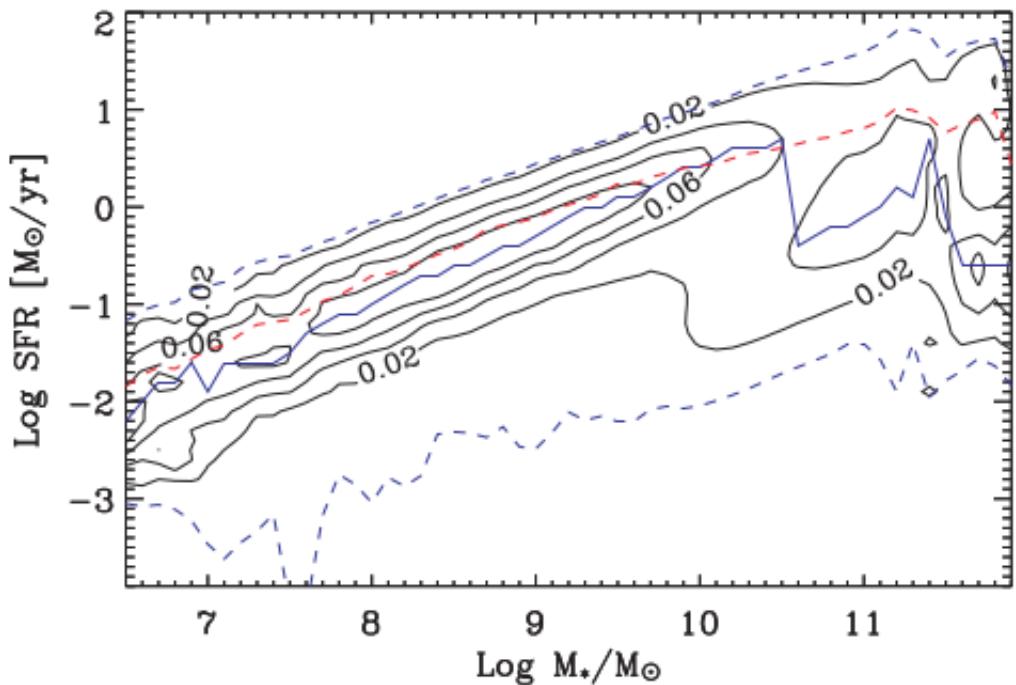
EMISIÓN DEL MIE

Masa de gas
TFE
Metalicidad del gas

(Conroy+2014, Hayes+2016)

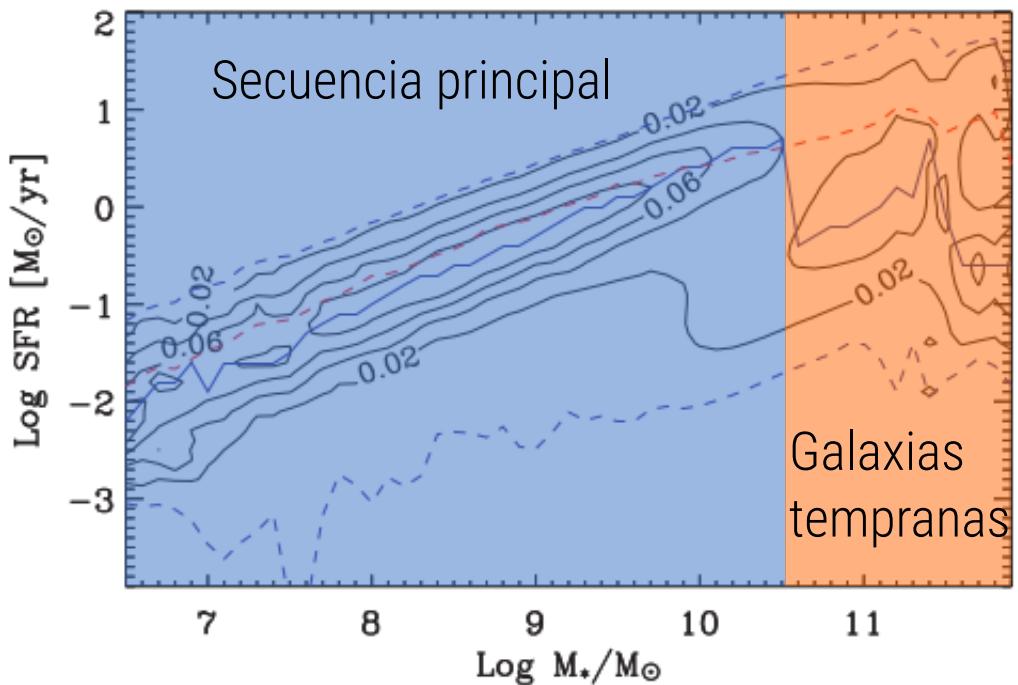
RELACIÓN MASA – TFE

(Brinchmann+2004)

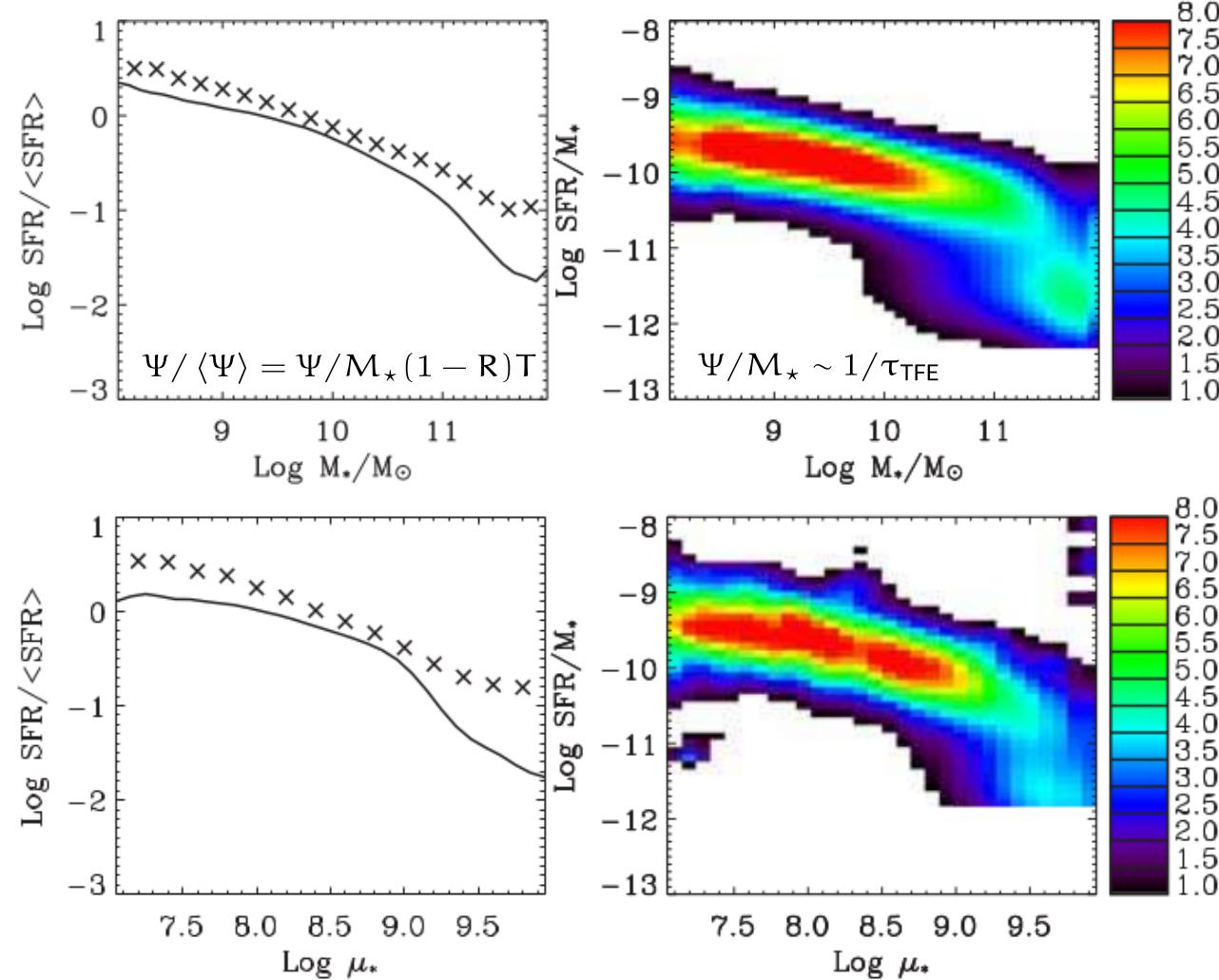
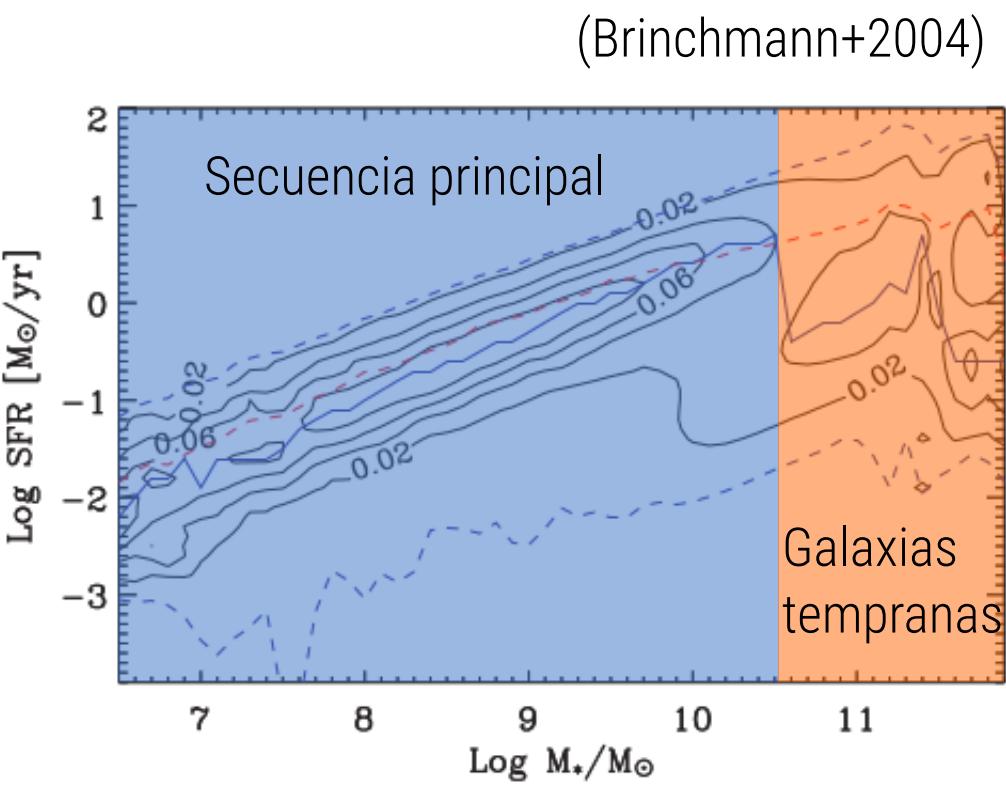


RELACIÓN MASA – TFE

(Brinchmann+2004)

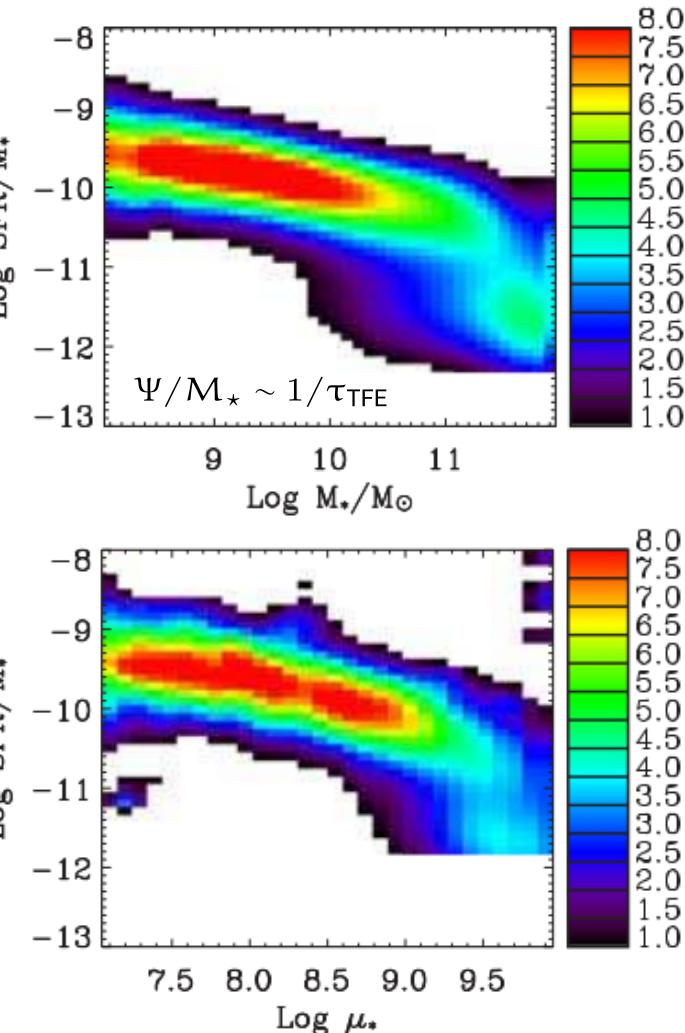
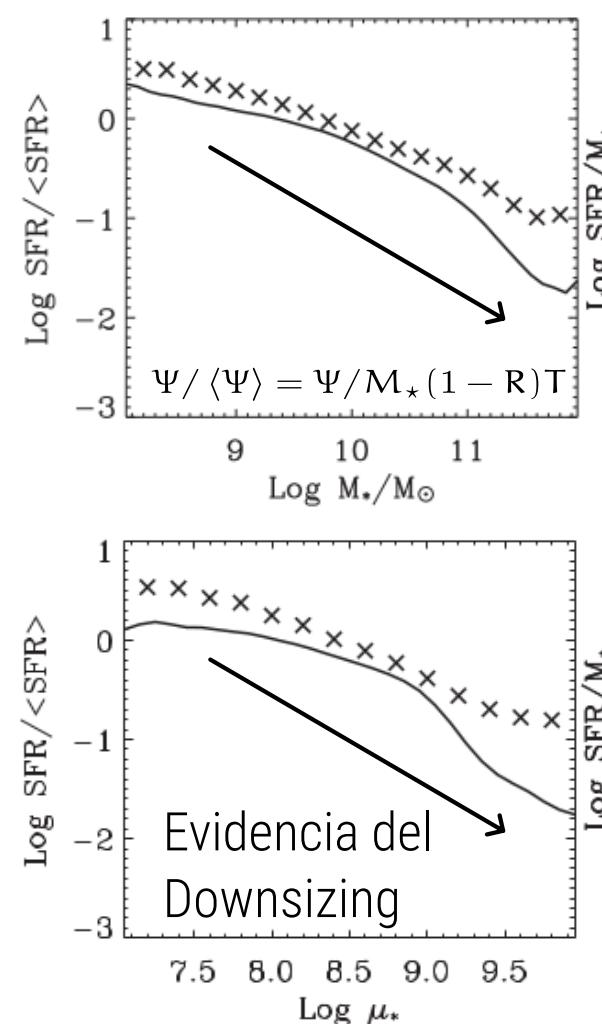
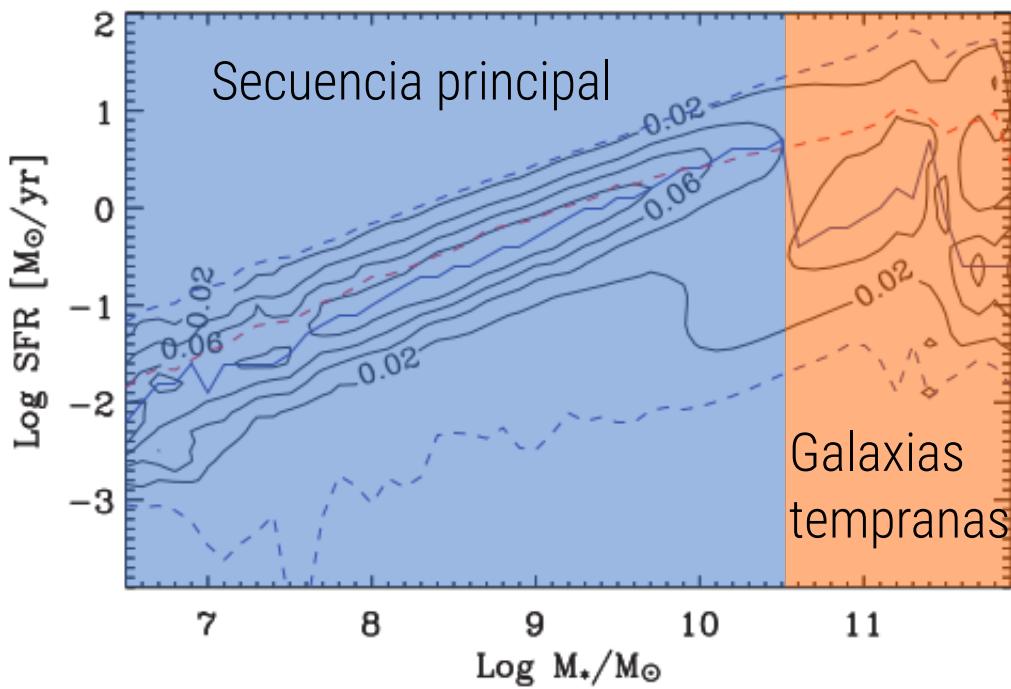


RELACIÓN MASA – TFE



RELACIÓN MASA – TFE

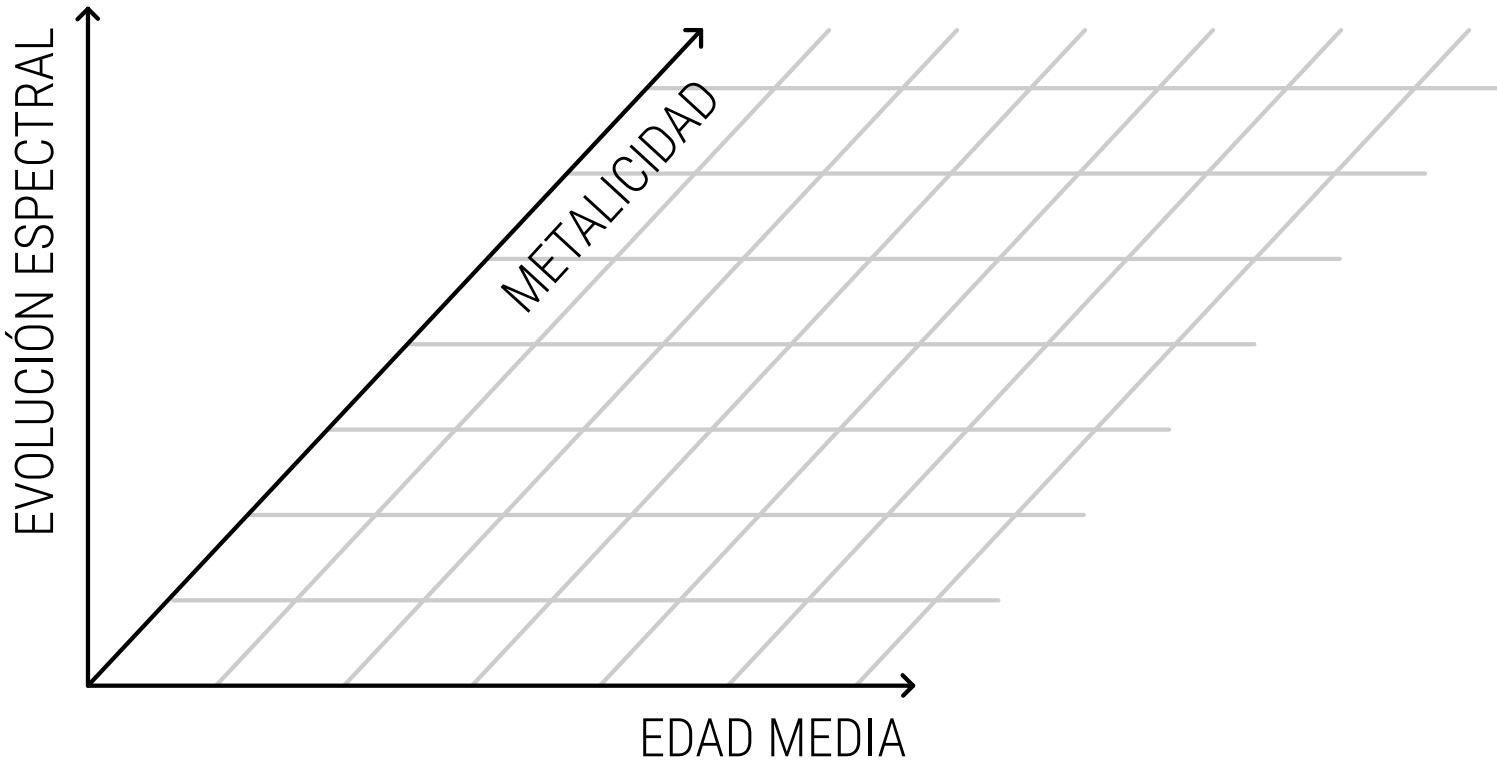
(Brinchmann+2004)



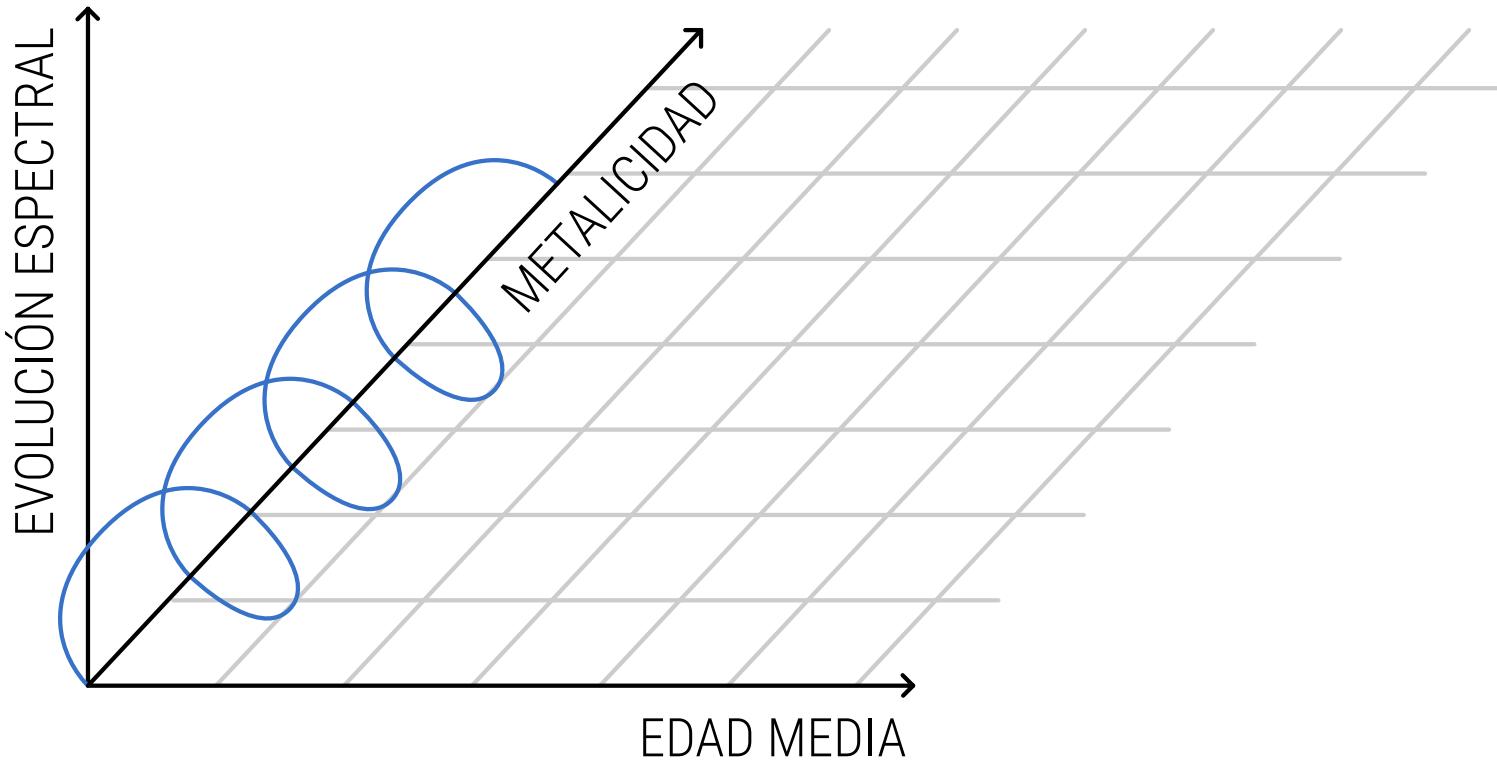
¿La relación masa – TFE tiene origen local o global?

$$\Sigma_{TFE} \propto \Sigma_{\text{frio}}^{1,5}$$

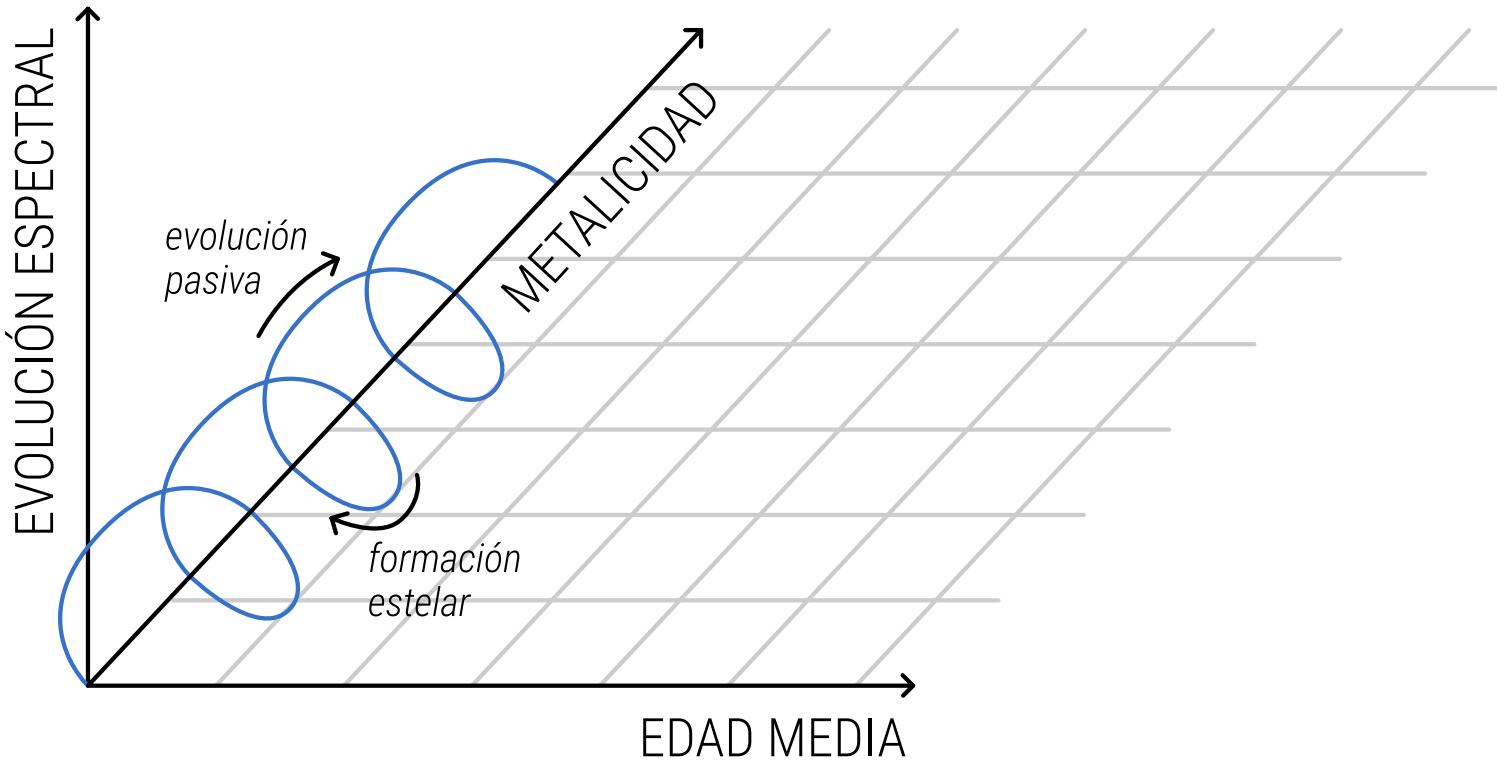
RELACIÓN EDAD – METALICIDAD



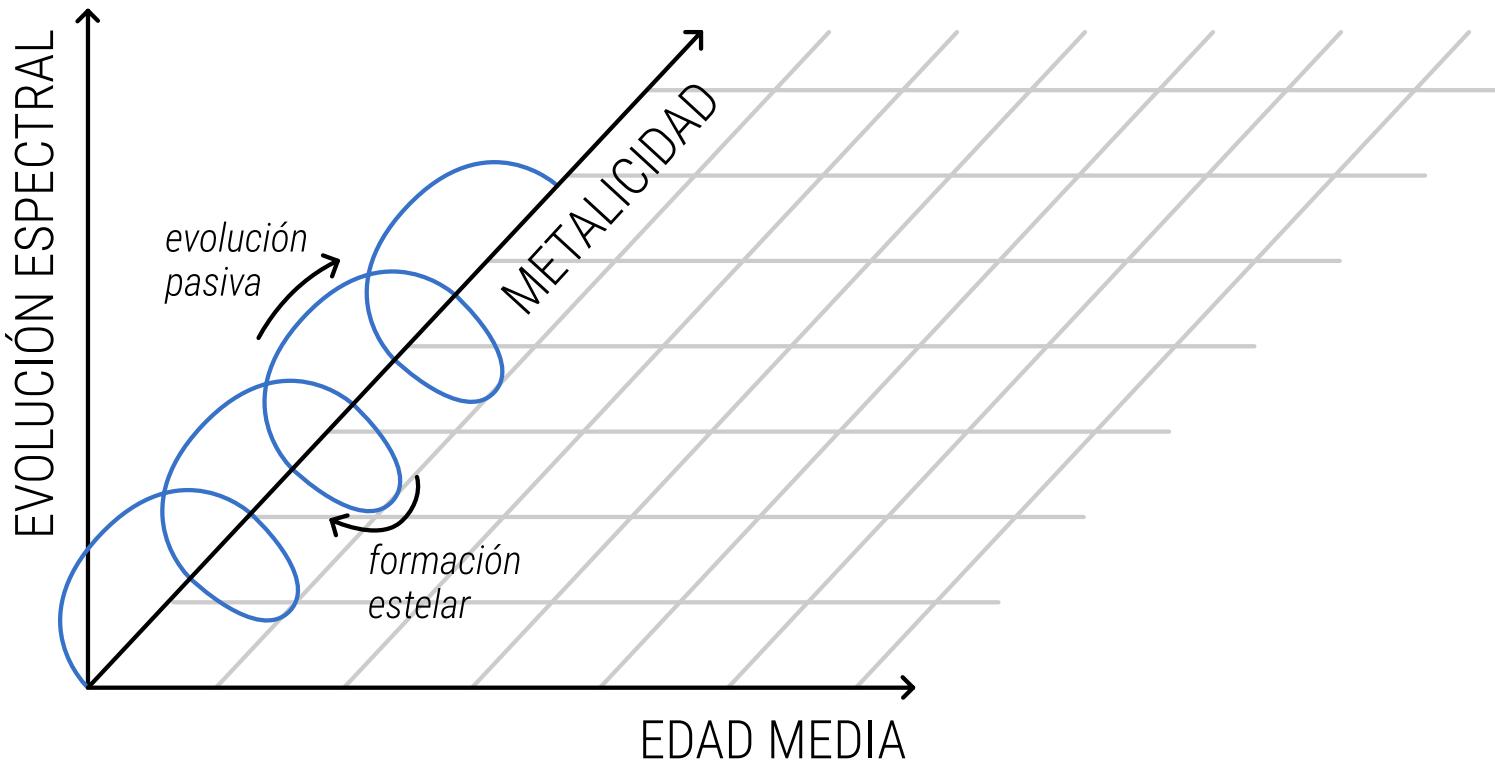
RELACIÓN EDAD – METALICIDAD



RELACIÓN EDAD – METALICIDAD



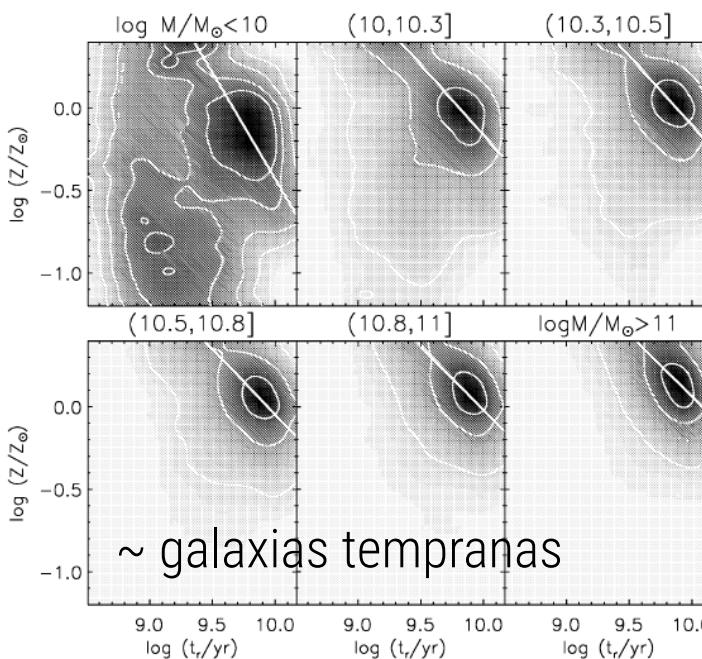
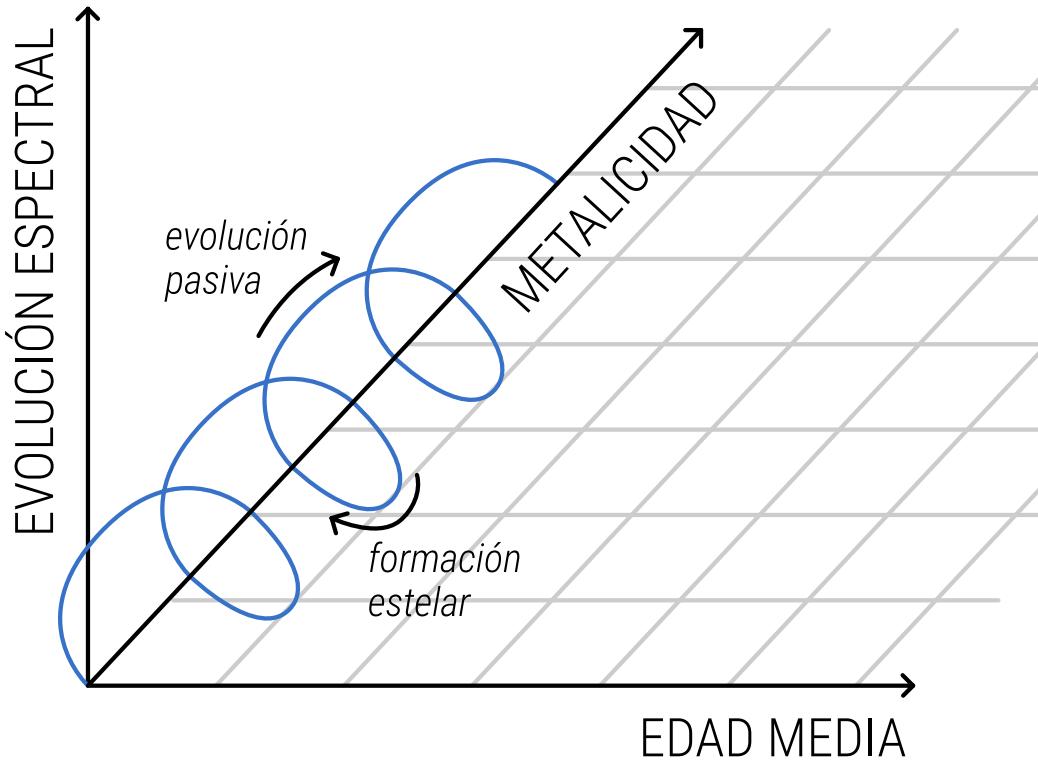
RELACIÓN EDAD – METALICIDAD



De acuerdo con Ocvirk+2006:

$$\Lambda(t) = \frac{\Psi}{\Delta\lambda} \int_{\lambda_{\min}}^{\lambda_{\max}} L_{\lambda}^{\text{PES}}(Z; t) d\lambda$$

RELACIÓN EDAD – METALICIDAD



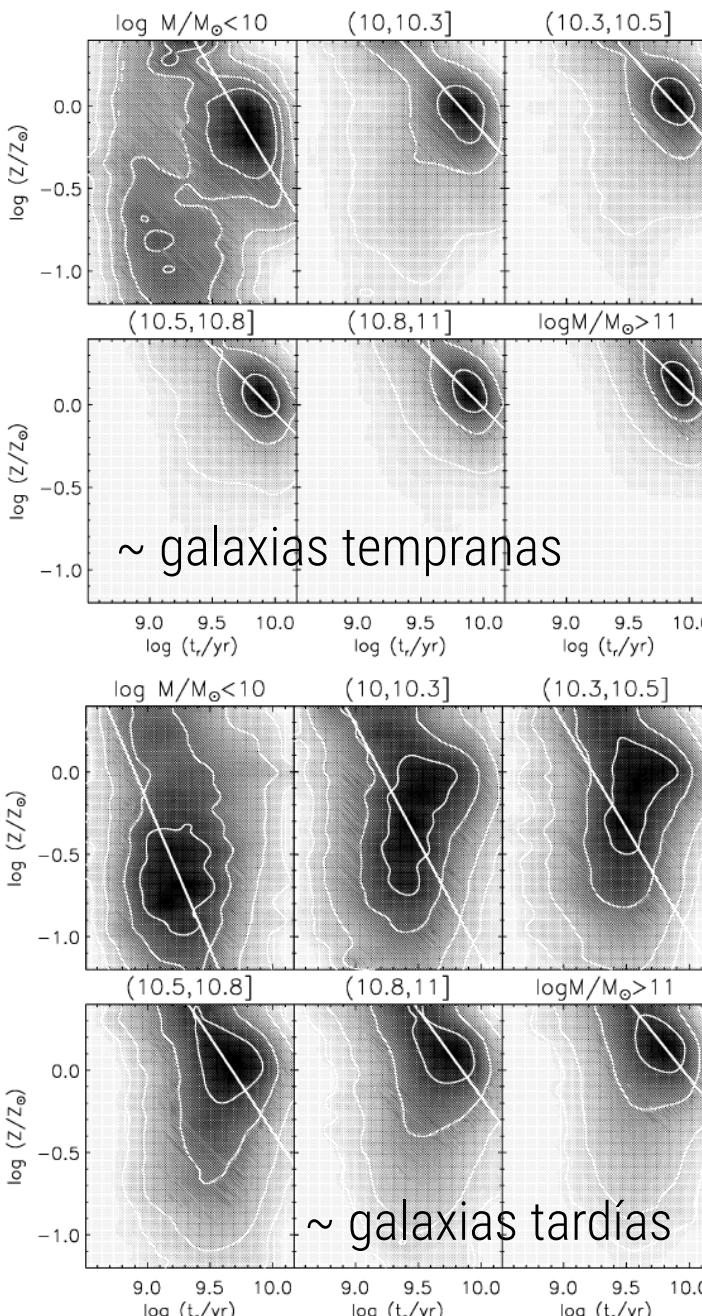
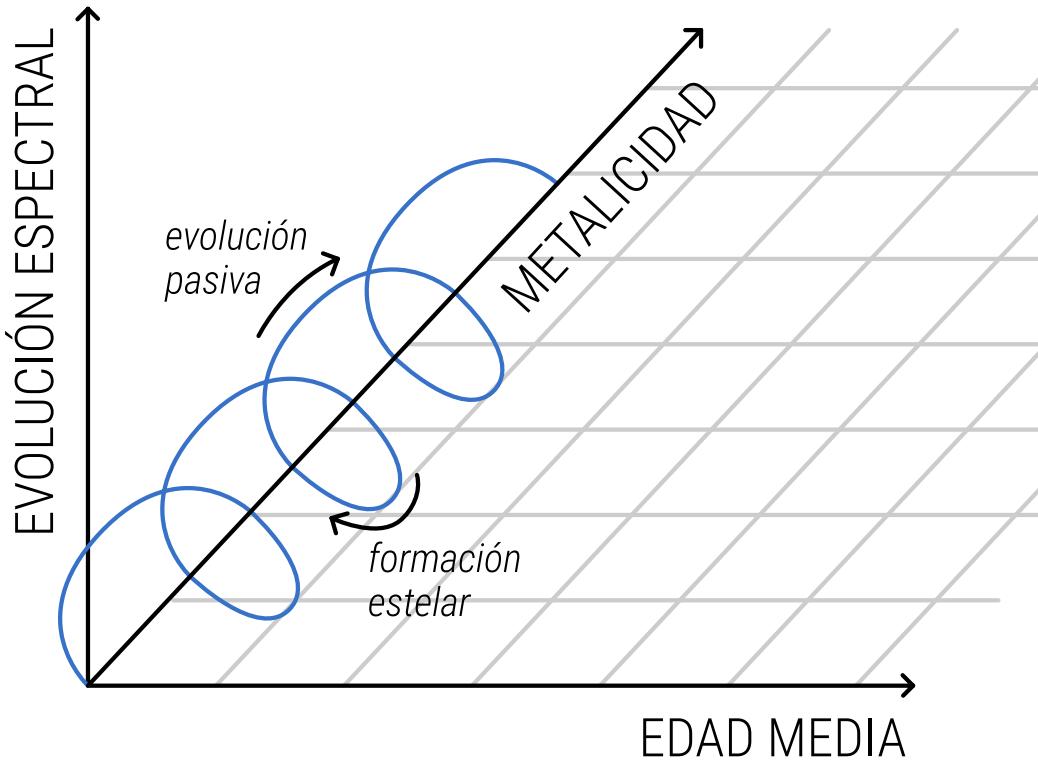
(Gallazzi+2005)

Independiente de la masa
Degeneración edad-metalicidad

De acuerdo con Ocvirk+2006:

$$\Lambda(t) = \frac{\Psi}{\Delta\lambda} \int_{\lambda_{\min}}^{\lambda_{\max}} L_{\lambda}^{\text{PES}}(Z; t) d\lambda$$

RELACIÓN EDAD – METALICIDAD



(Gallazzi+2005)

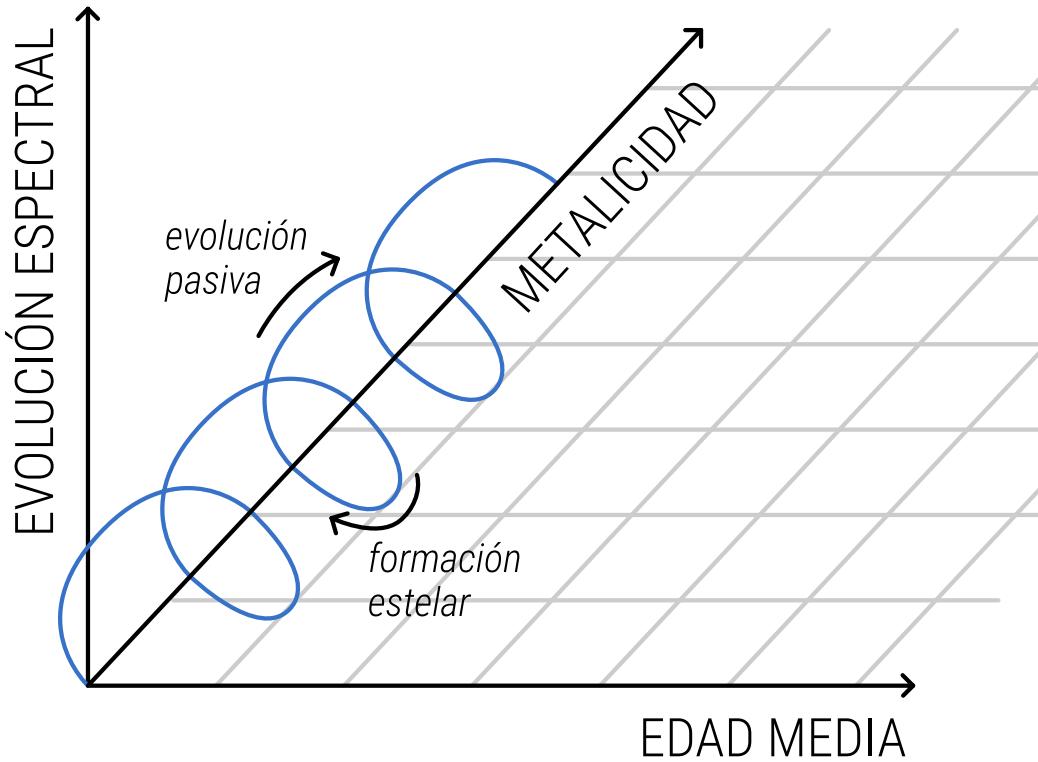
Independiente de la masa
Degeneración edad-metalicidad

Dependencia con la masa
Gran dispersión en metalicidad

De acuerdo con Ocvirk+2006:

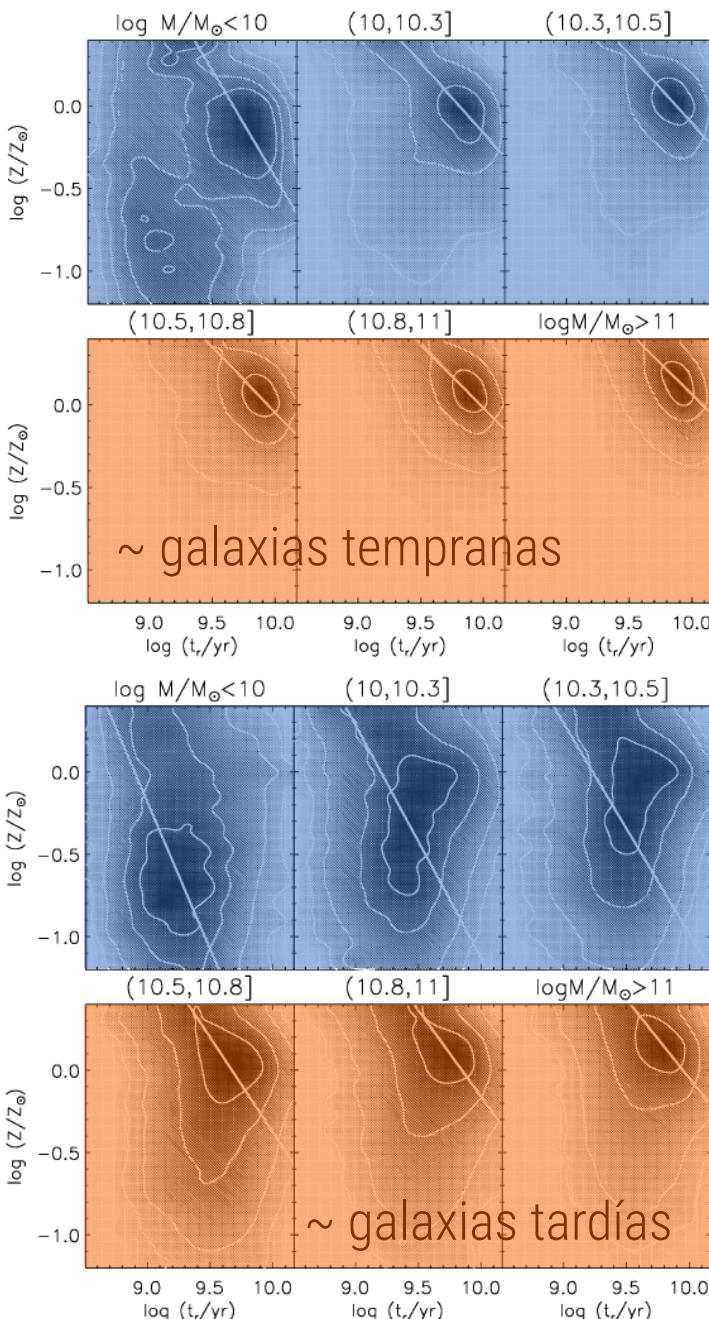
$$\Lambda(t) = \frac{\Psi}{\Delta\lambda} \int_{\lambda_{\min}}^{\lambda_{\max}} L_\lambda^{\text{PES}}(Z; t) d\lambda$$

RELACIÓN EDAD – METALICIDAD



De acuerdo con Ocvirk+2006:

$$\Lambda(t) = \frac{\Psi}{\Delta\lambda} \int_{\lambda_{\min}}^{\lambda_{\max}} L_{\lambda}^{\text{PES}}(Z; t) d\lambda$$



(Gallazzi+2005)

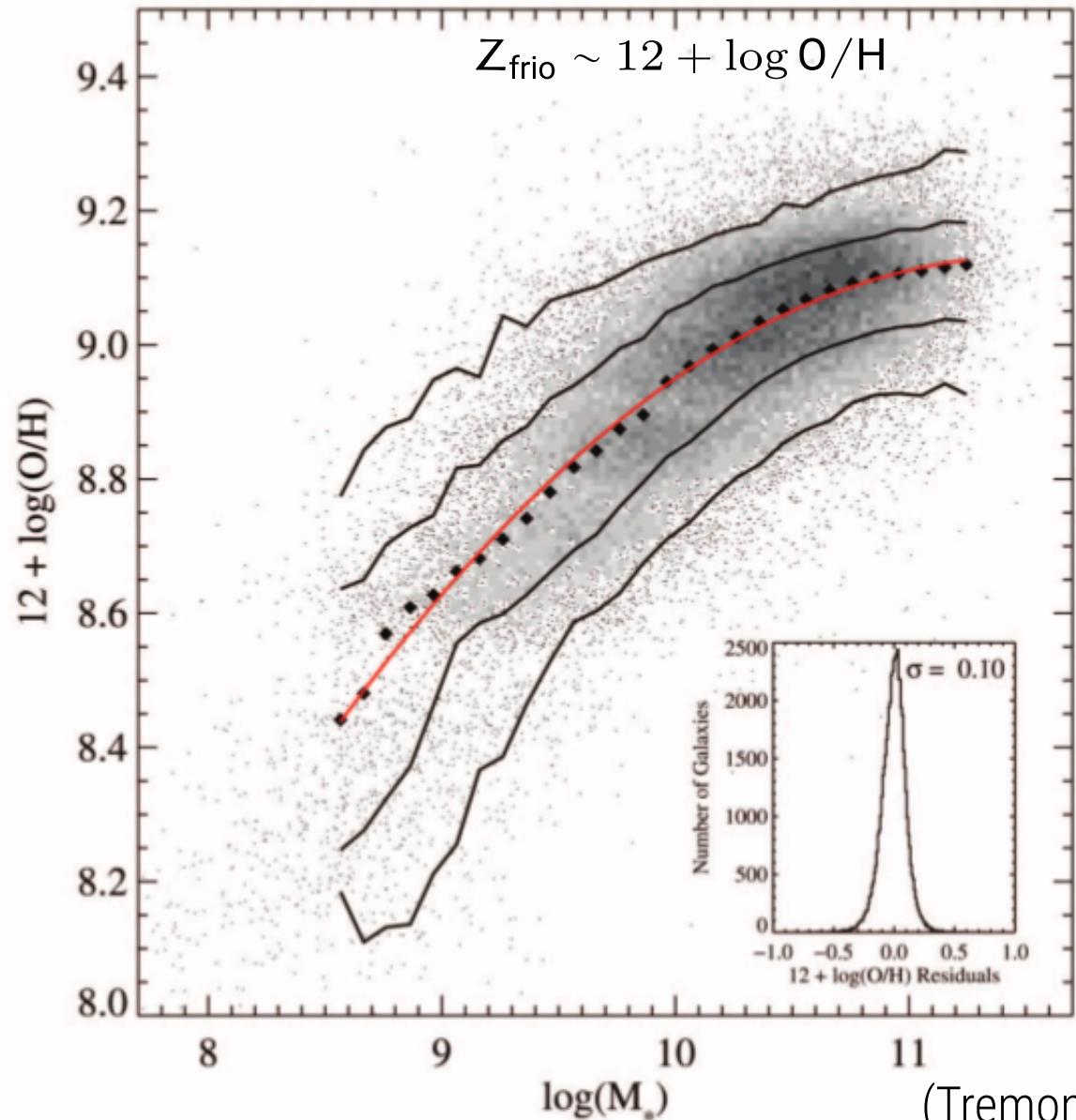
Galaxias pasivas

Independiente de la masa
Degeneración edad-metalicidad

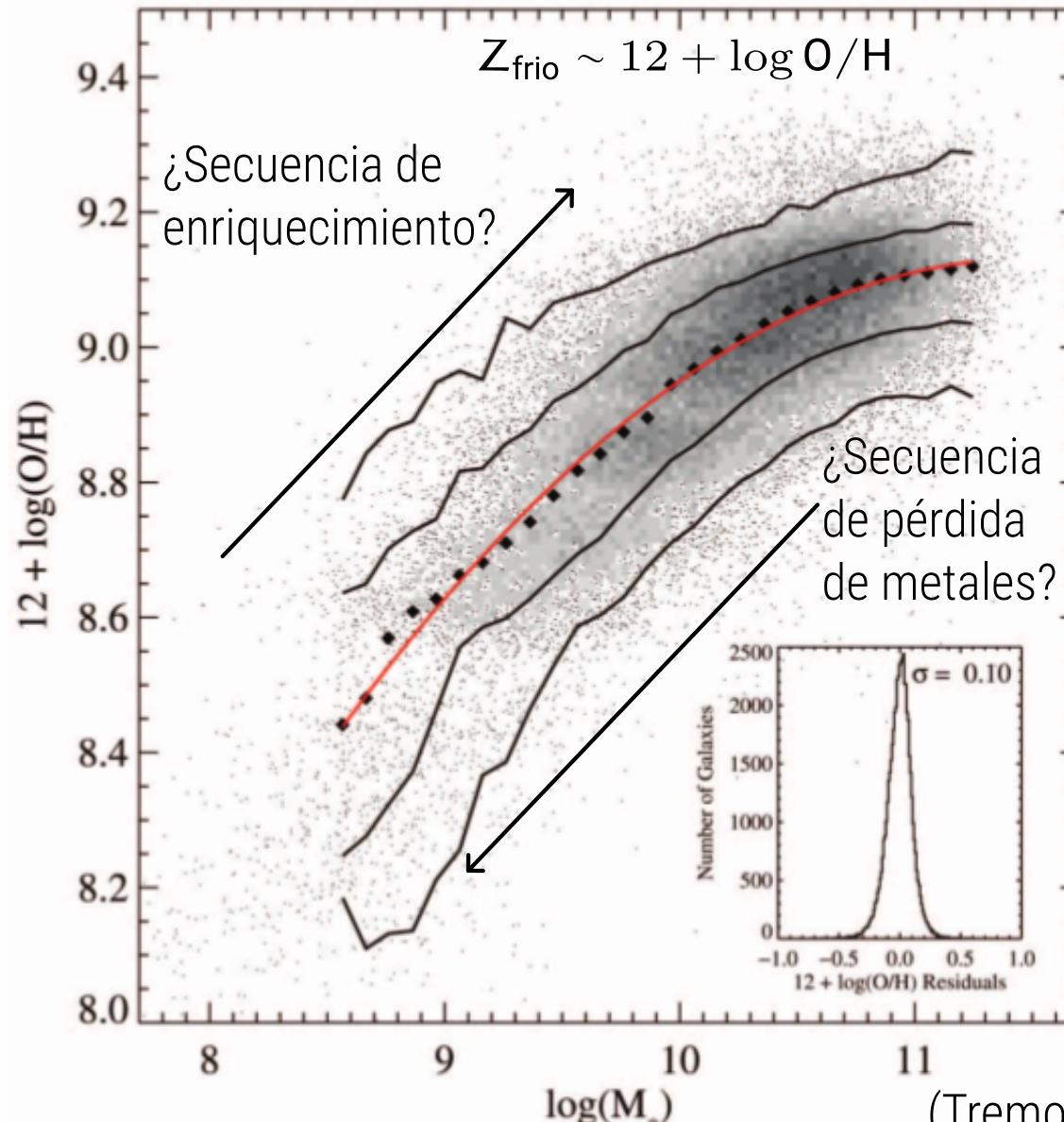
Galaxias en transición

Dependencia con la masa
Gran dispersión en metalicidad

RELACIÓN MASA – METALICIDAD

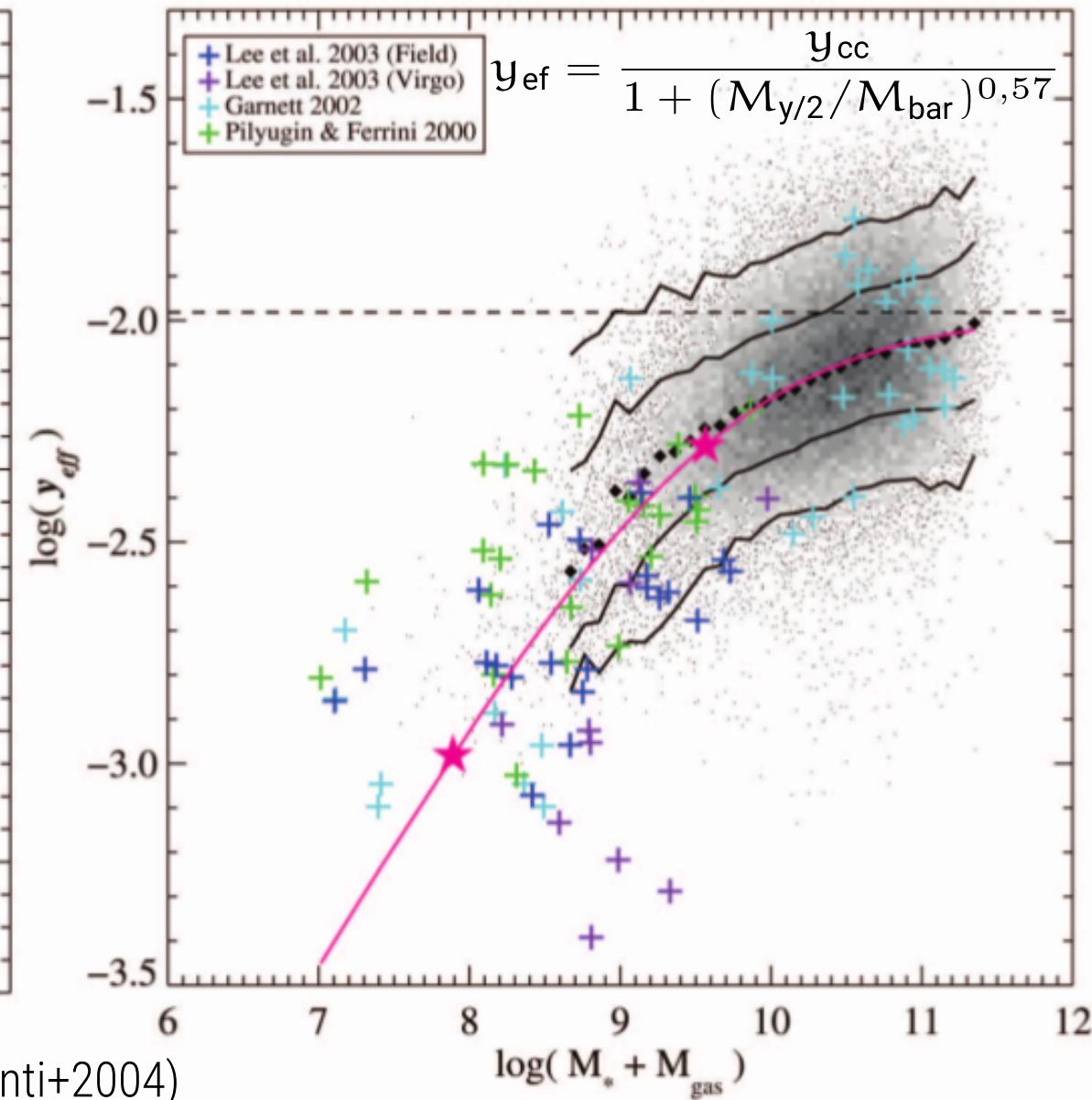
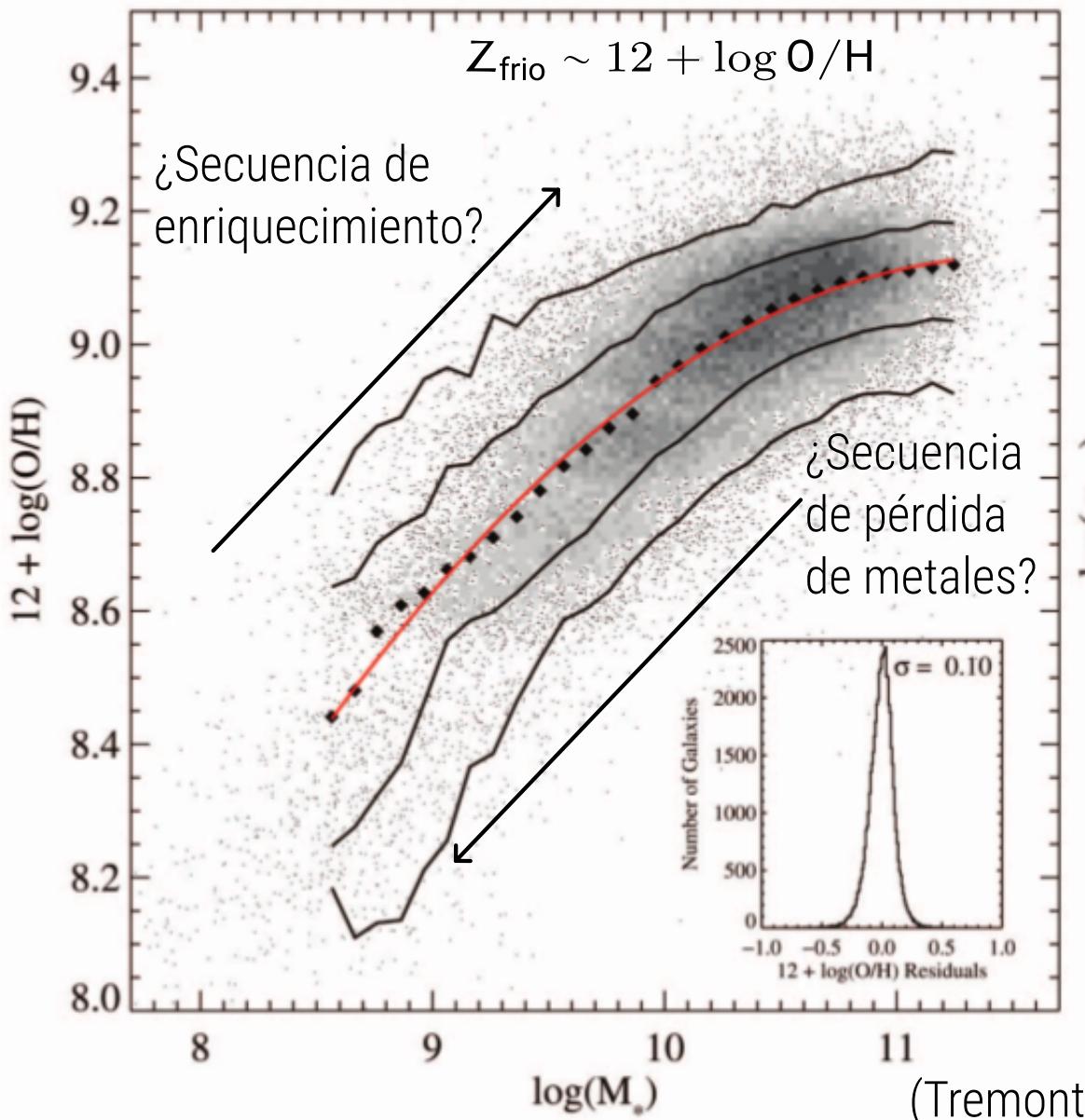


RELACIÓN MASA – METALICIDAD

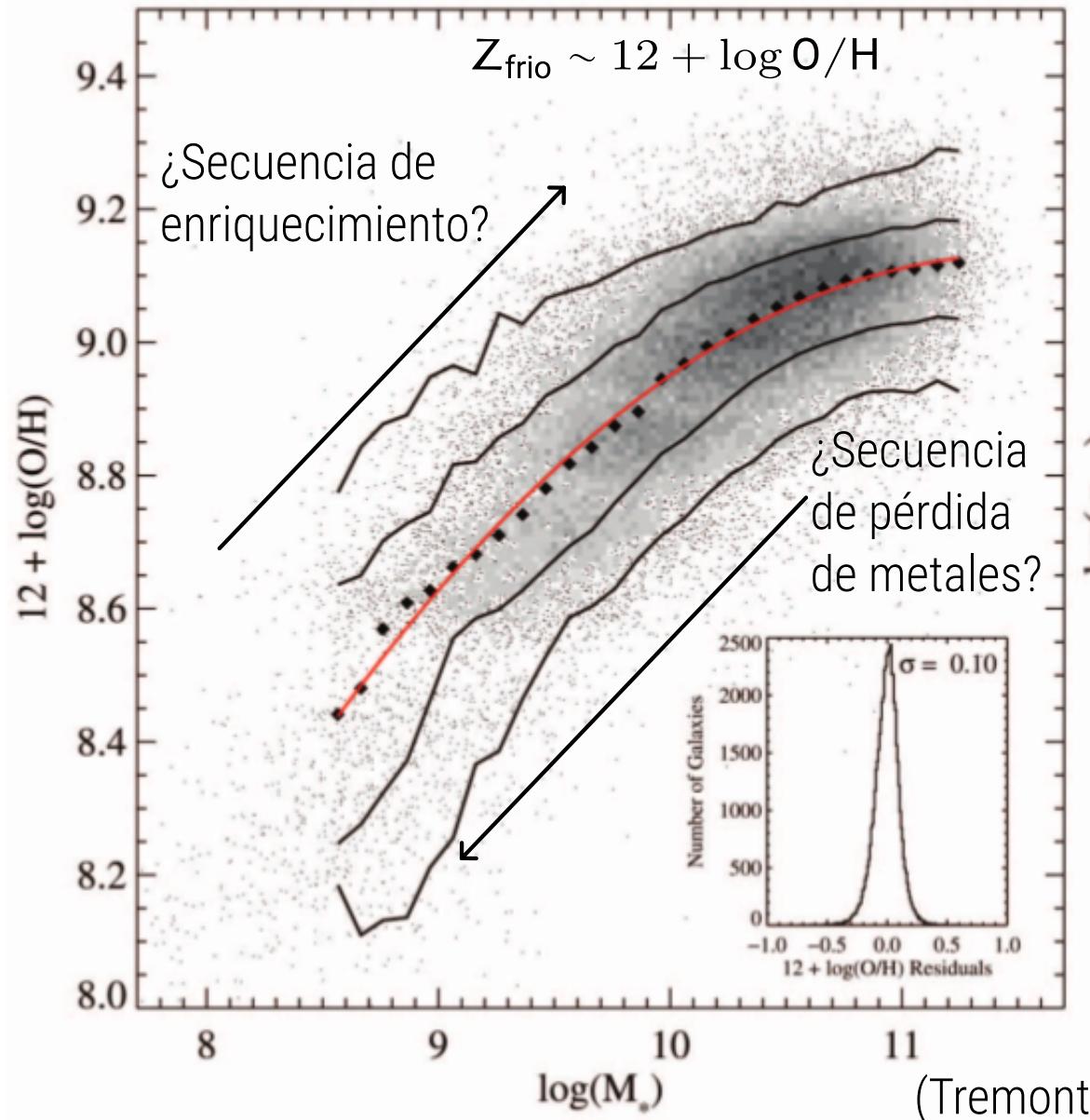


(Tremonti+2004)

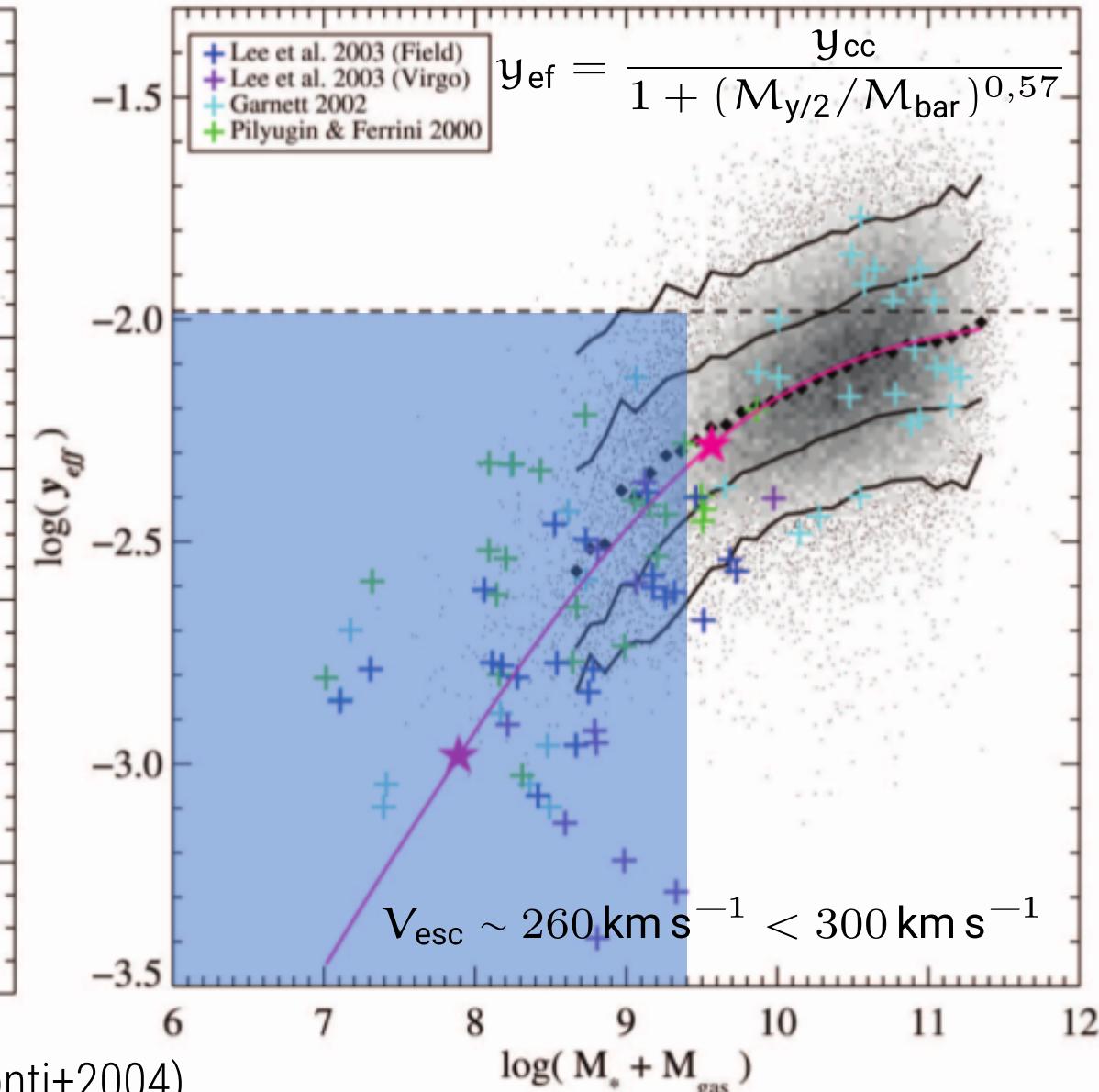
RELACIÓN MASA – METALICIDAD



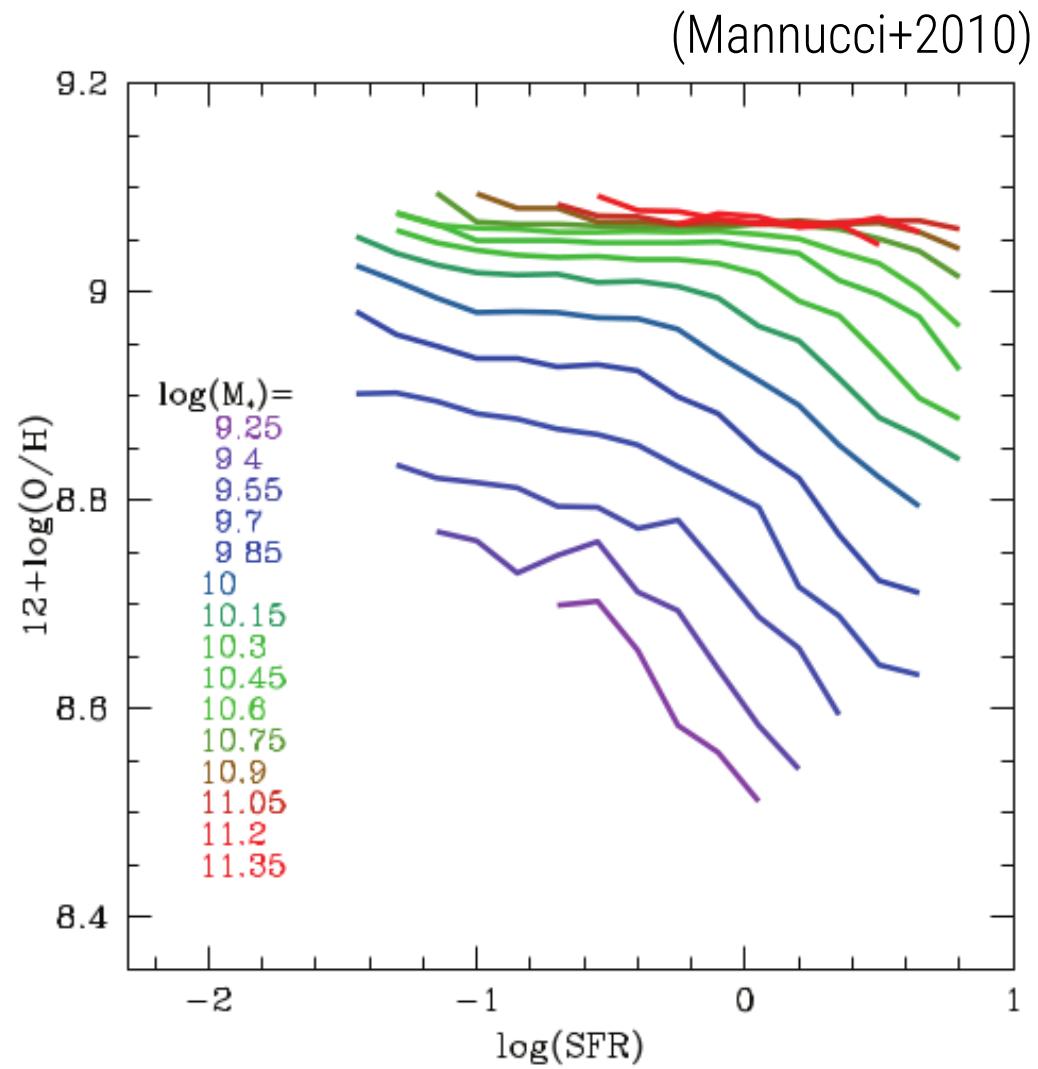
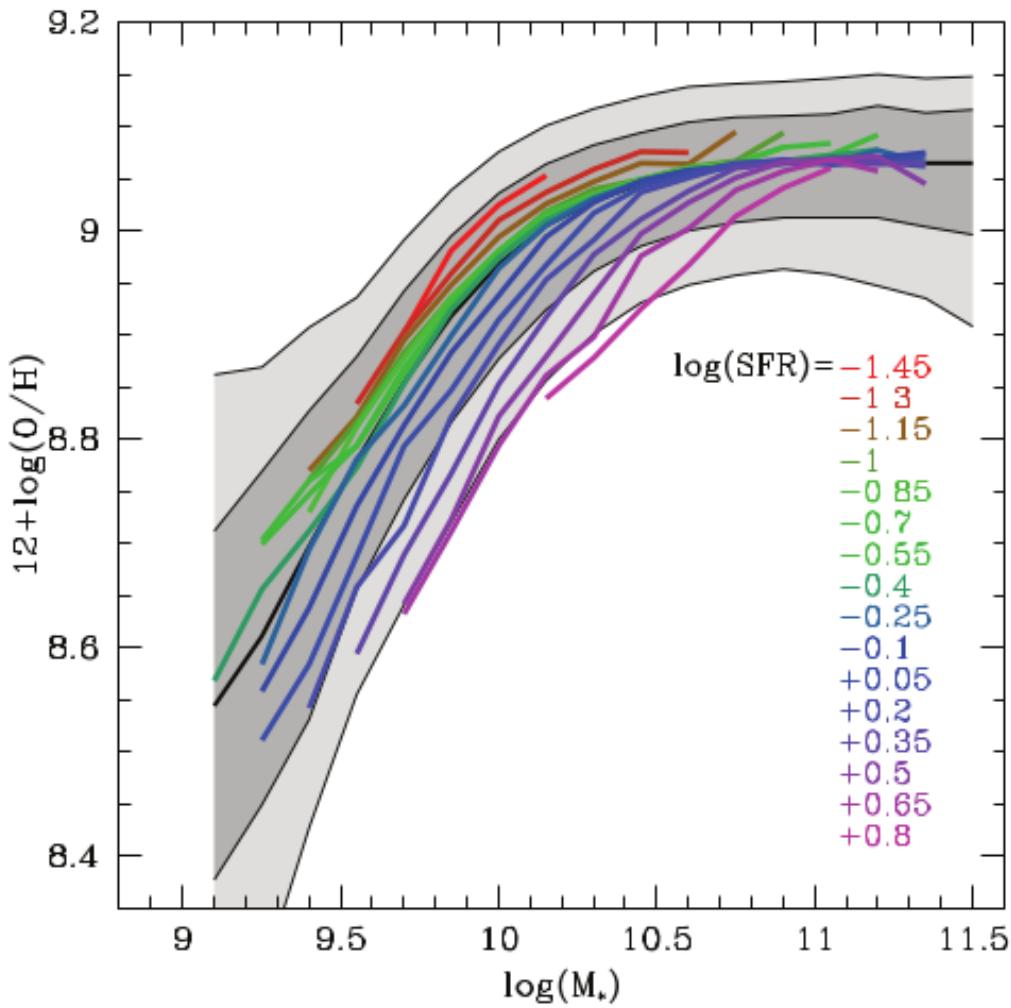
RELACIÓN MASA – METALICIDAD



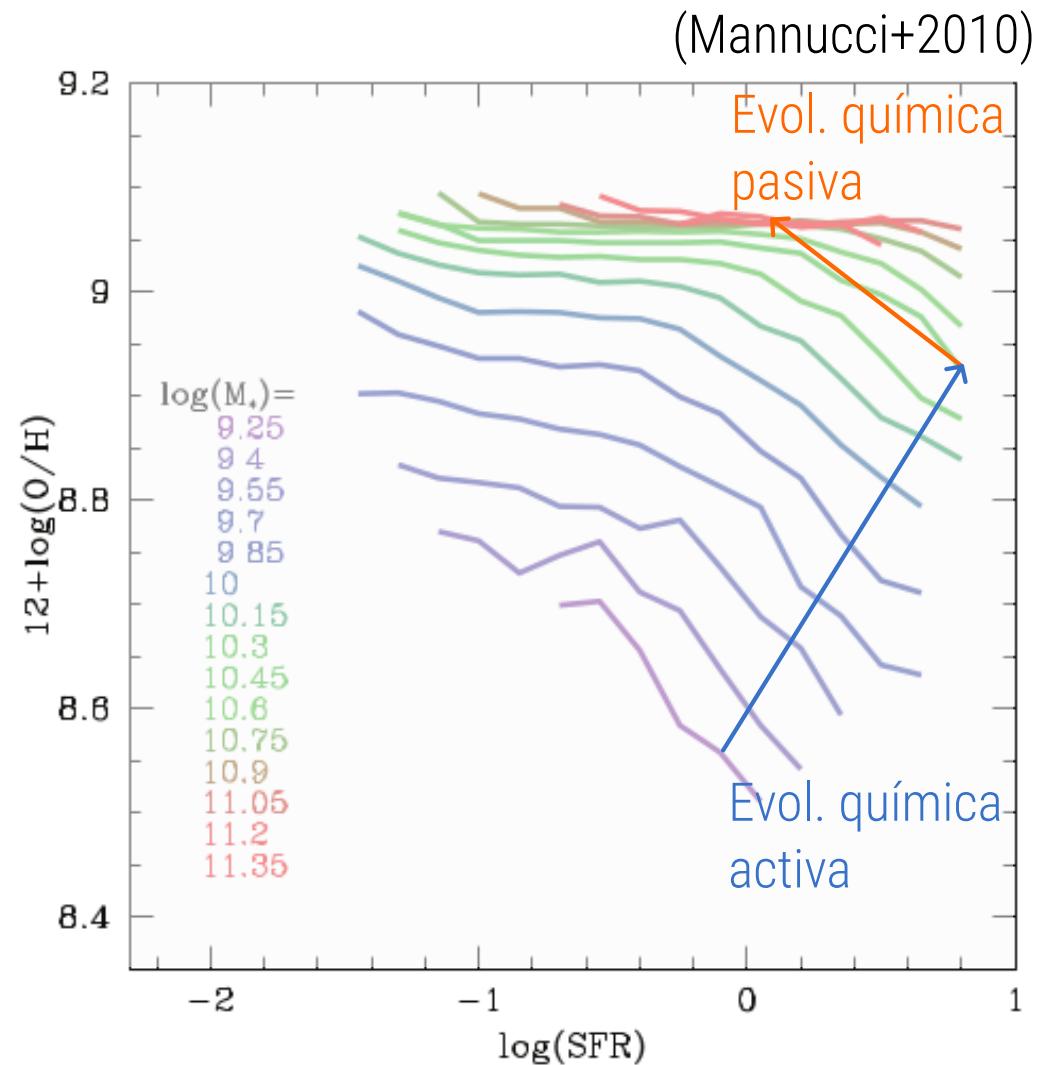
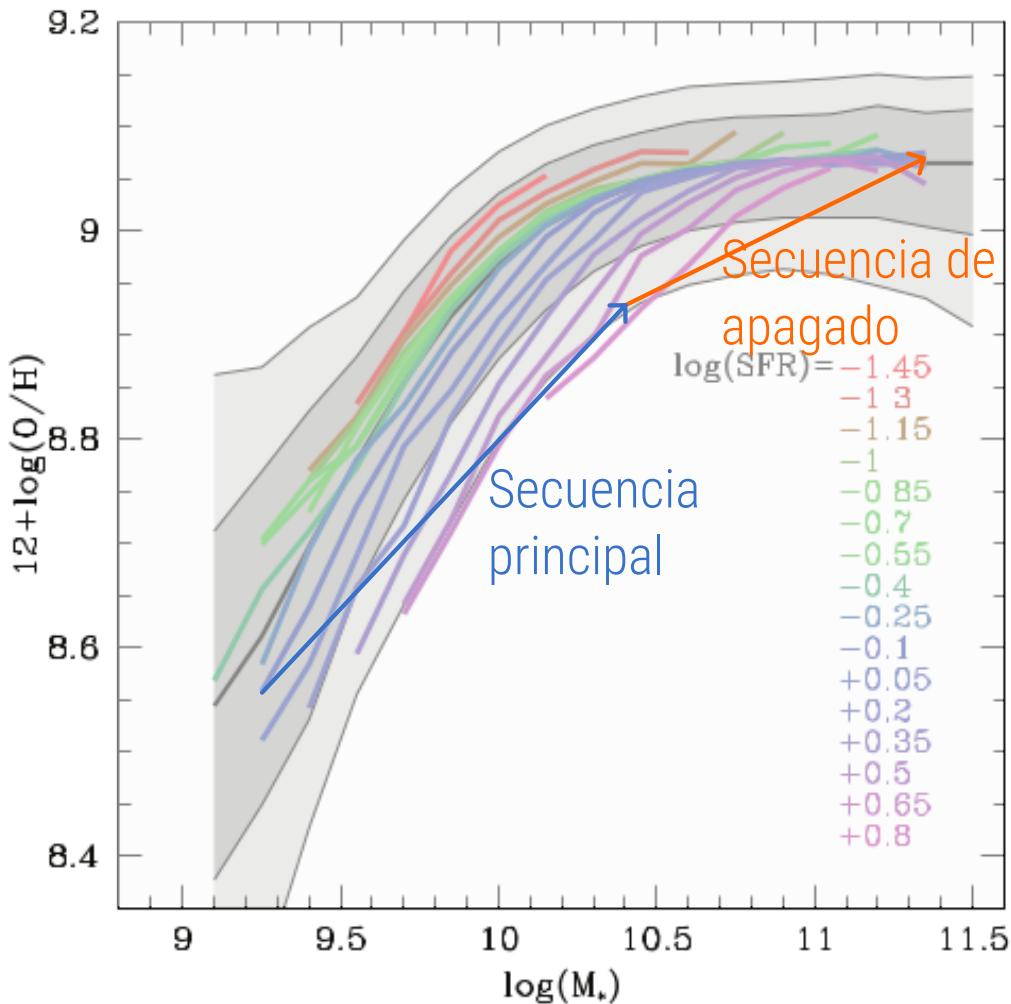
(Tremonti+2004)



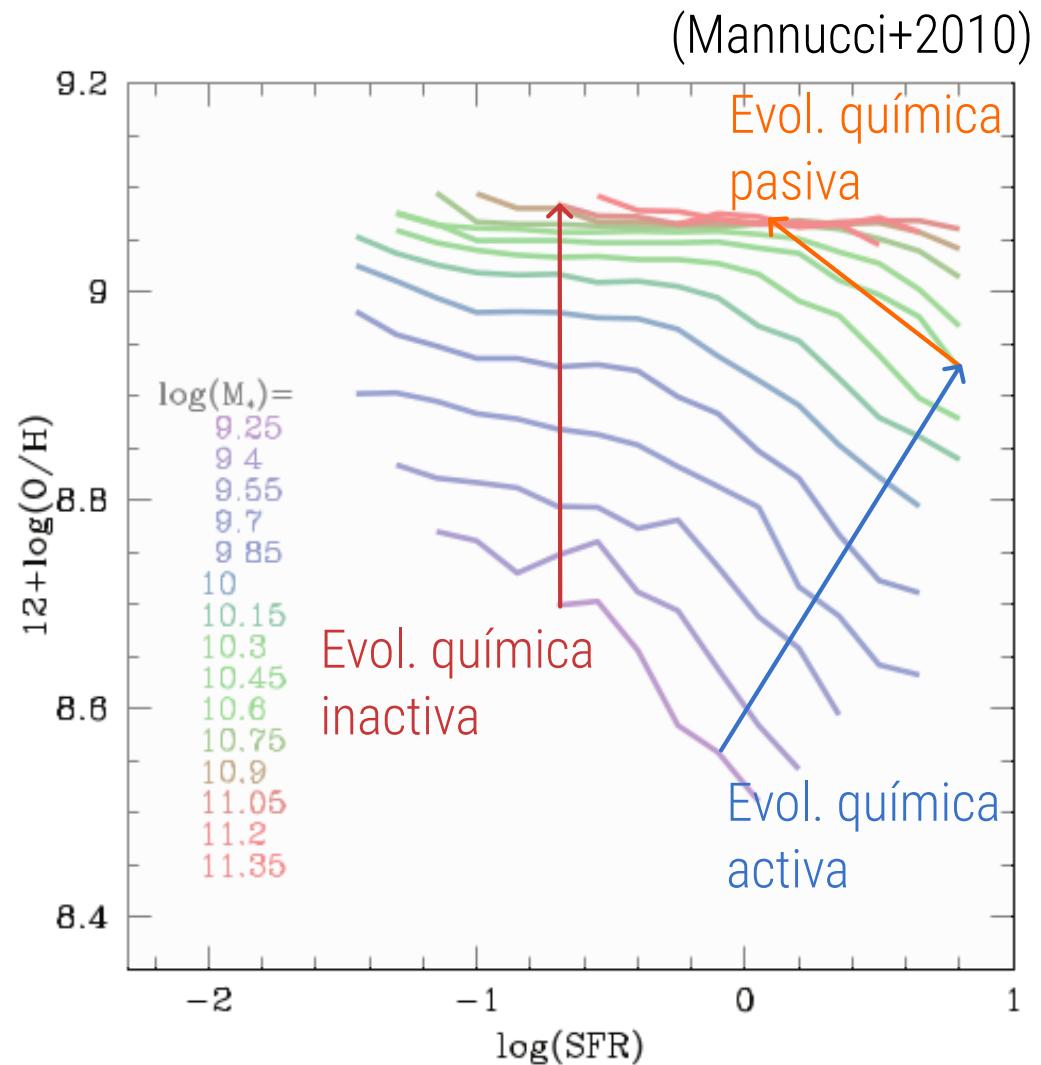
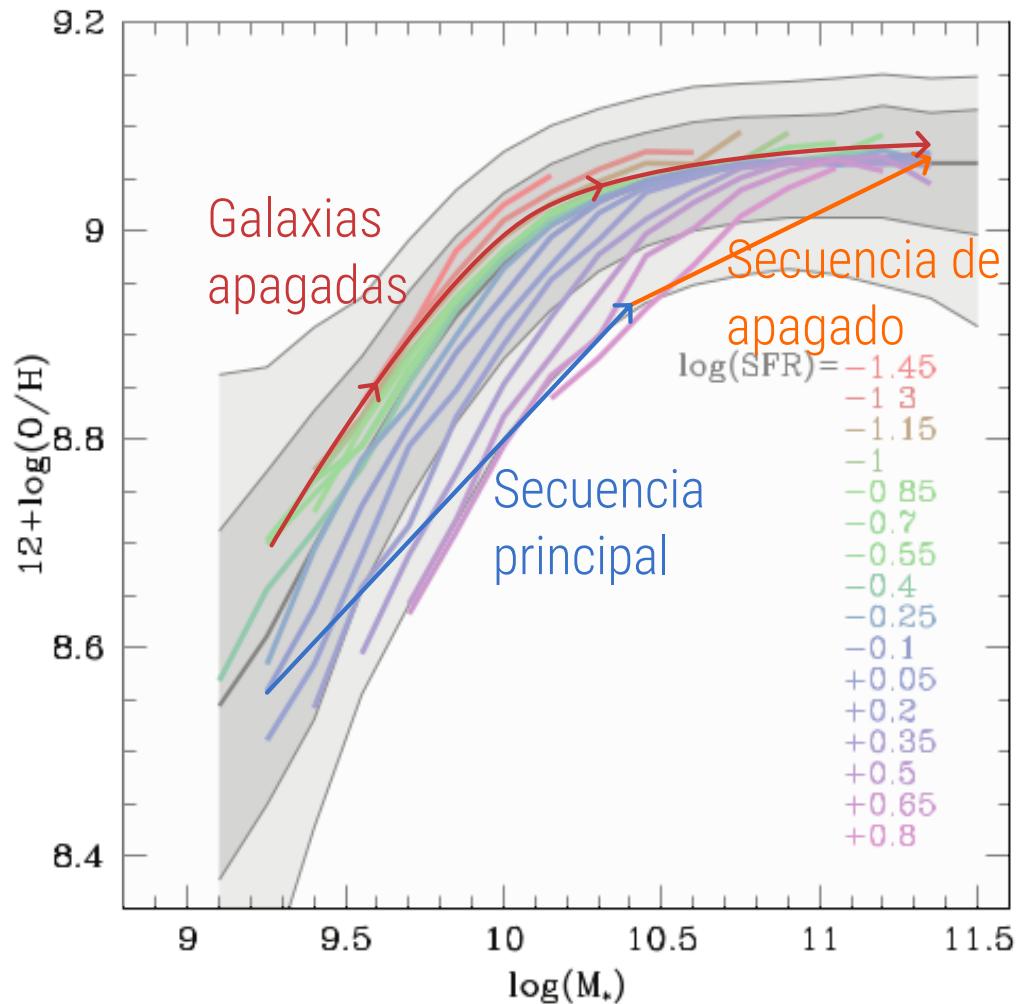
RELACIÓN MASA – METALICIDAD – TFE



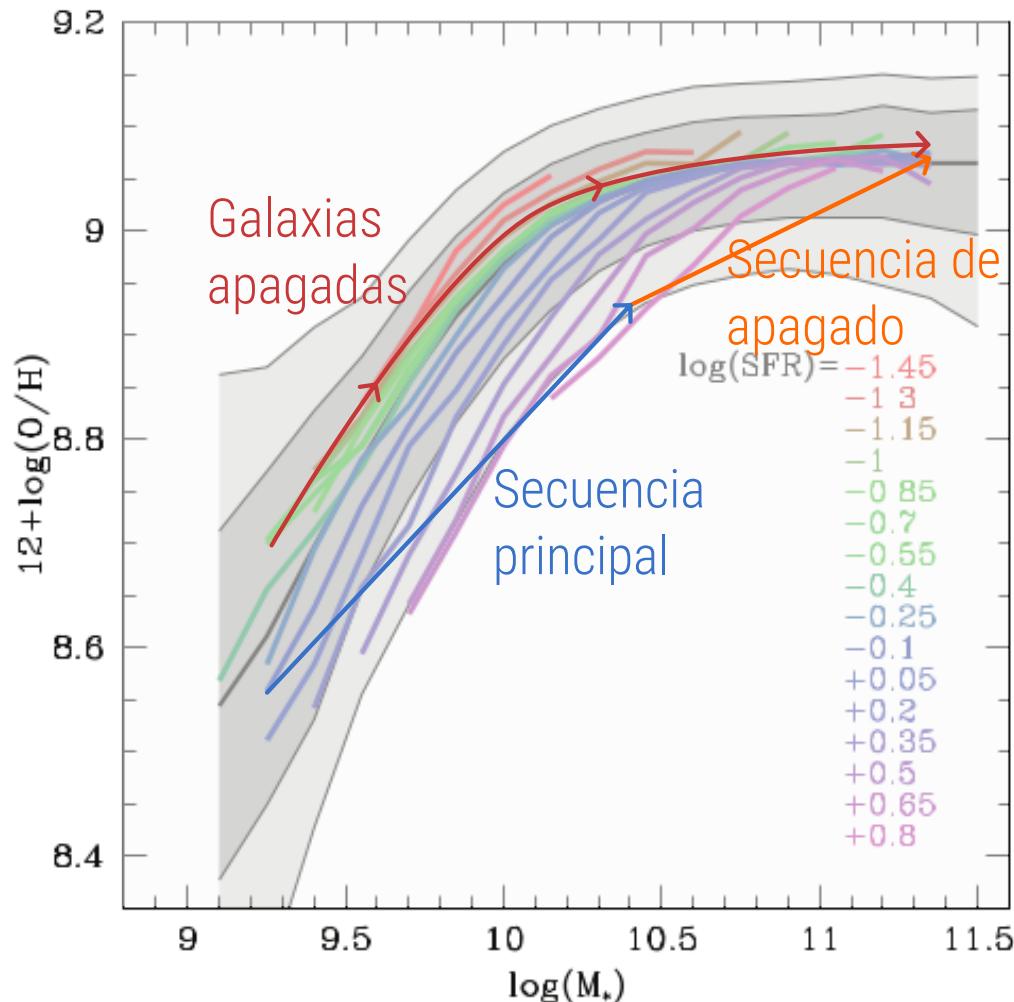
RELACIÓN MASA – METALICIDAD – TFE



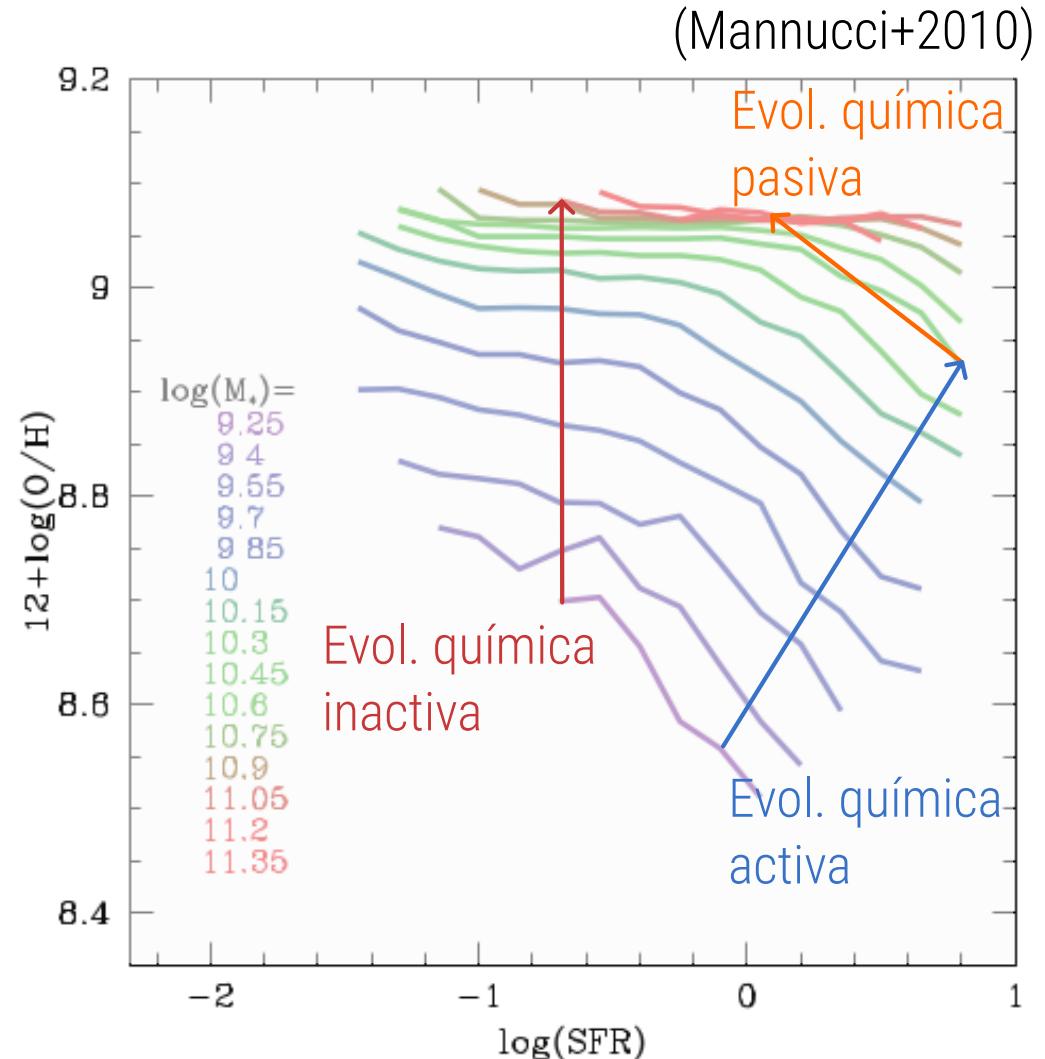
RELACIÓN MASA – METALICIDAD – TFE



RELACIÓN MASA – METALICIDAD – TFE

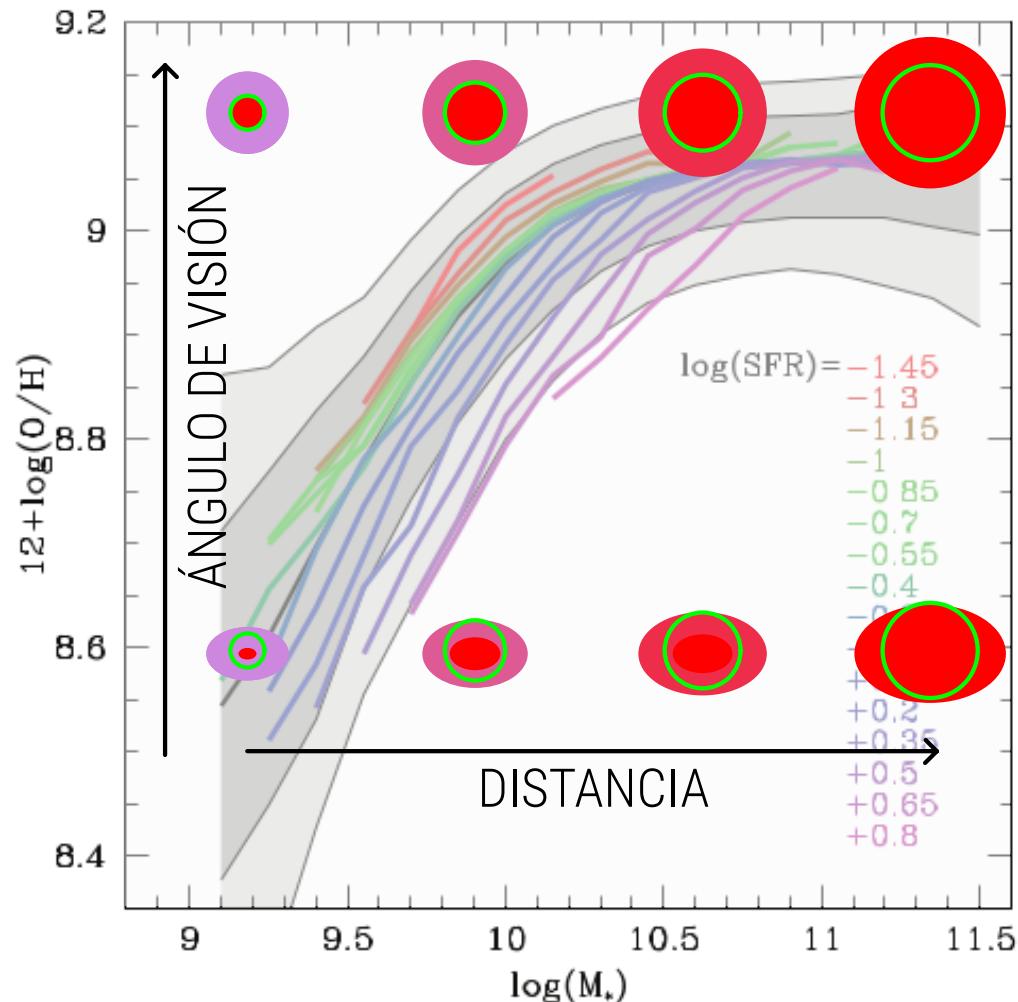


¿Qué tan importante es el efecto de la apertura fija?

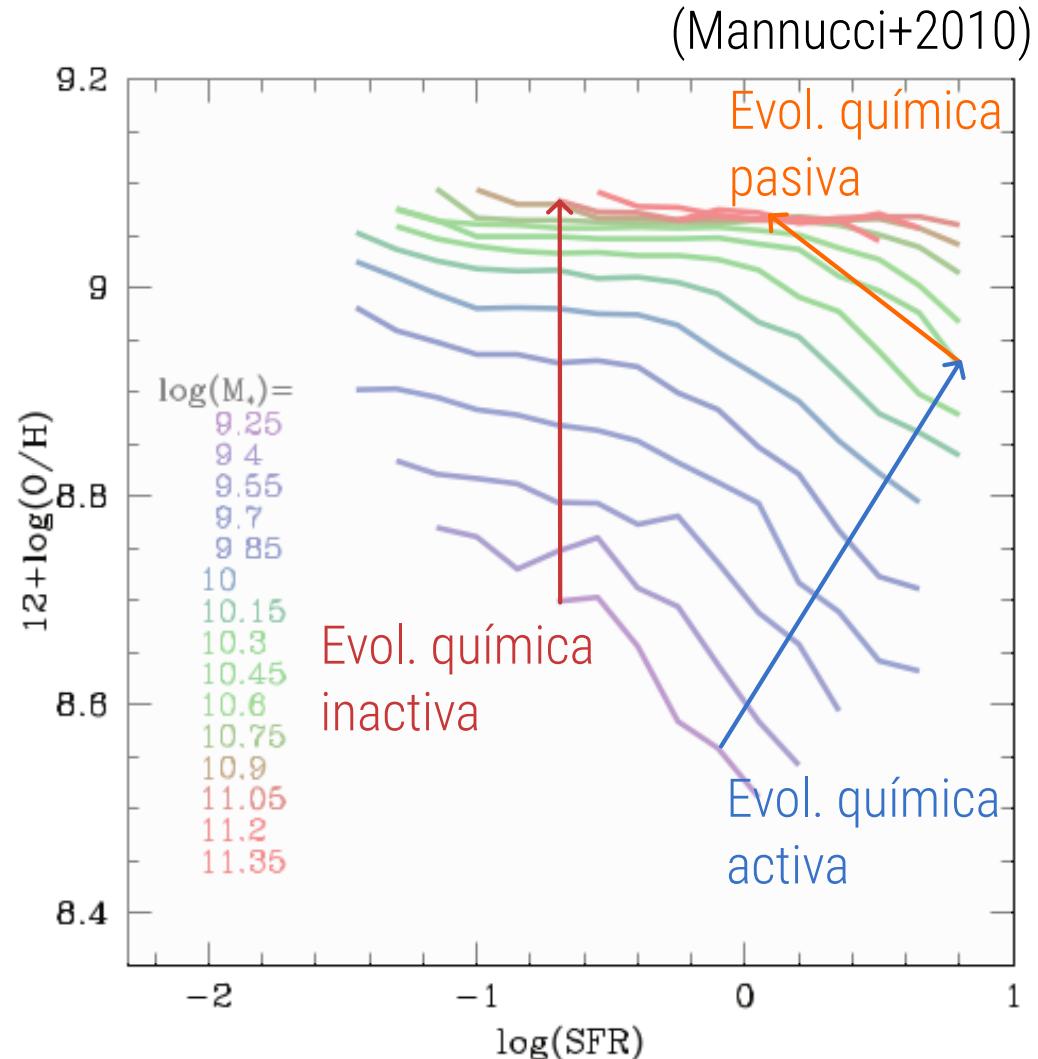


(Mannucci+2010)

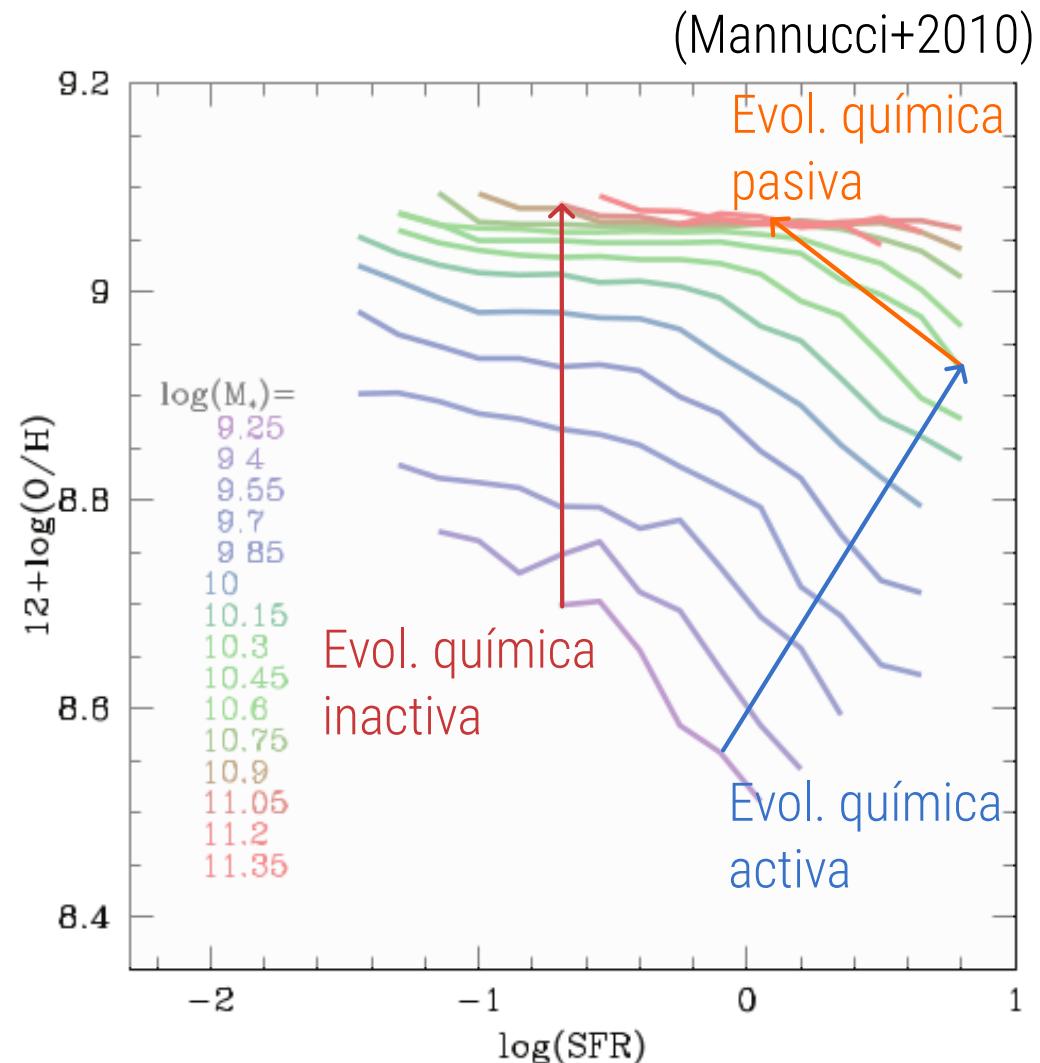
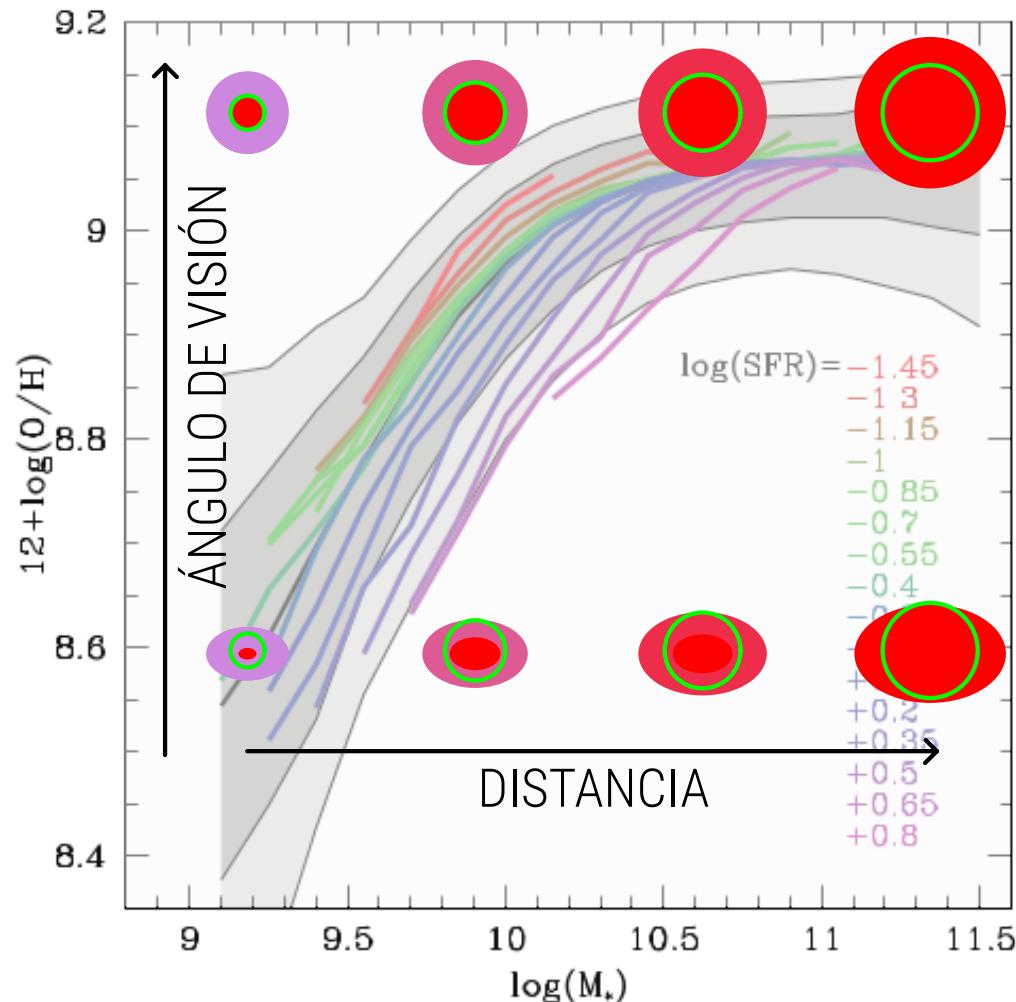
RELACIÓN MASA – METALICIDAD – TFE



¿Qué tan importante es el efecto de la apertura fija?



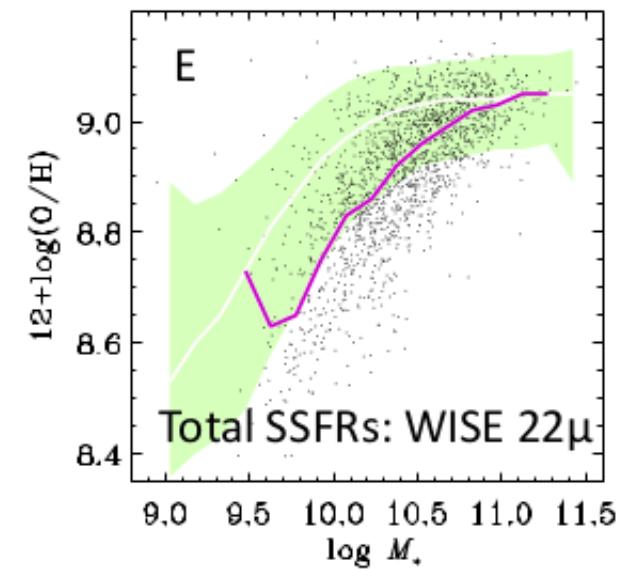
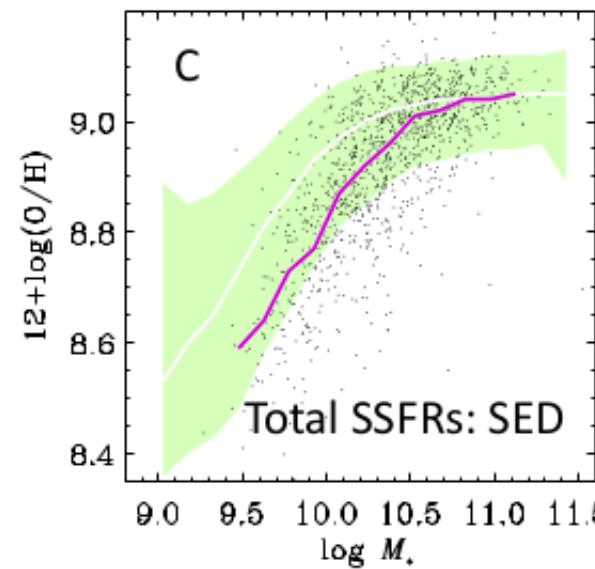
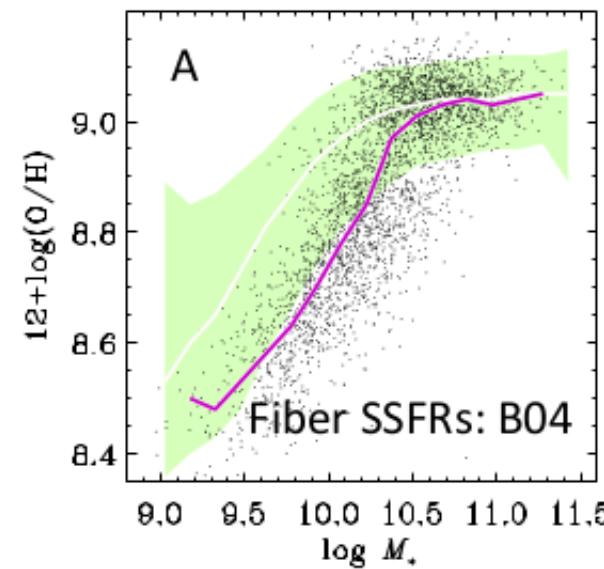
RELACIÓN MASA – METALICIDAD – TFE



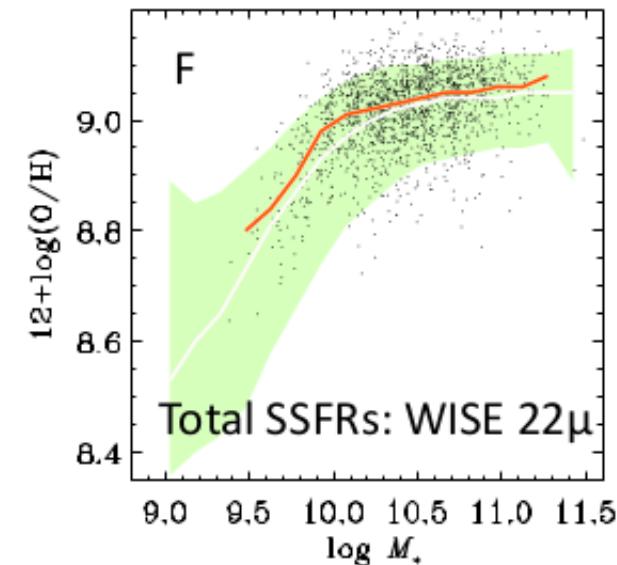
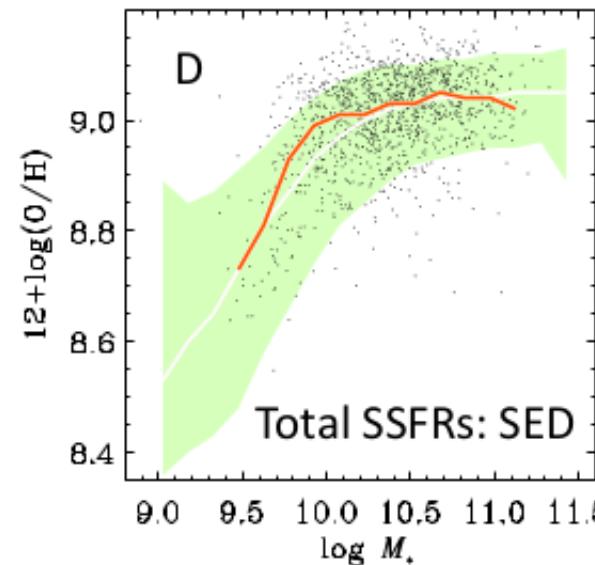
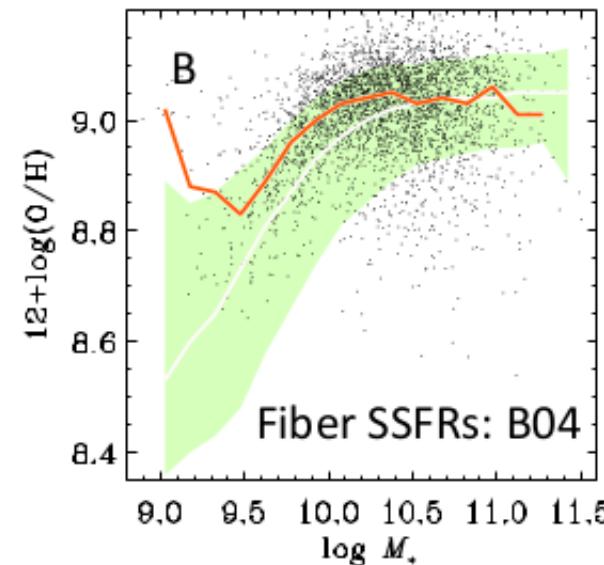
¿Qué tan importante es el efecto de la apertura fija?
¿Es la relación con la TFE primaria?

RELACIÓN MASA – METALICIDAD – TFE

(Salim+2014)



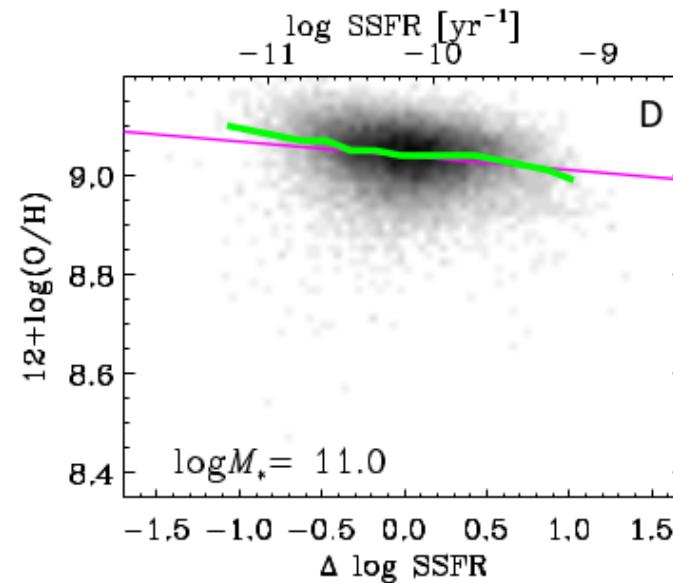
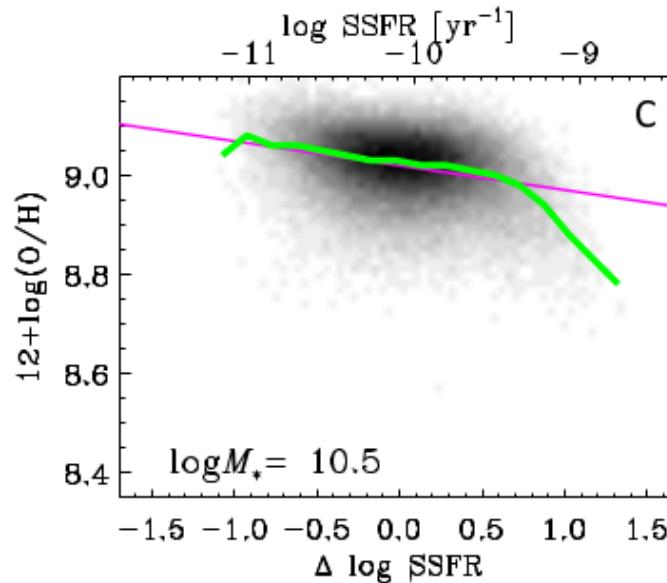
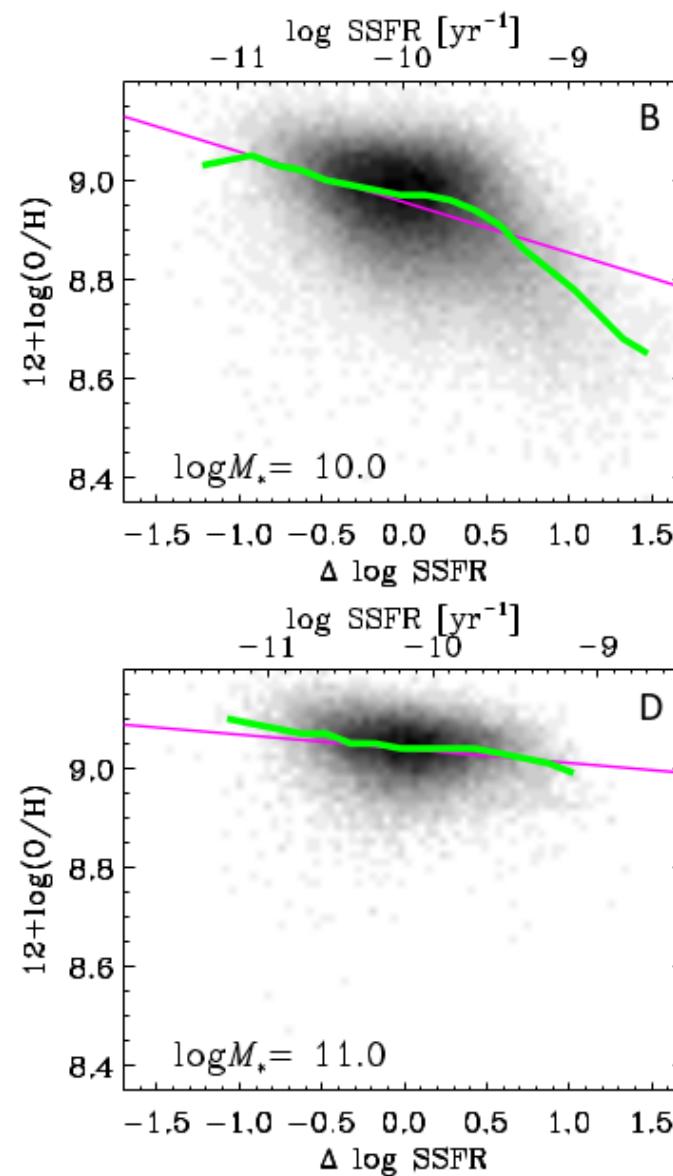
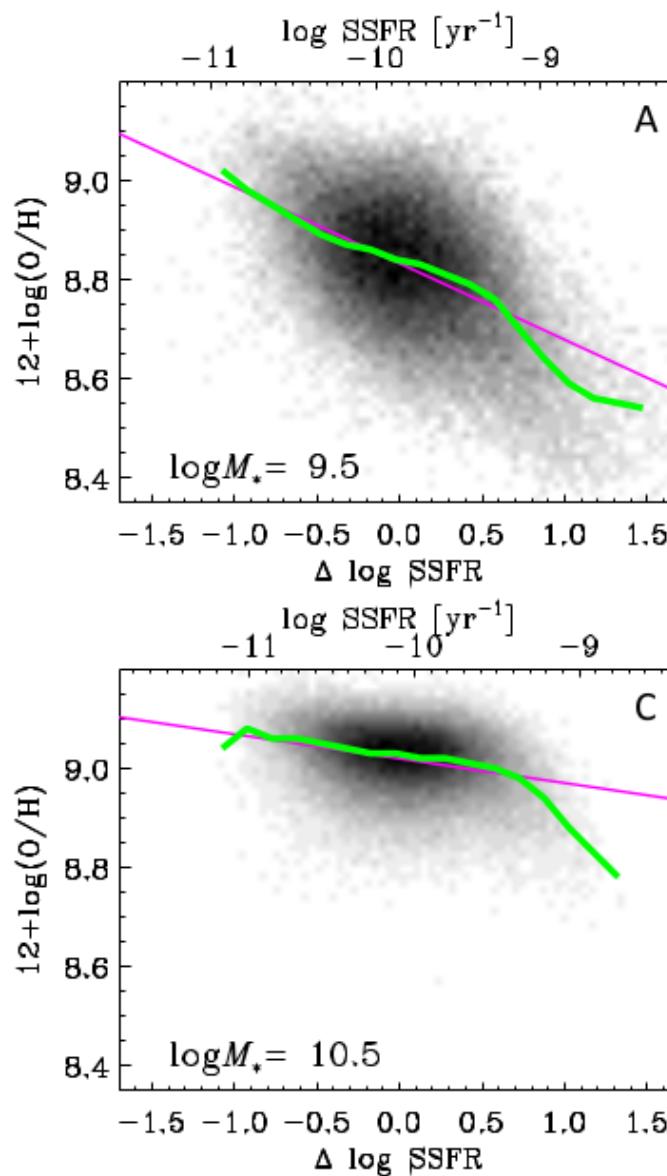
Las tendencias son las mismas que encontró Mannucci+2010.



¡El efecto de la apertura no es importante!

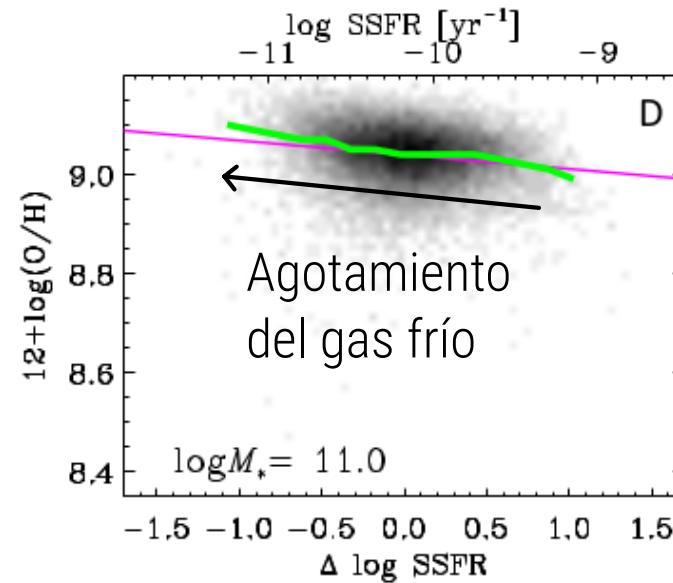
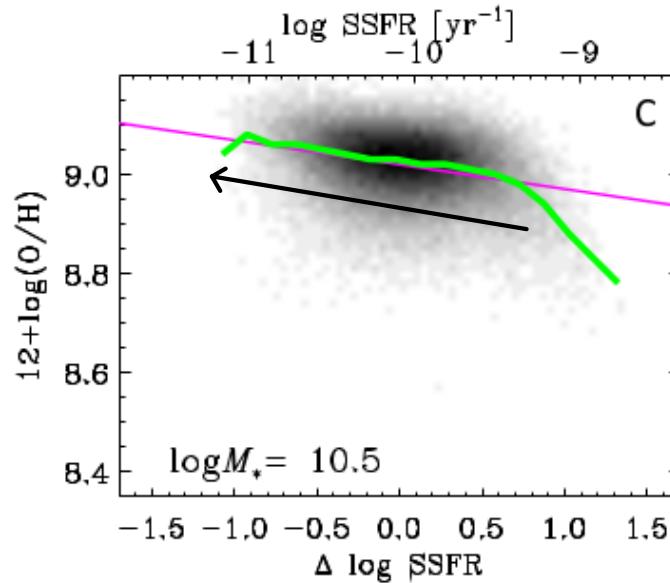
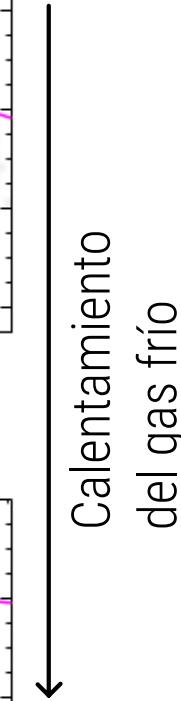
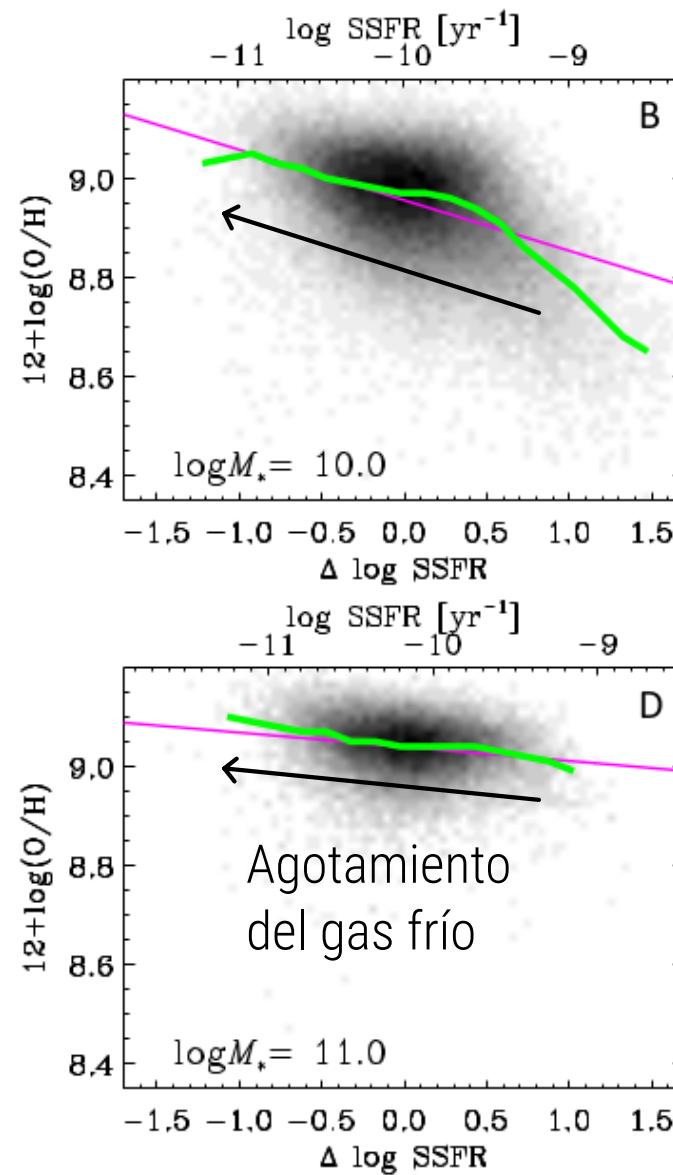
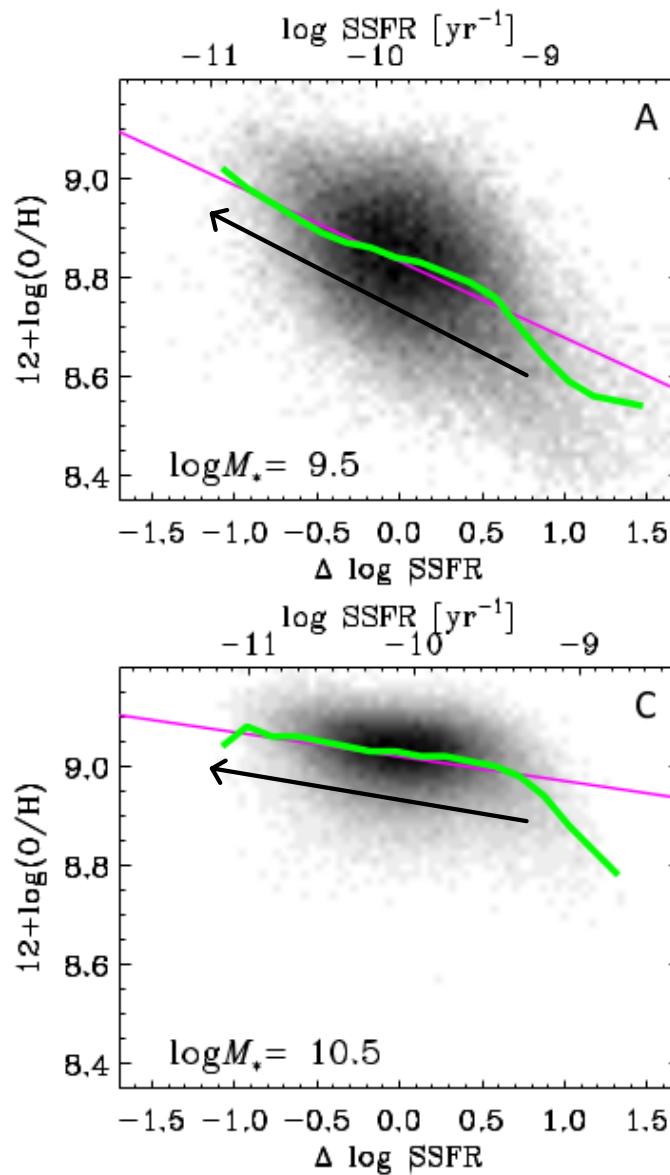
RELACIÓN MASA – METALICIDAD – TFE

(Salim+2014)



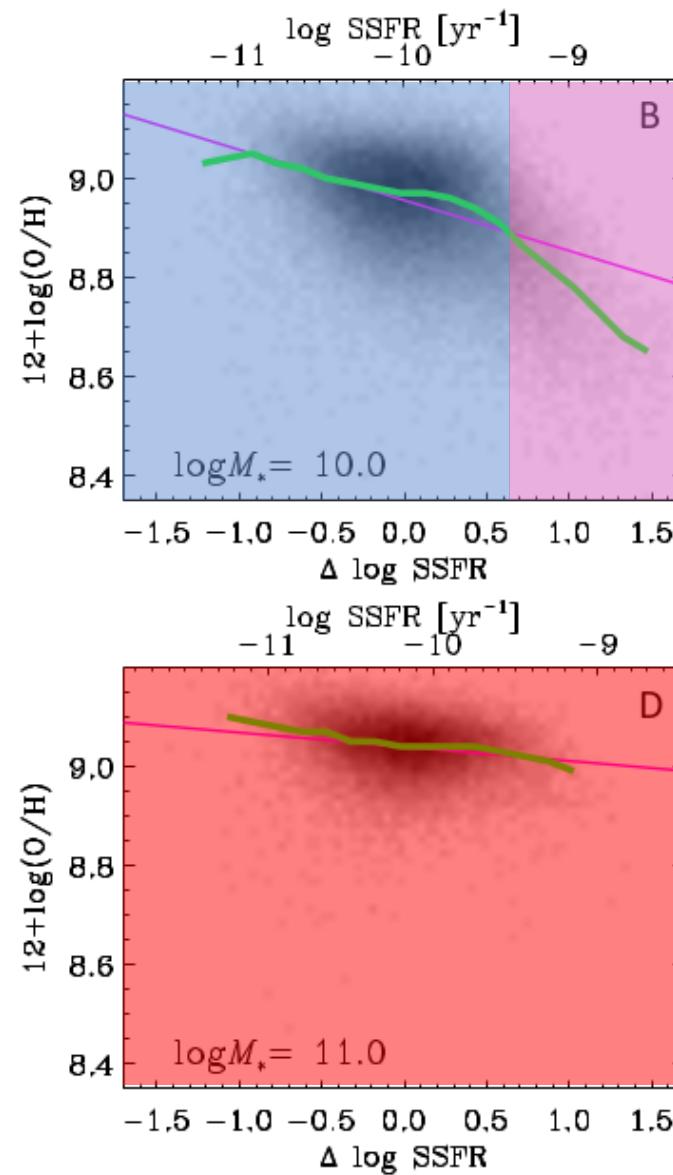
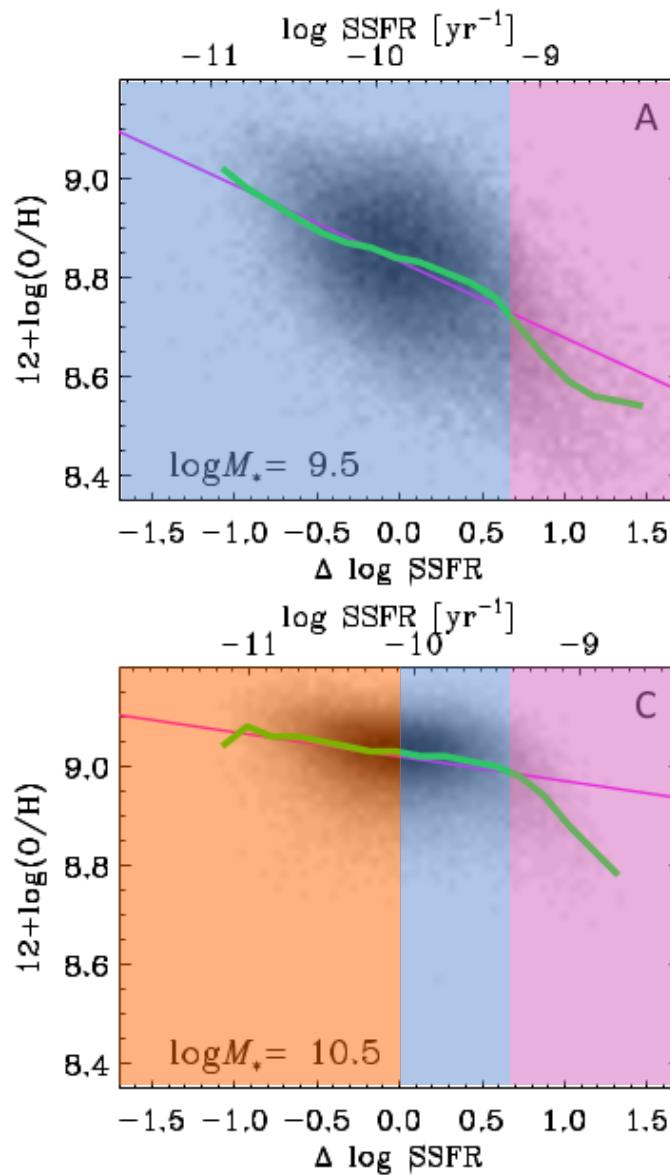
RELACIÓN MASA – METALICIDAD – TFE

(Salim+2014)

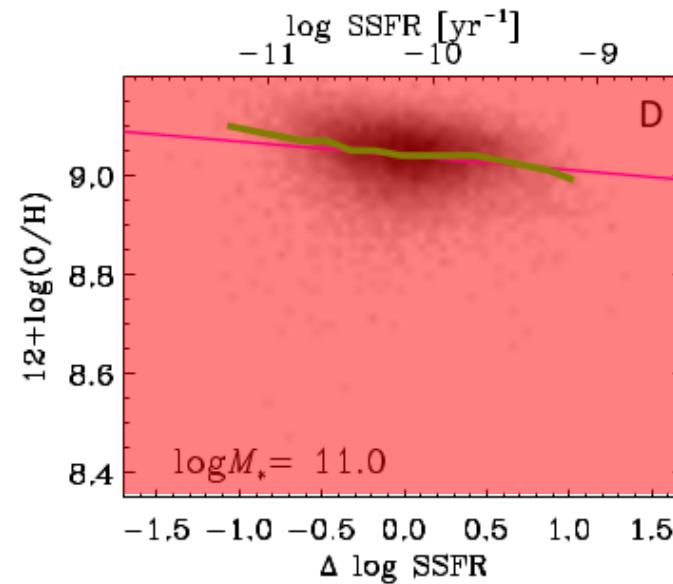
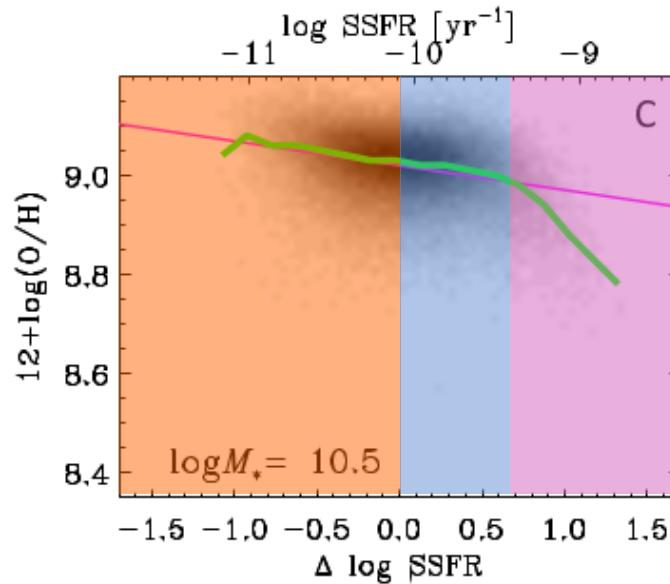


RELACIÓN MASA – METALICIDAD – TFE

(Salim+2014)

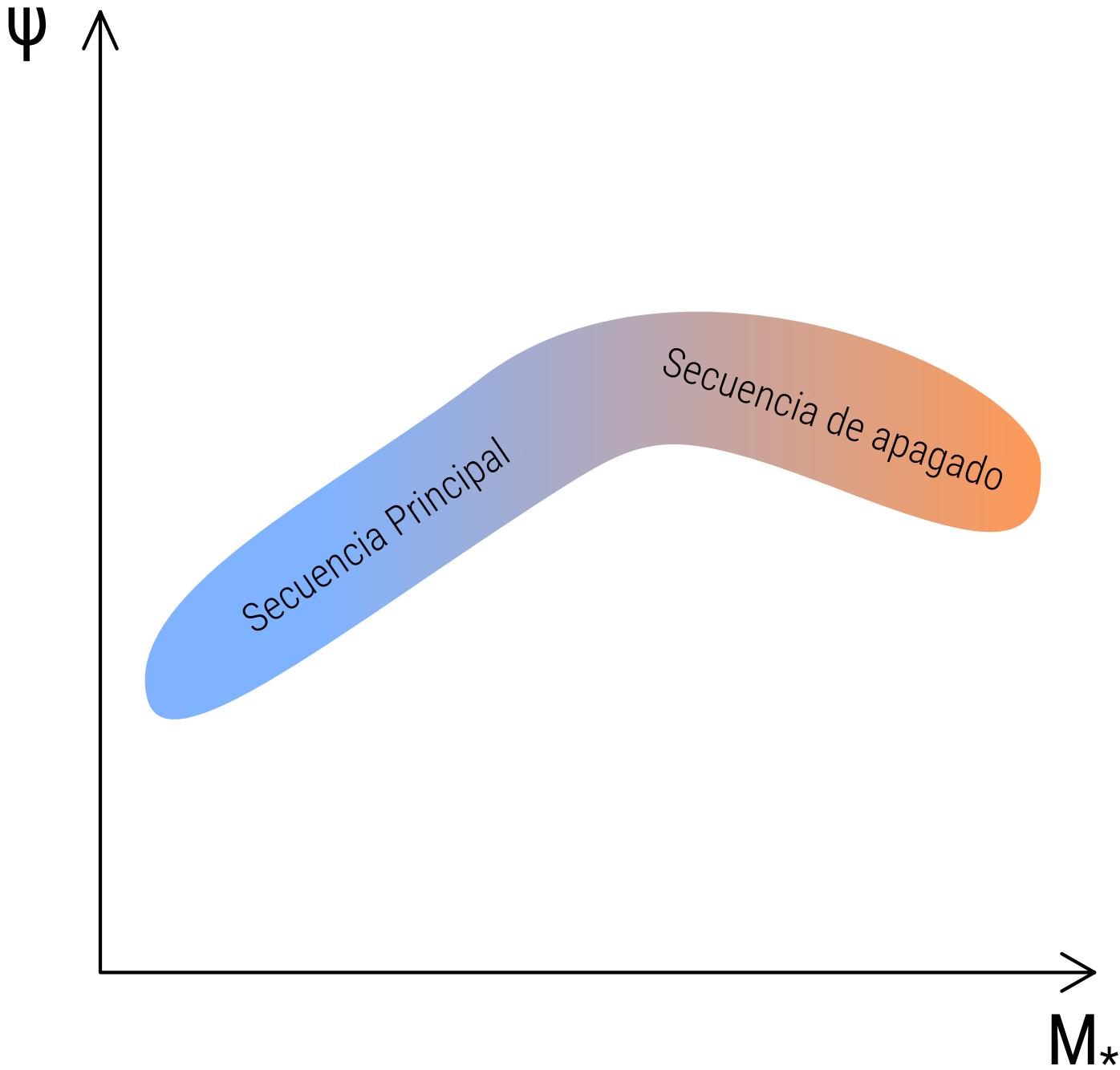


Enriquecimiento activo
Enriquecimiento violento

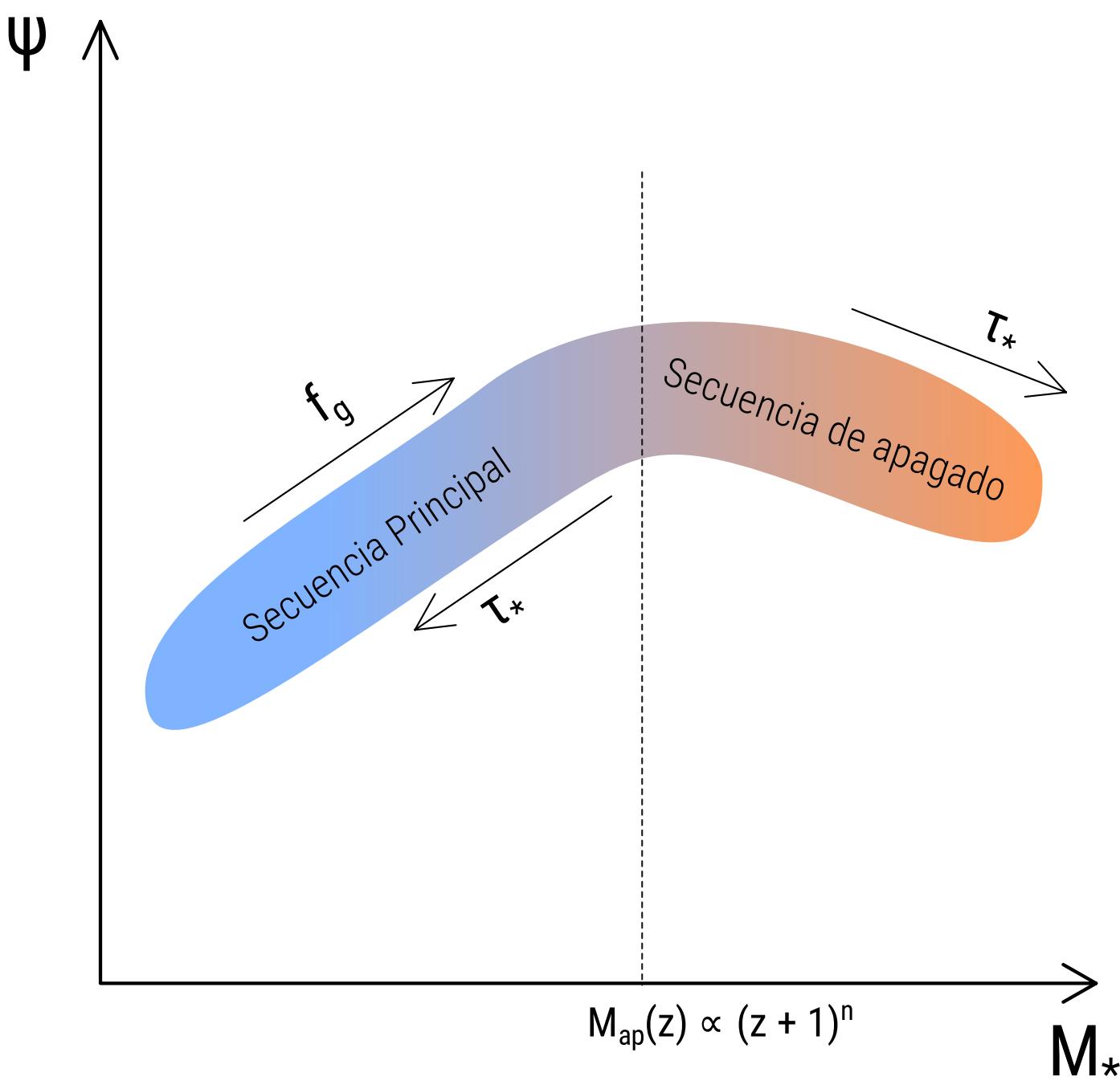


Enriquecimiento pasivo
Enriquecimiento inactivo

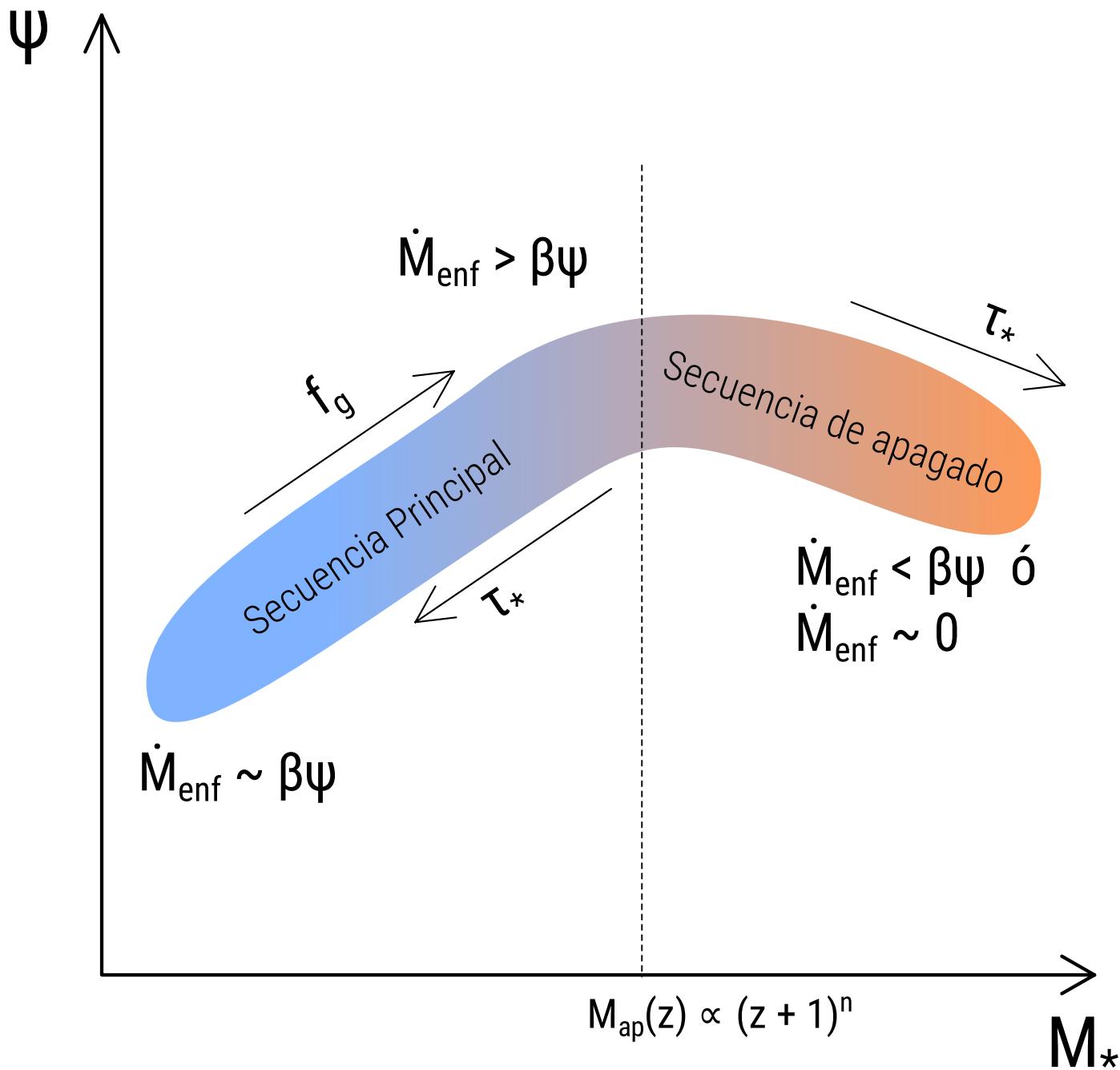
RESUMEN



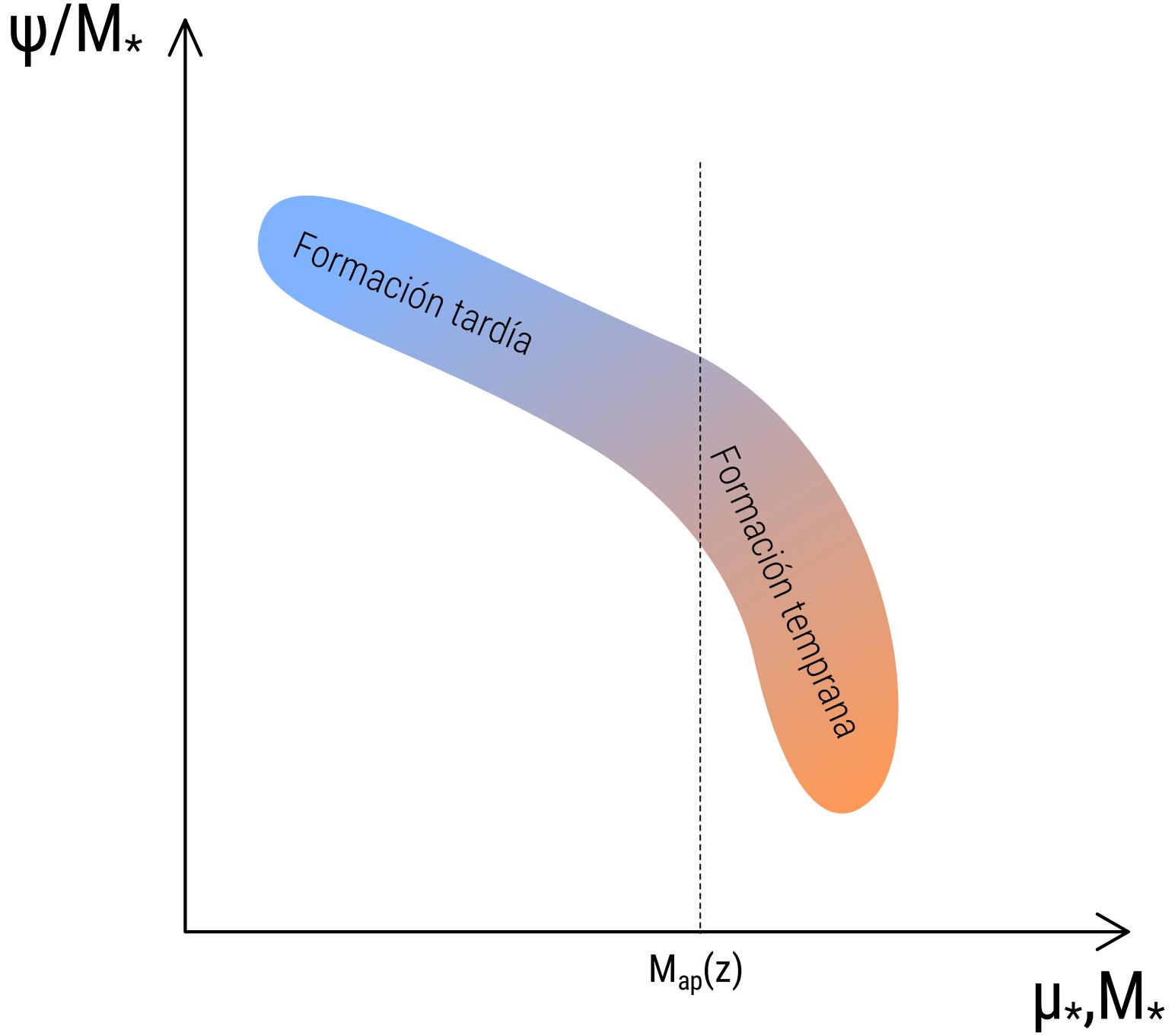
RESUMEN



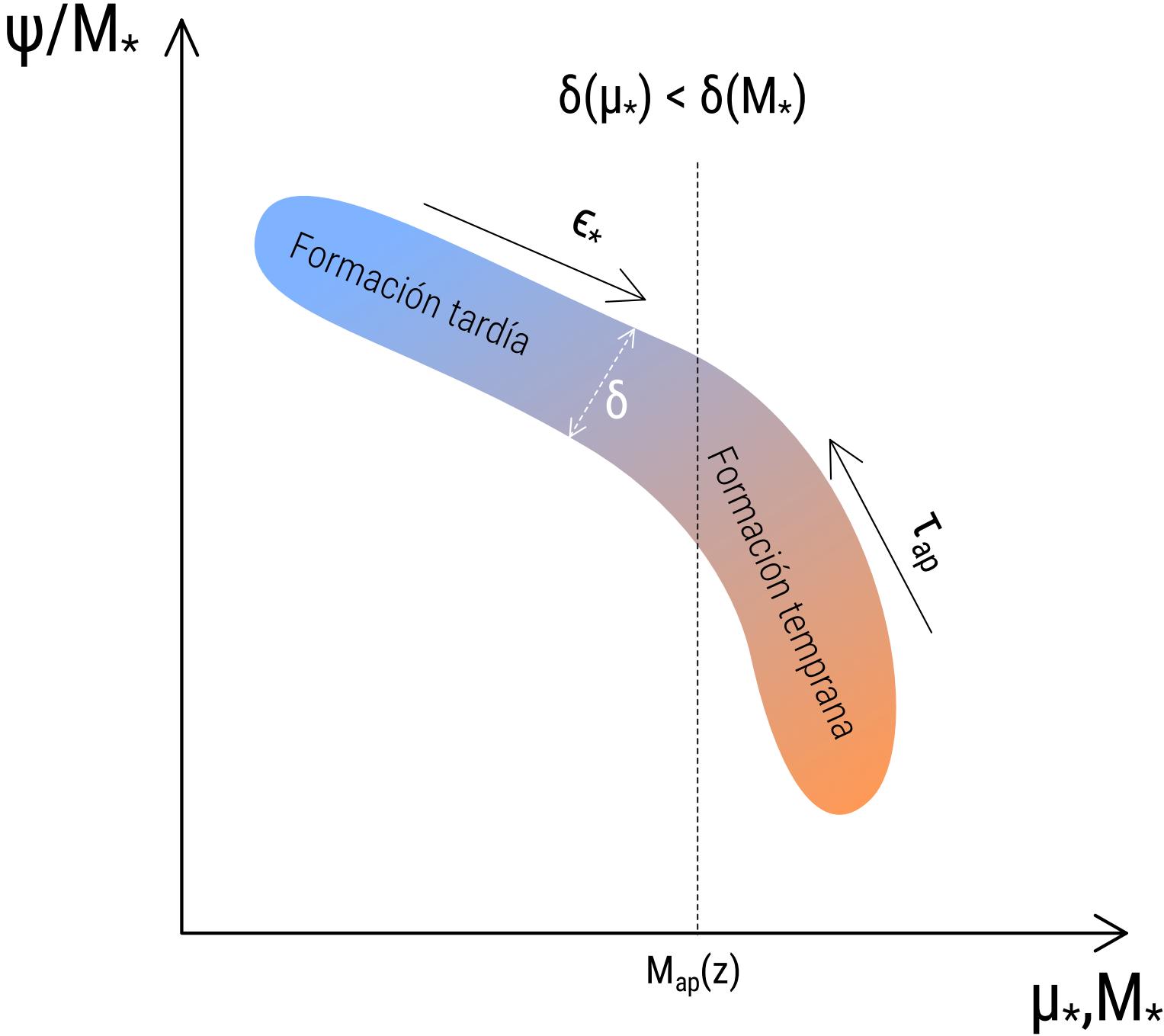
RESUMEN



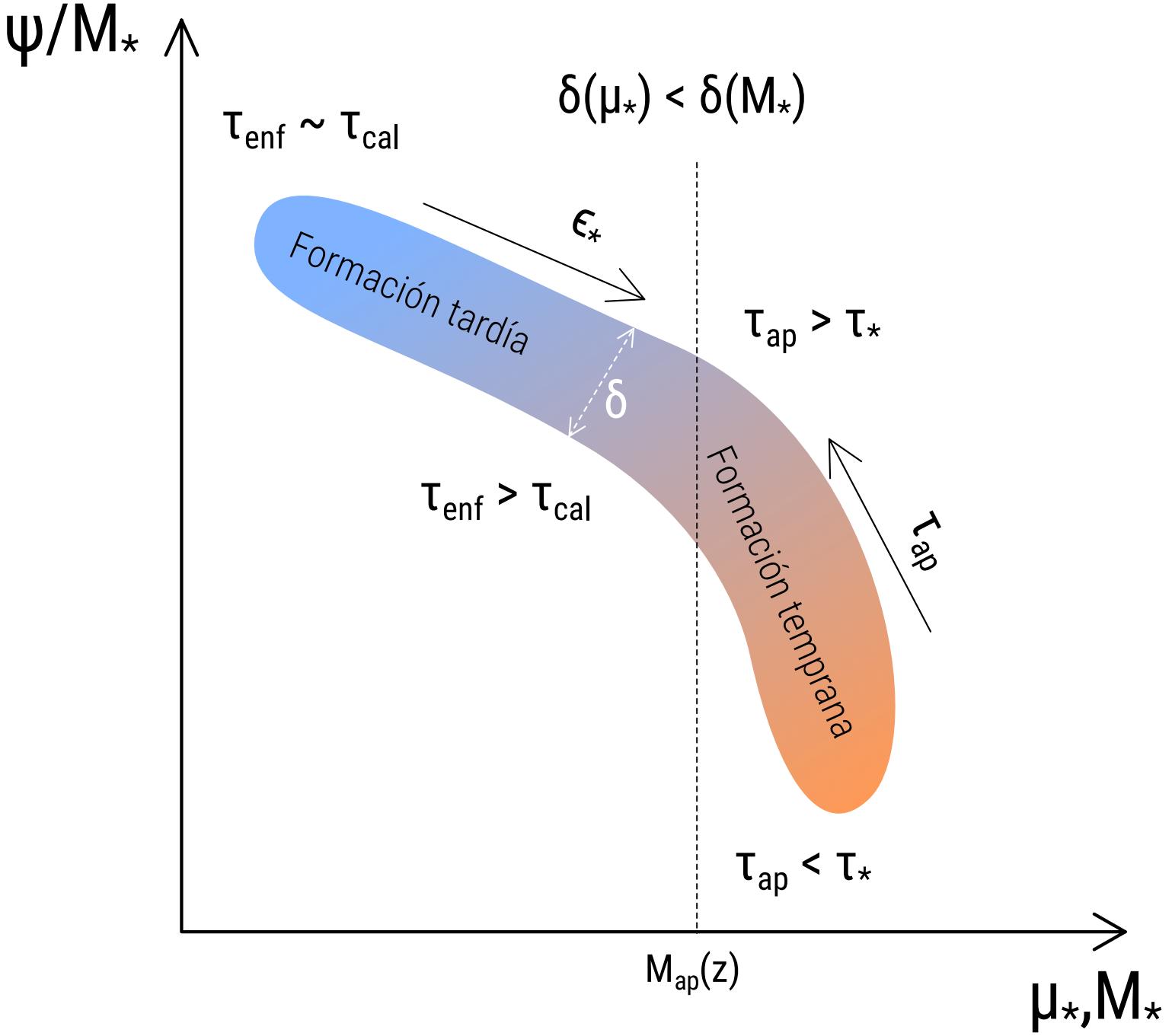
RESUMEN



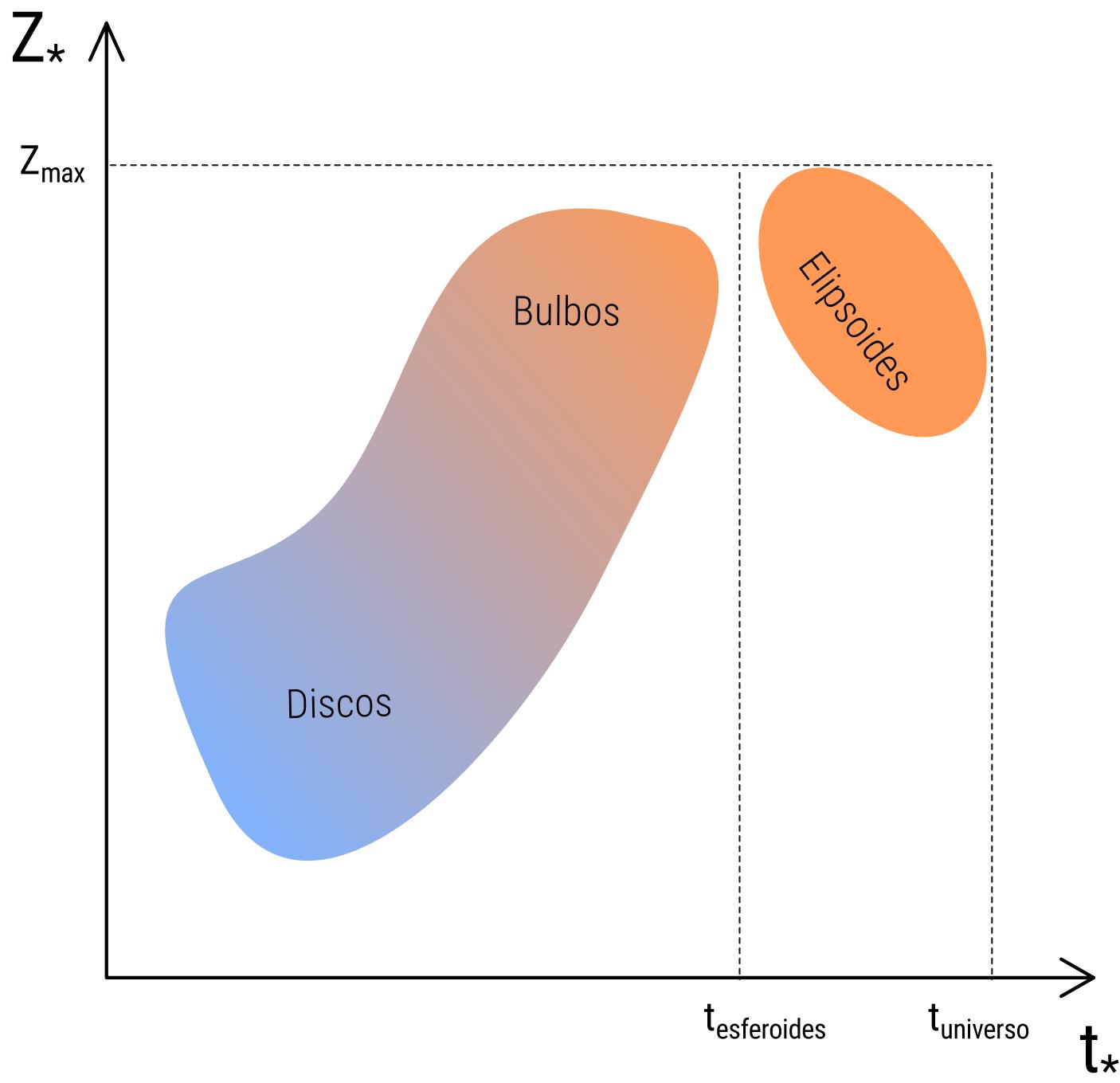
RESUMEN



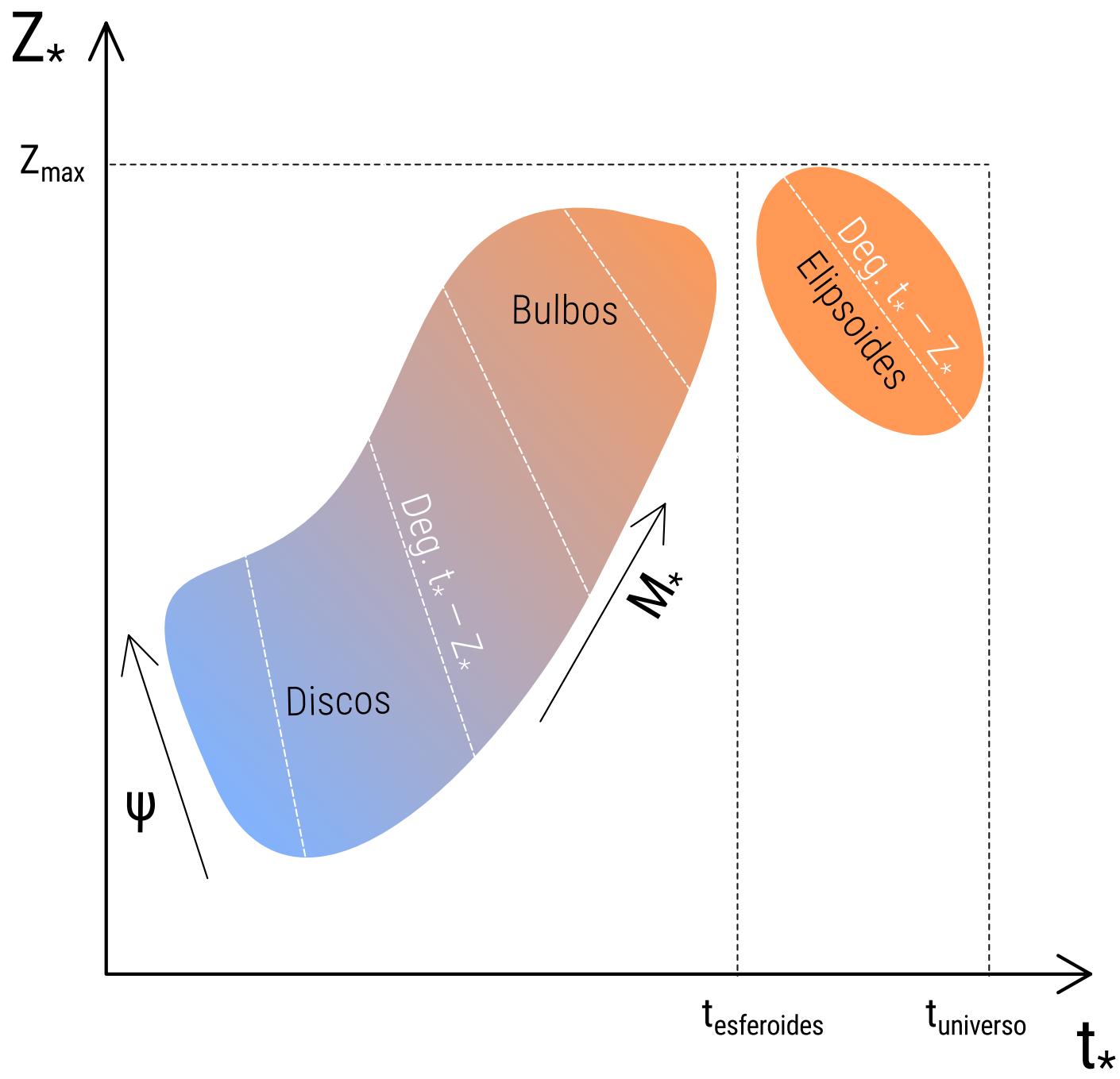
RESUMEN



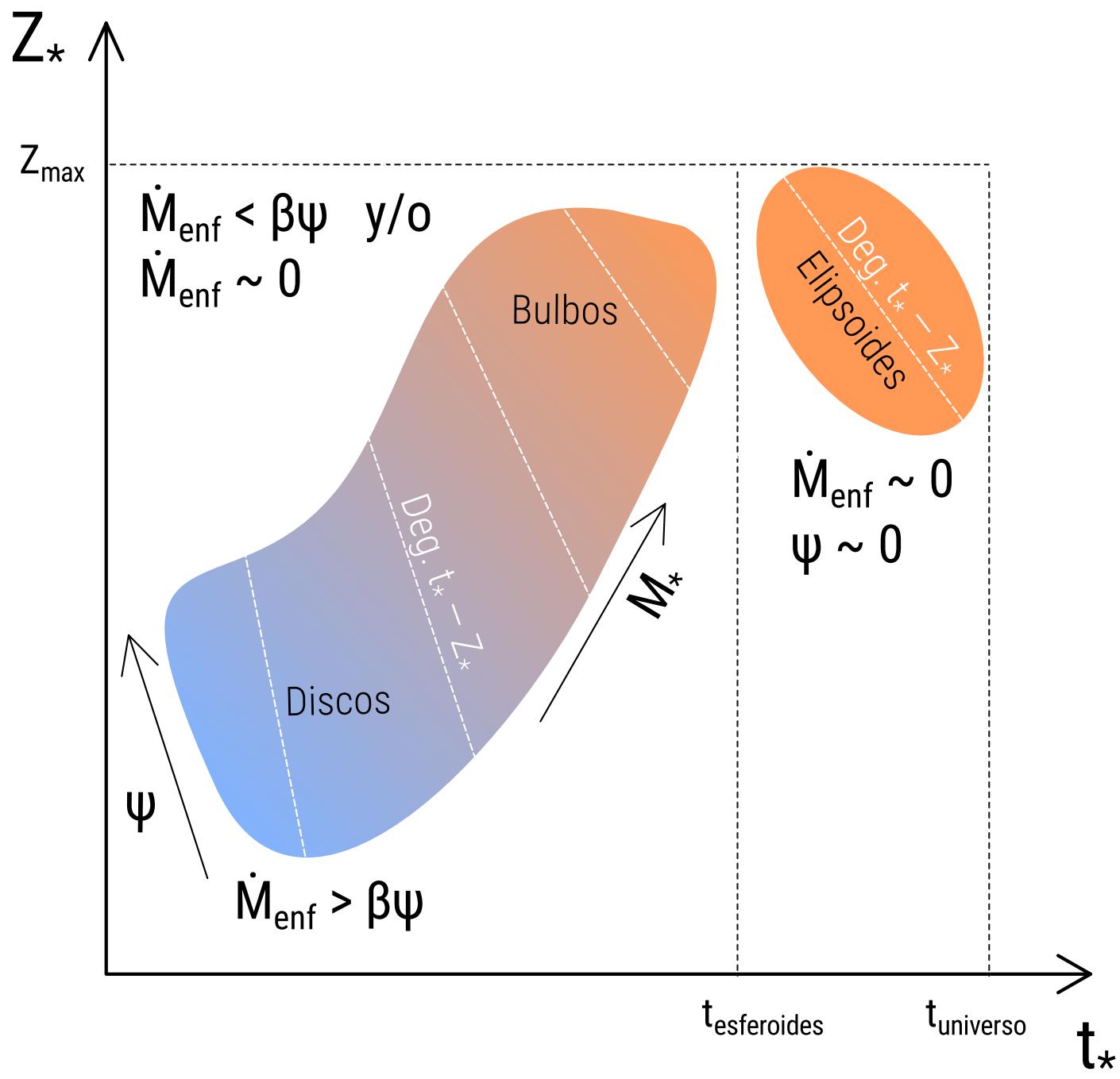
RESUMEN



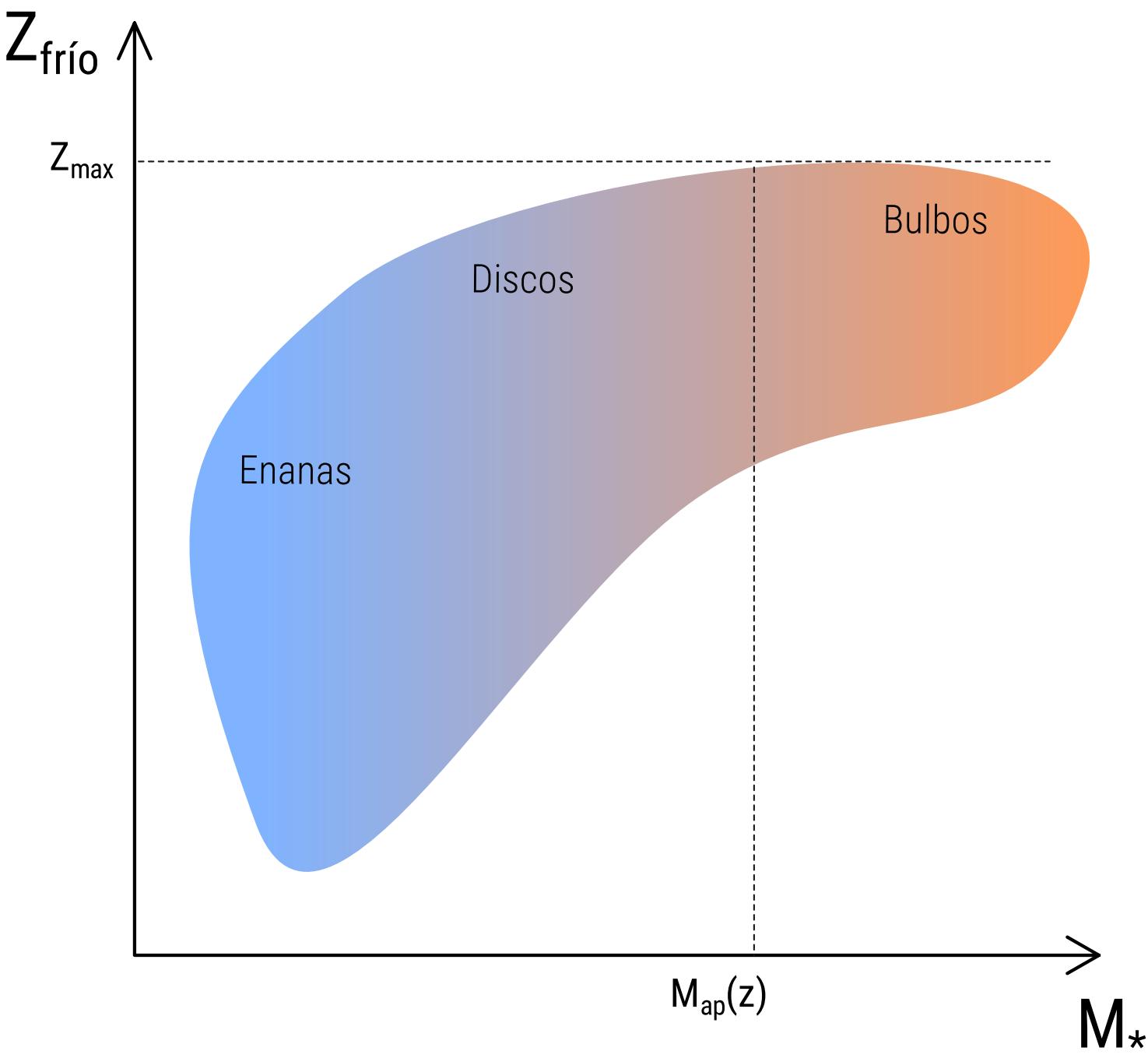
RESUMEN



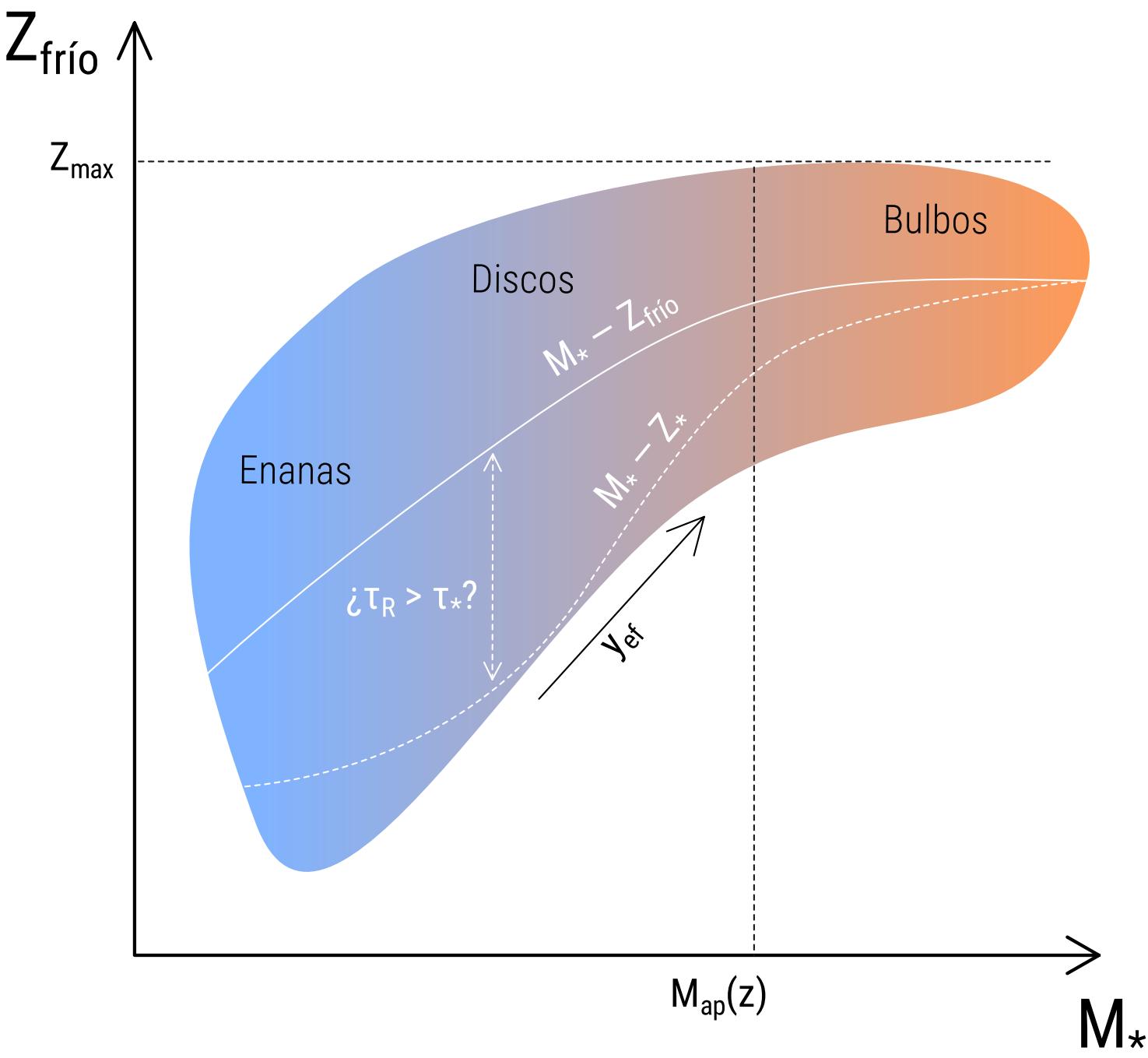
RESUMEN



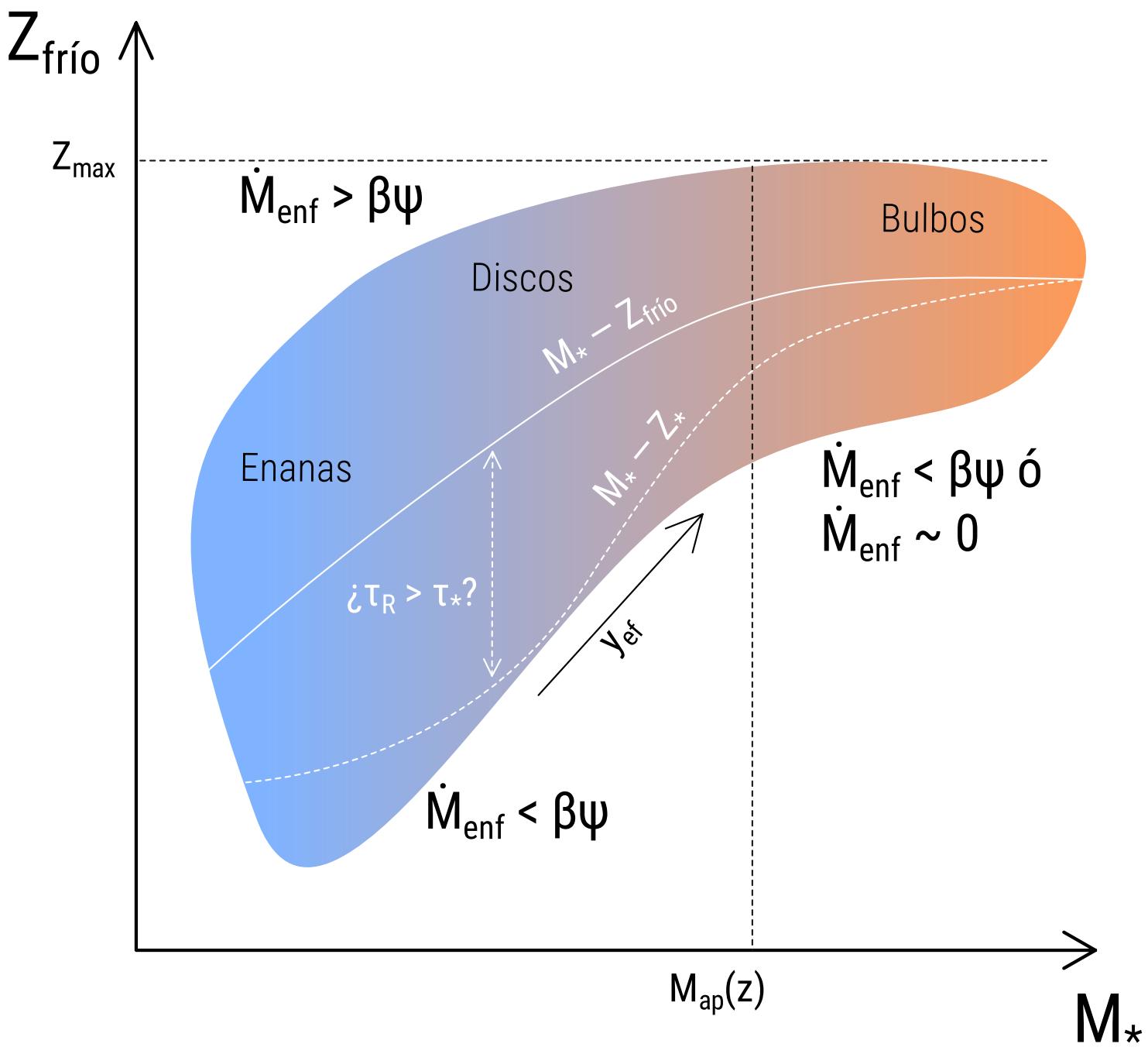
RESUMEN



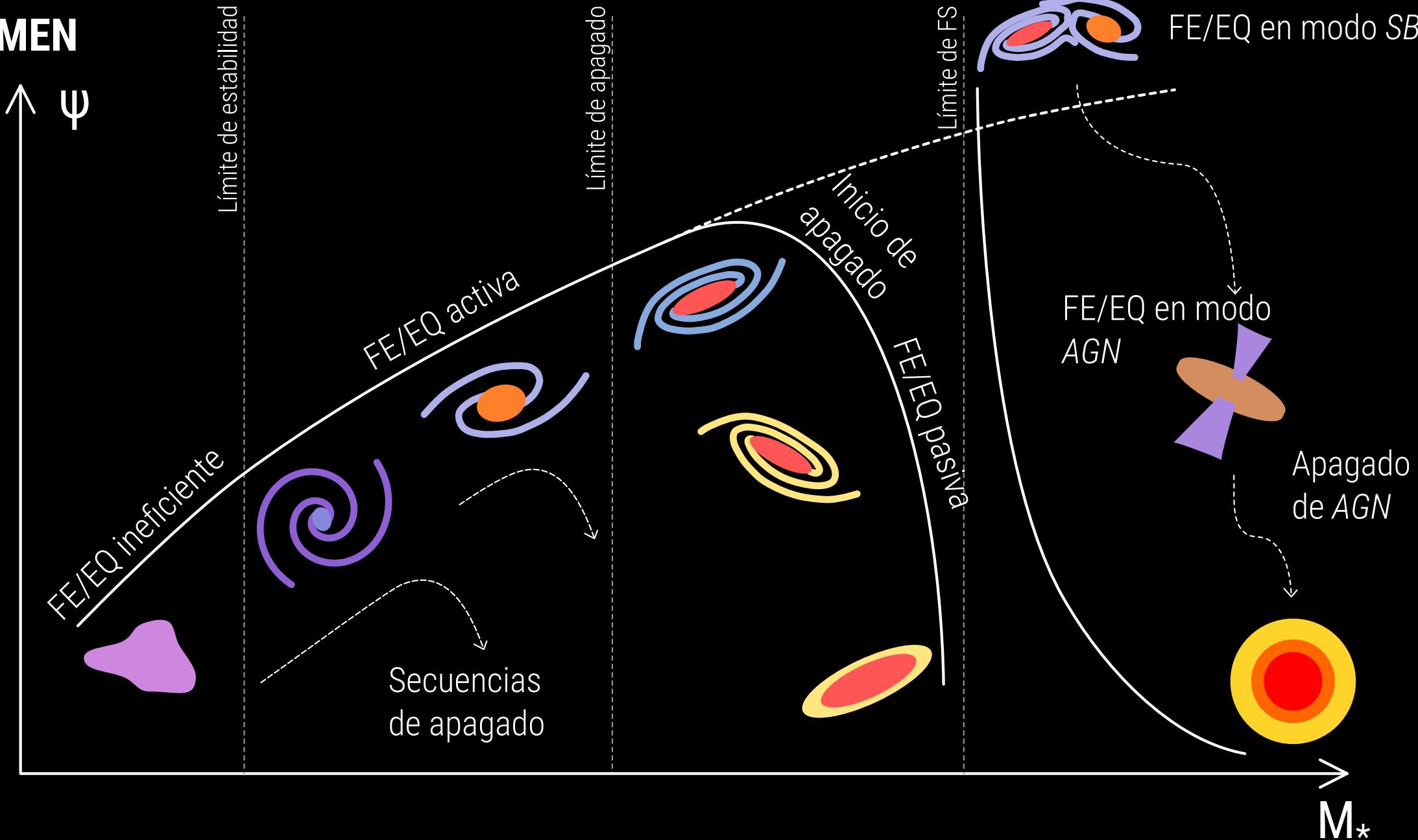
RESUMEN



RESUMEN



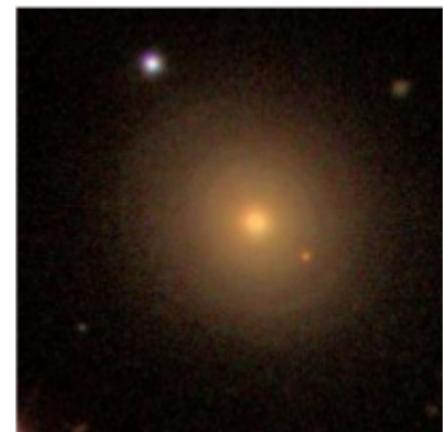
RESUMEN



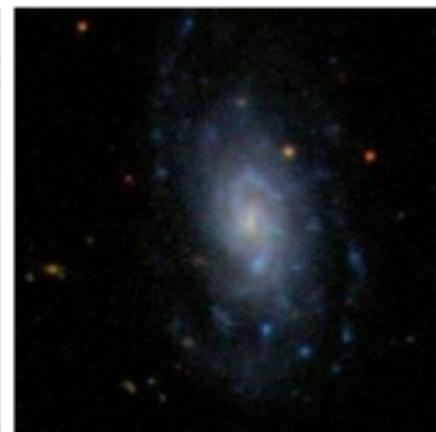
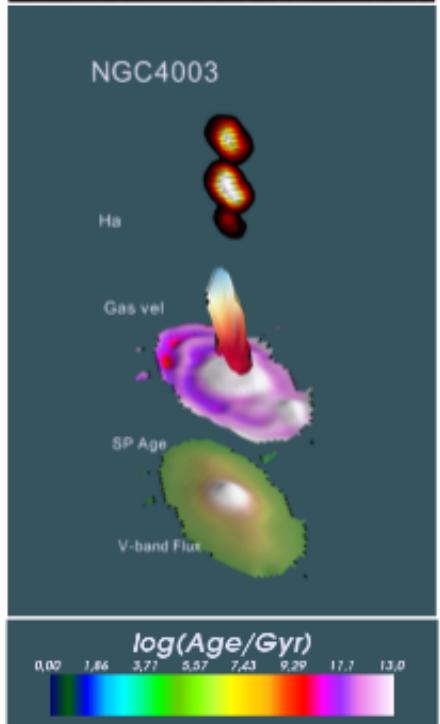
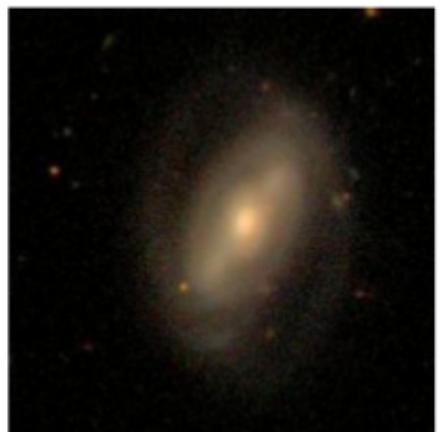
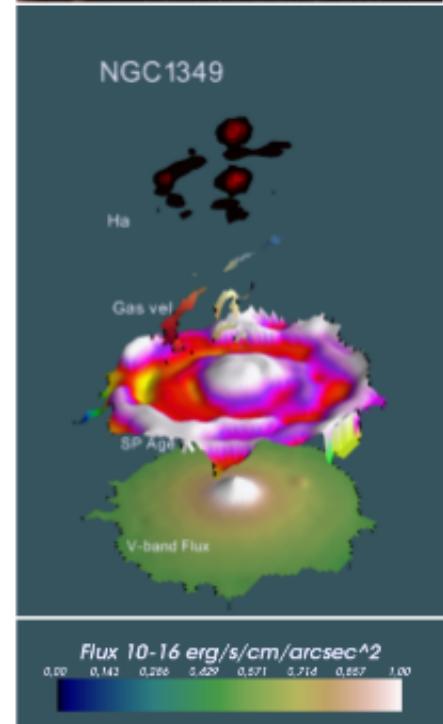
CICLO DE MASA VISTO POR CALIFA

(Sánchez+2012, Hussemann+2013)

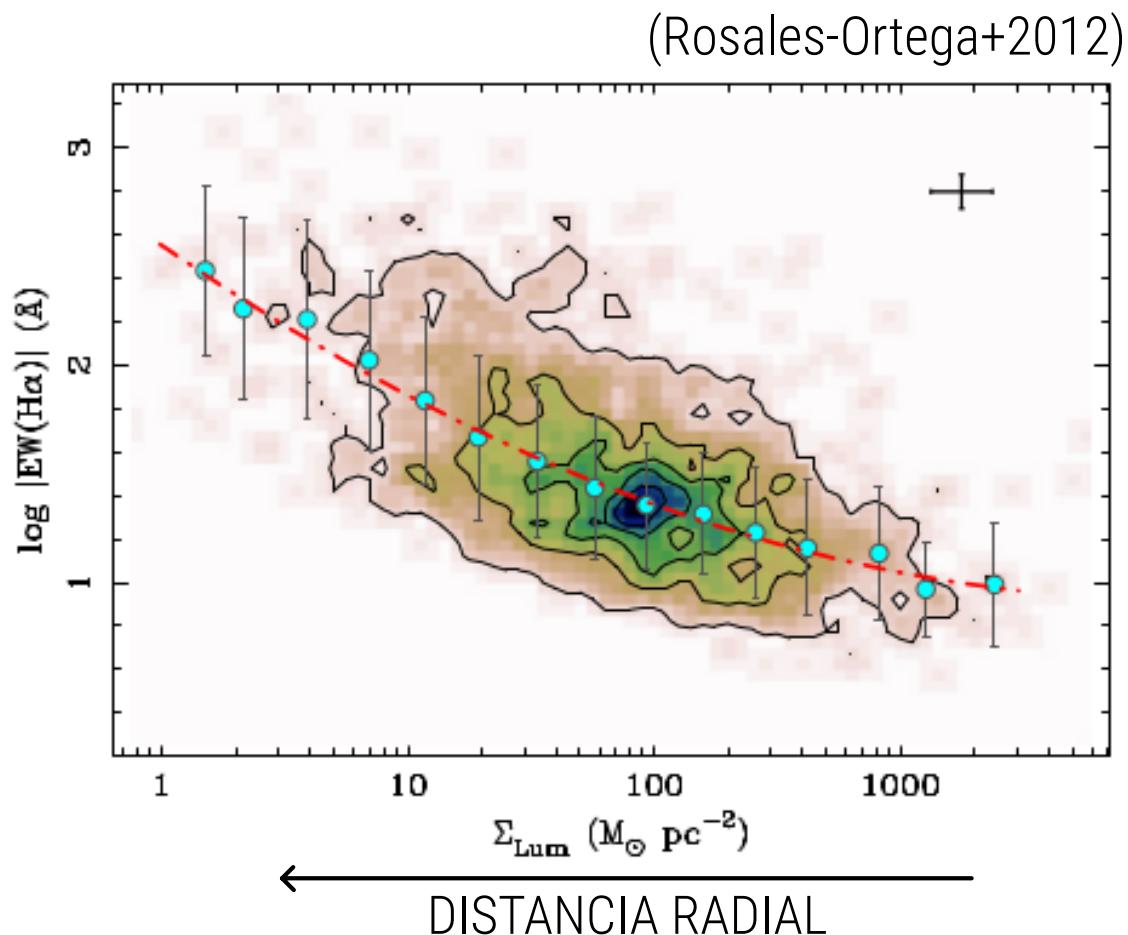
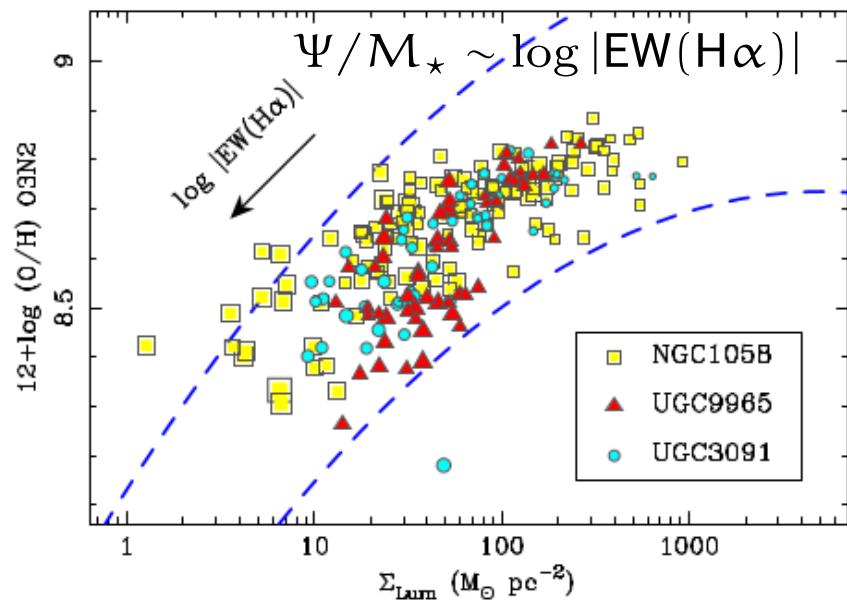
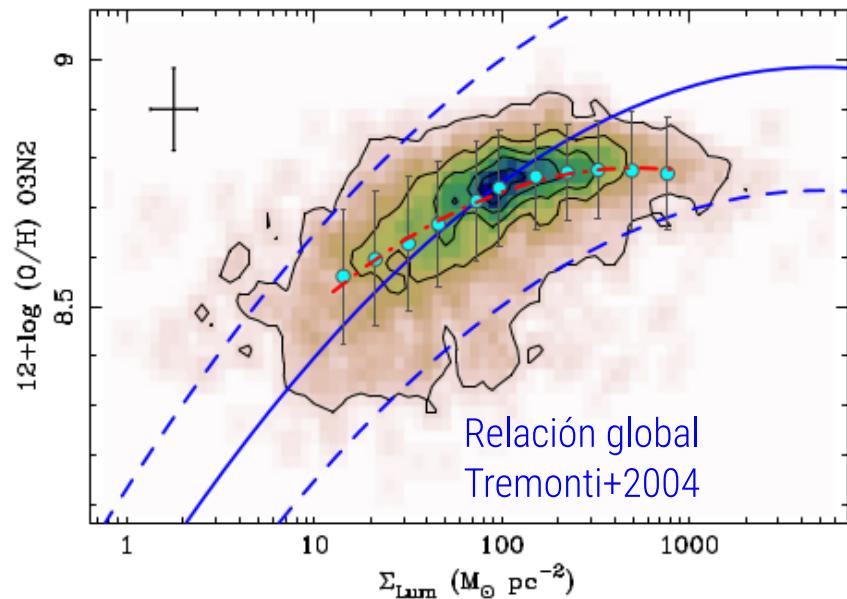
~ 600 galaxias
a lo largo de la
secuencia de
Hubble



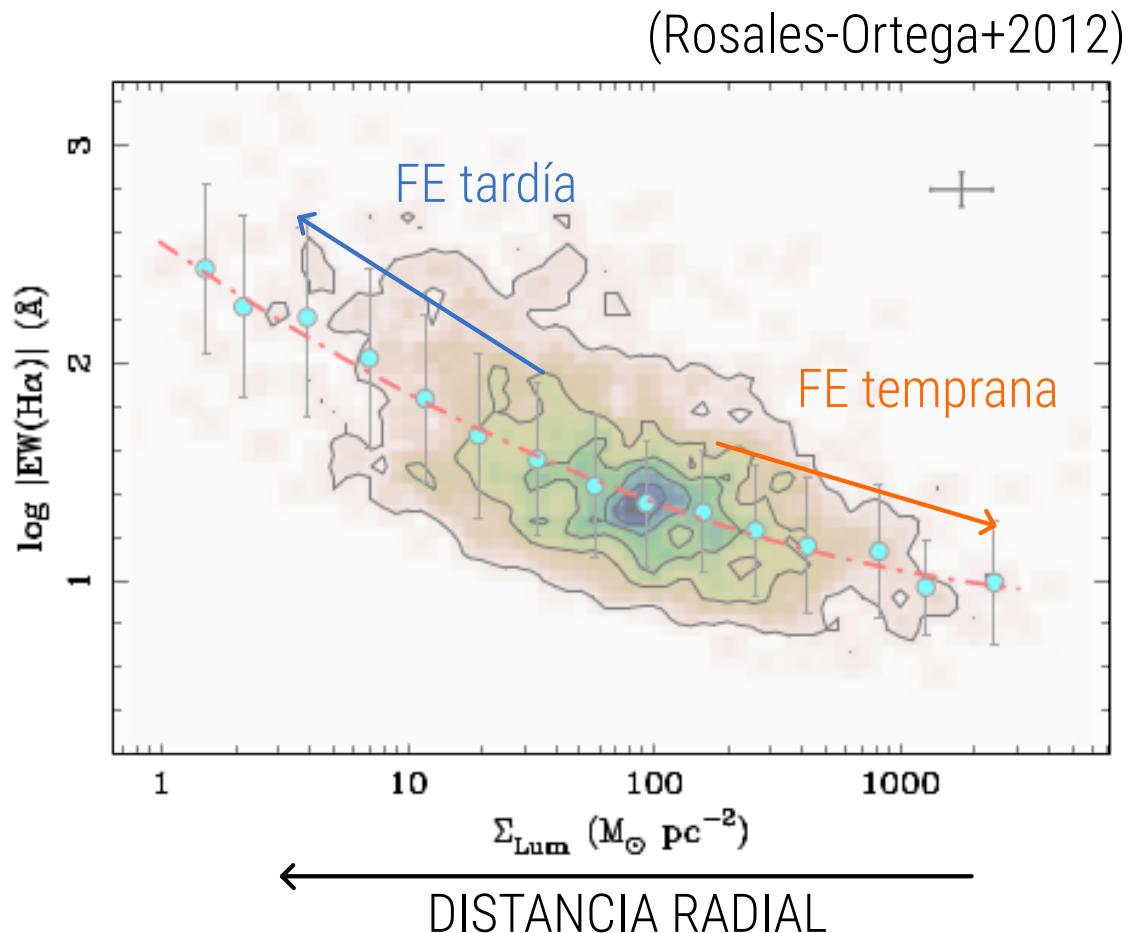
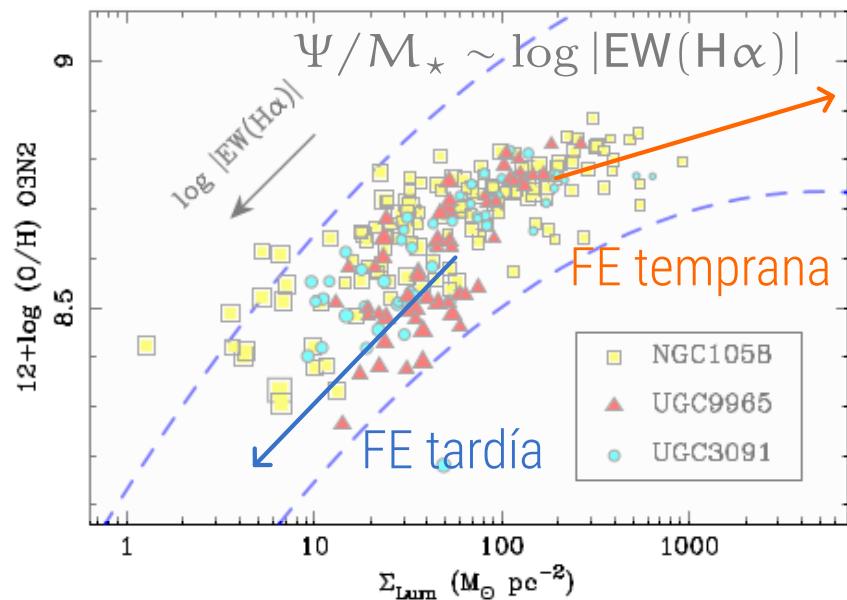
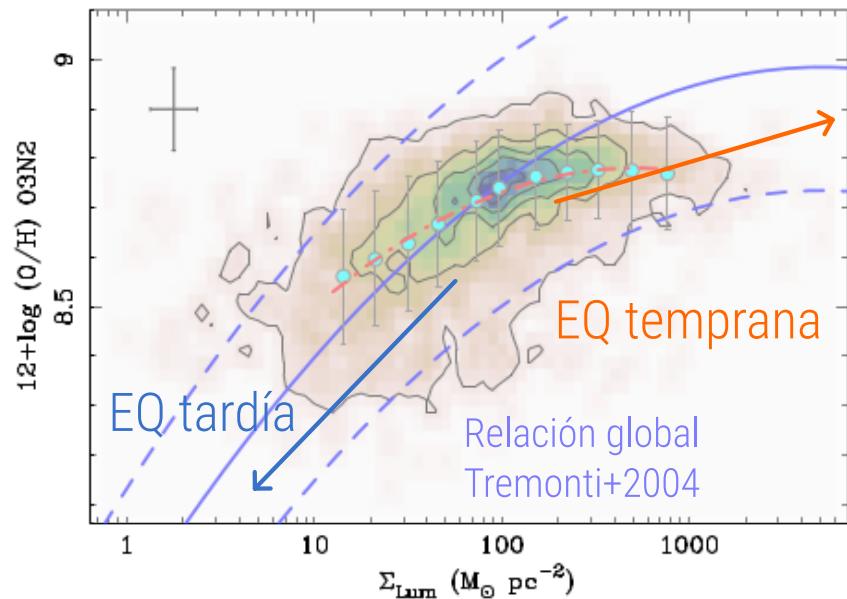
Resolución espacial ~1kpc
~1000 espectros por galaxia
resolución espectral ~1000



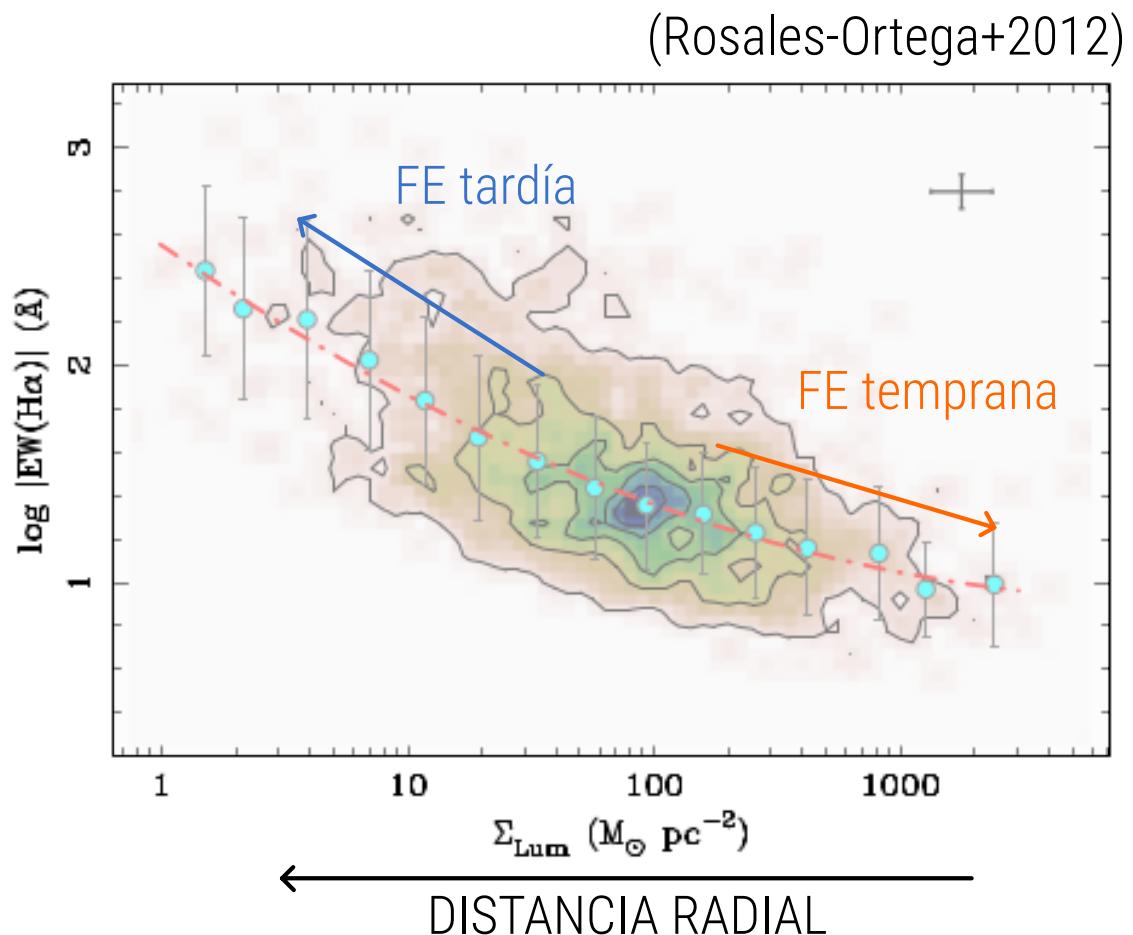
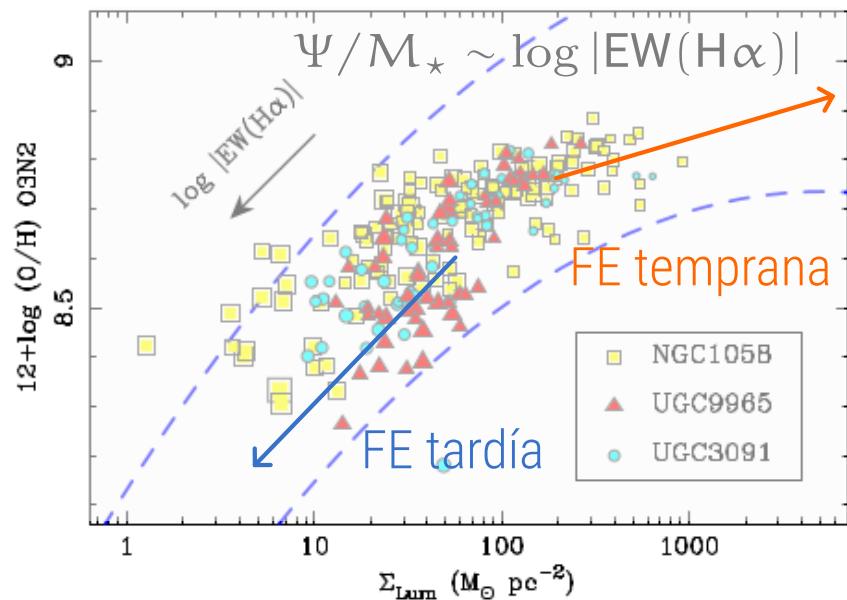
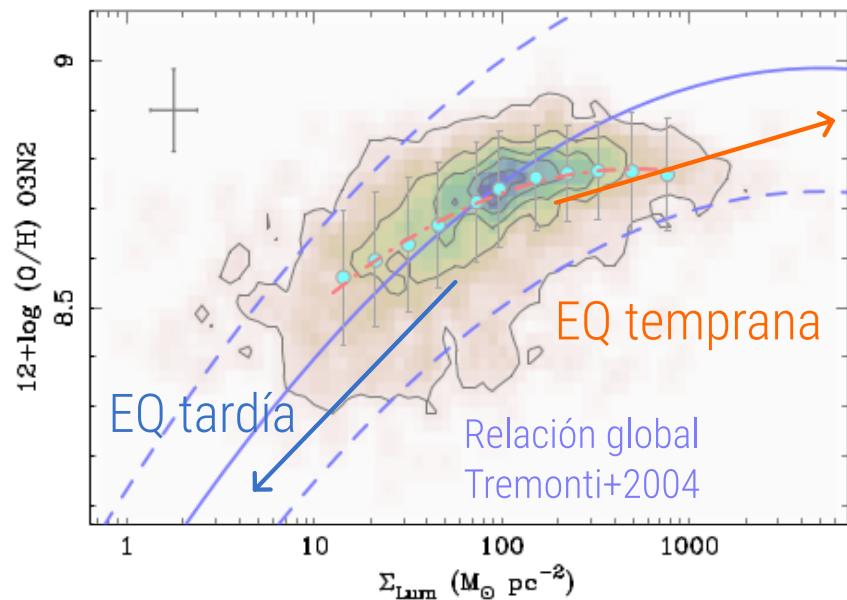
CICLO DE MASA VISTO POR CALIFA: RELACIÓN MASA – METALICIDAD – TFE



CICLO DE MASA VISTO POR CALIFA: RELACIÓN MASA – METALICIDAD – TFE



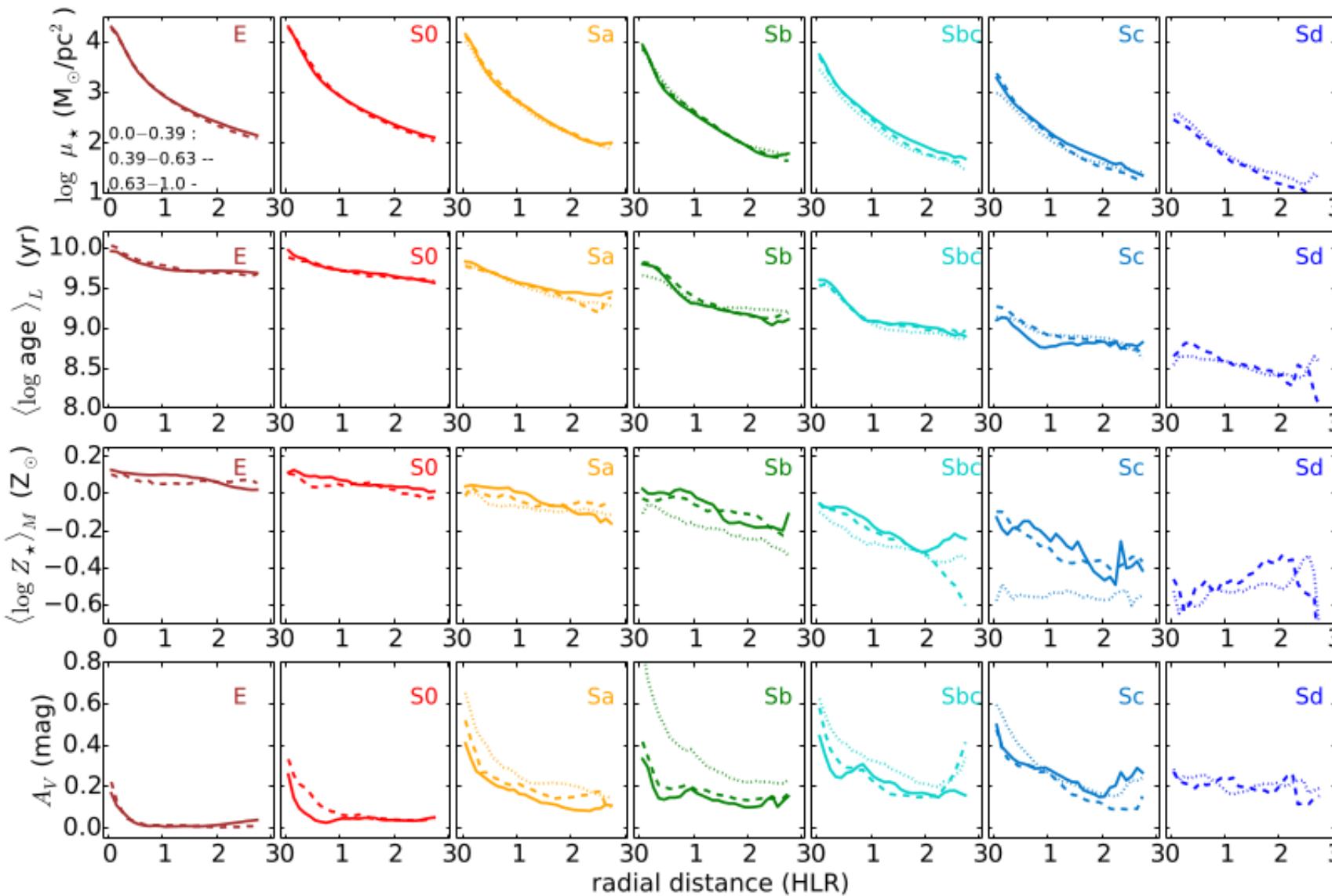
CICLO DE MASA VISTO POR CALIFA: RELACIÓN MASA – METALICIDAD – TFE



Estos resultados sugieren:
Crecimiento *inside-out*
Downsizing local

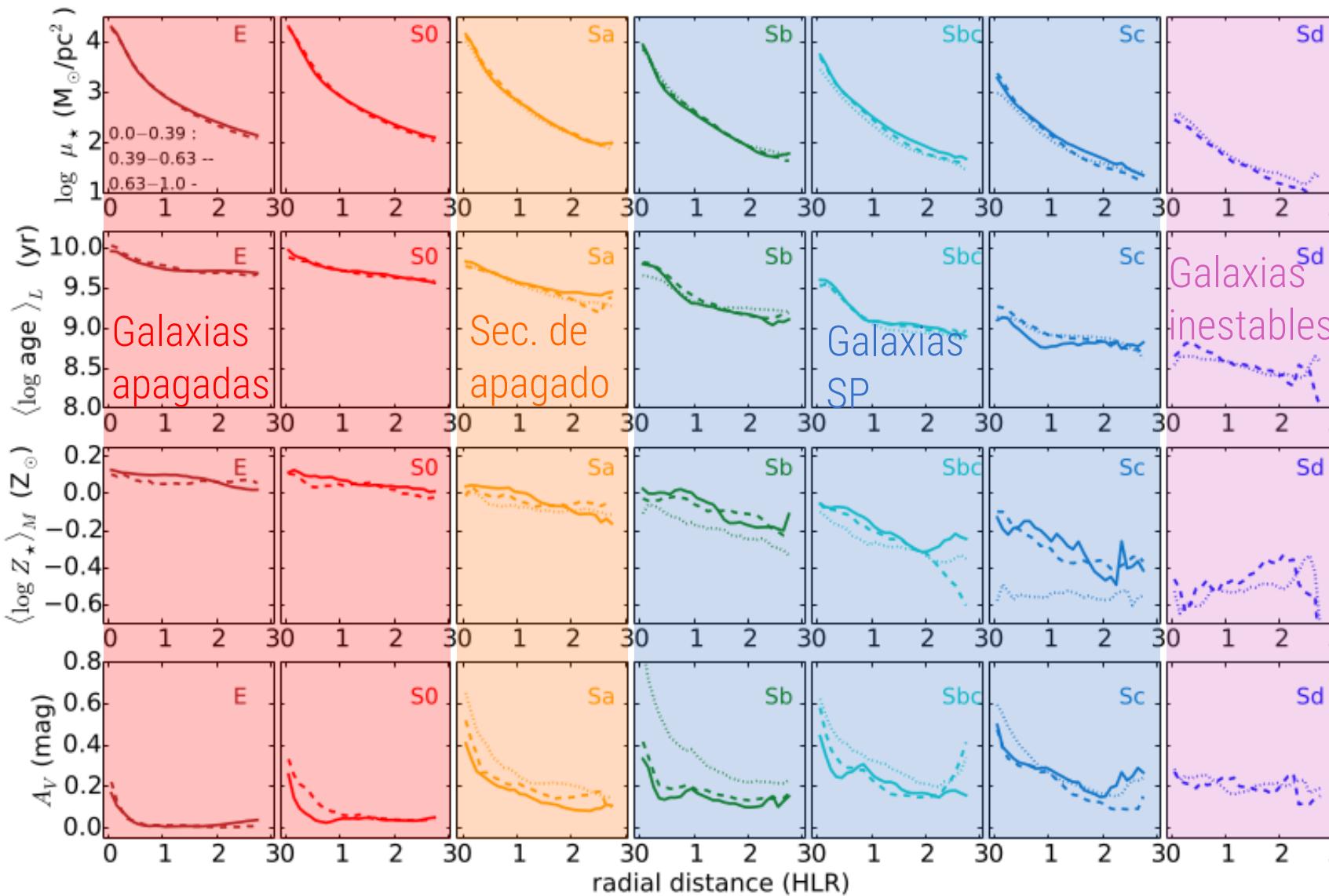
CICLO DE MASA VISTO POR CALIFA: GRADIENTES RADIALES

(González Delgado+2015)



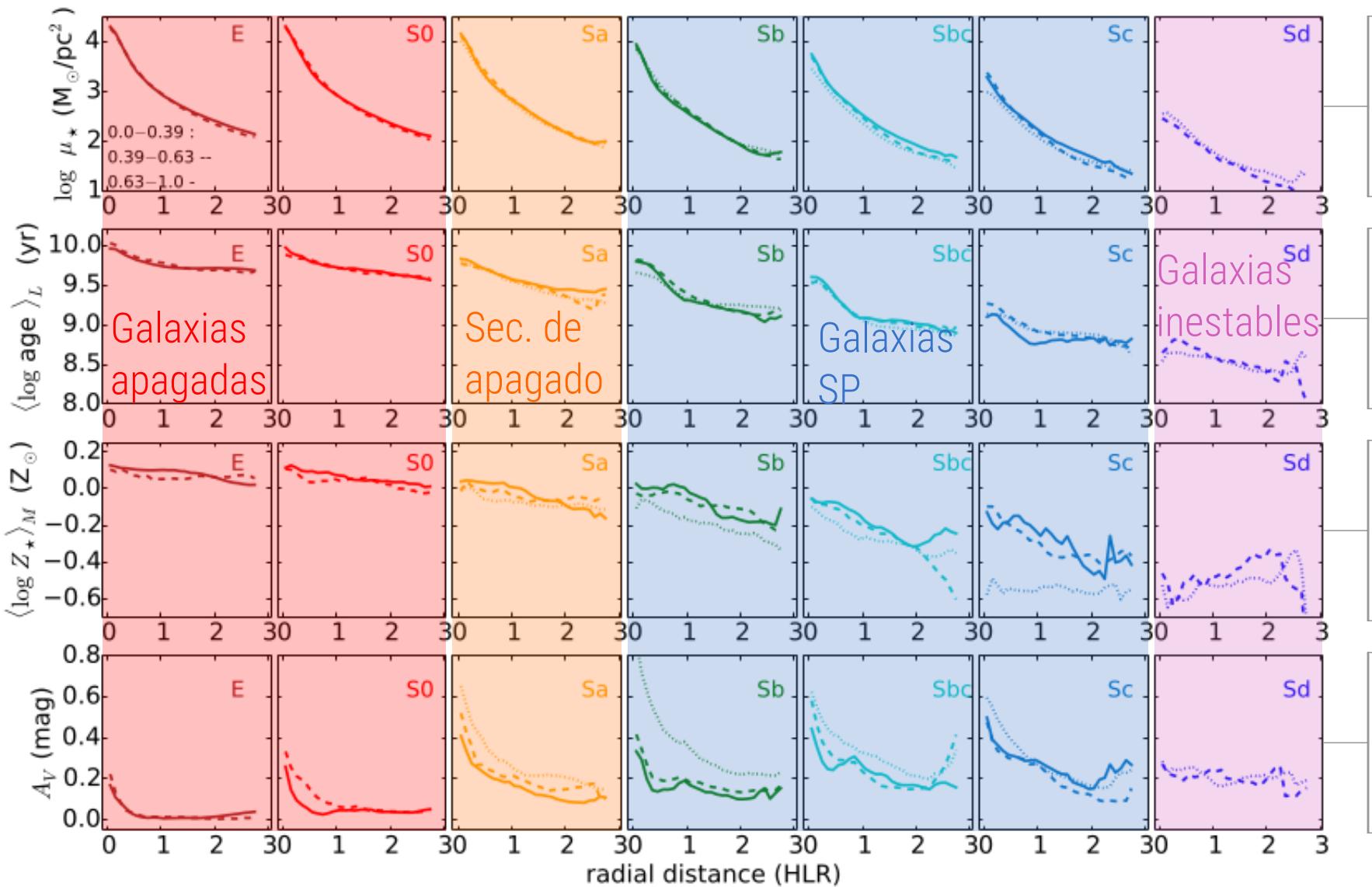
CICLO DE MASA VISTO POR CALIFA: GRADIENTES RADIALES

(González Delgado+2015)



CICLO DE MASA VISTO POR CALIFA: GRADIENTES RADIALES

(González Delgado+2015)



Evolución en escala

Perfiles ~uniformes

Perfiles con quiebre
en ~1HLR

Perfiles ~uniformes

EQ pasiva

EQ activa

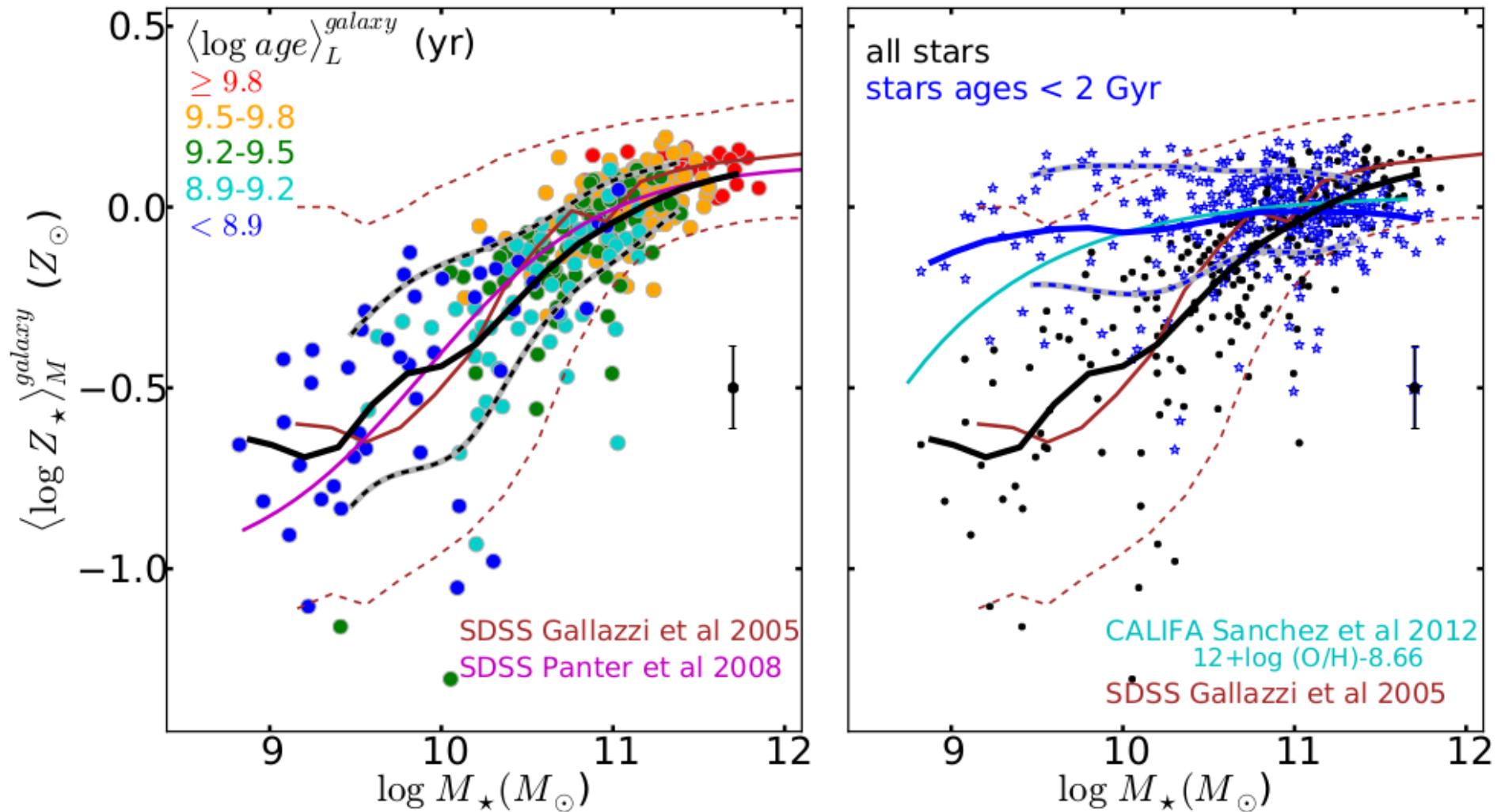
EQ ineficiente

Polvo en <1HLR

Perfiles de polvo
sensibles a la
inclinación

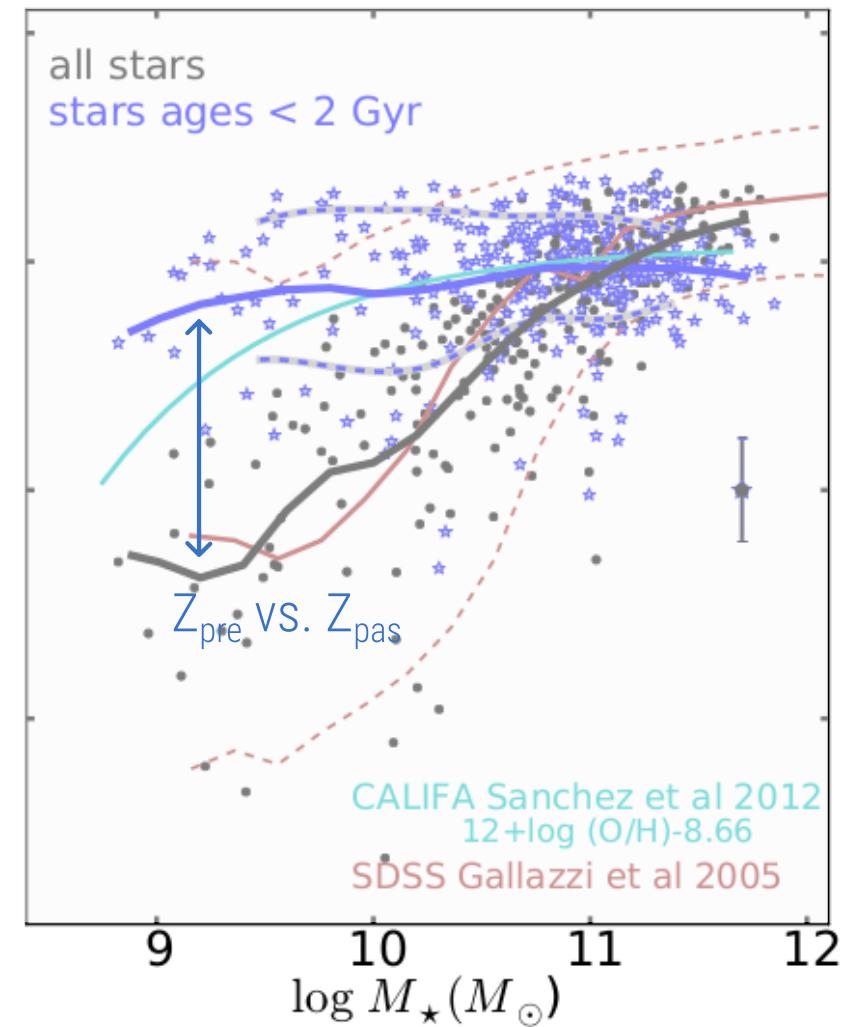
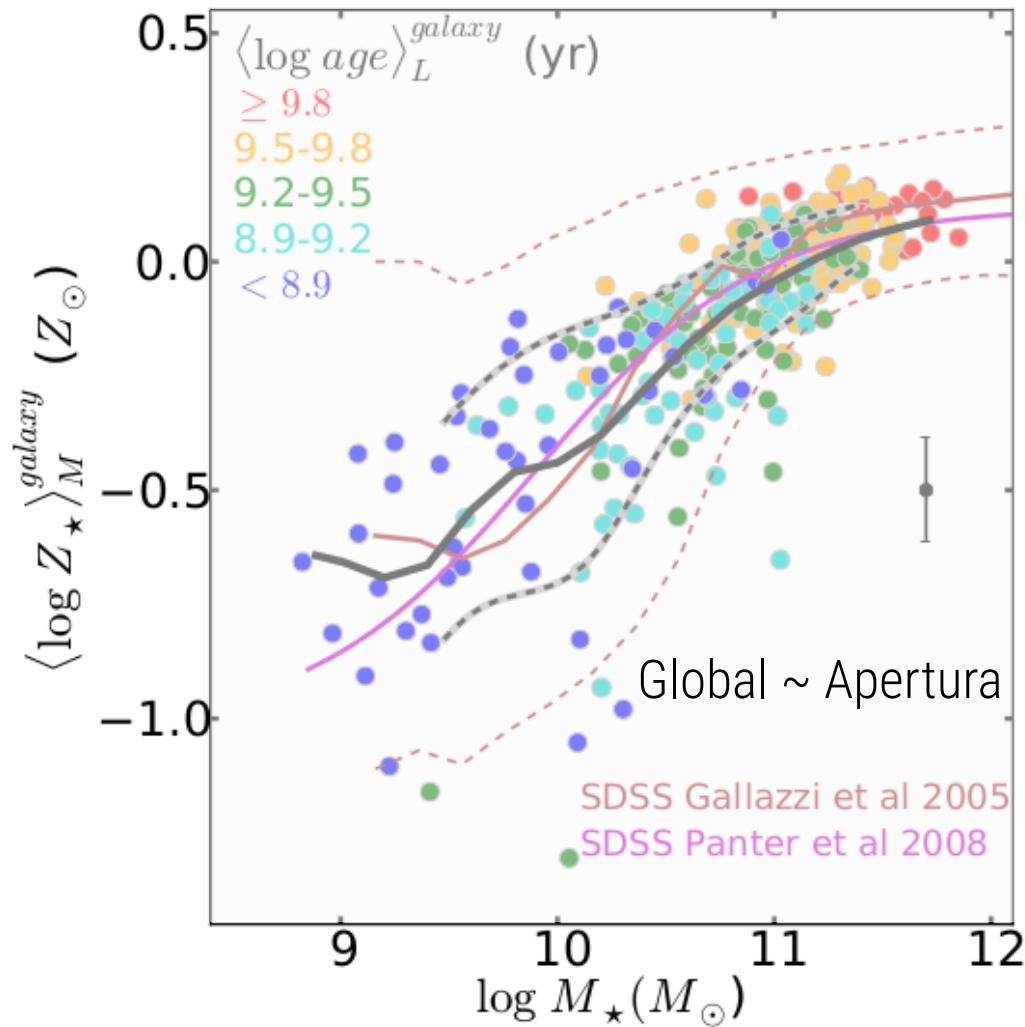
CICLO DE MASA VISTO POR CALIFA: RELACIÓN MASA – METALICIDAD

(González Delgado+2014)

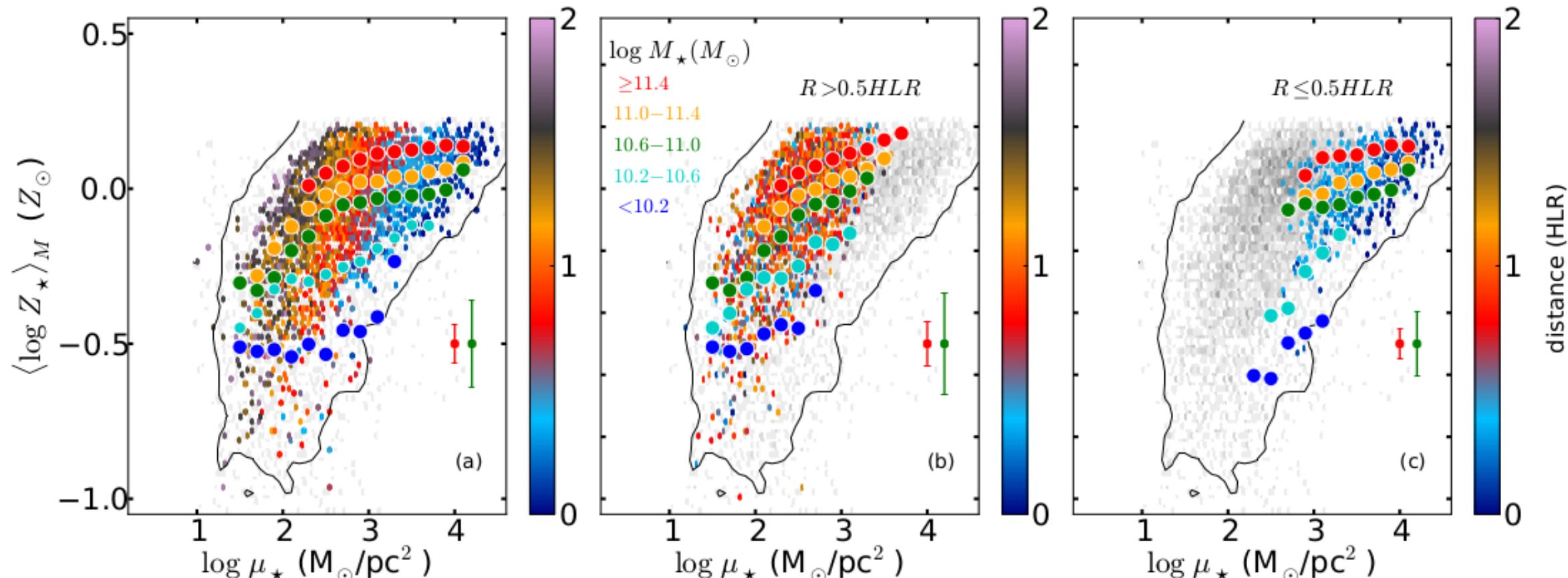


CICLO DE MASA VISTO POR CALIFA: RELACIÓN MASA – METALICIDAD

(González Delgado+2014)

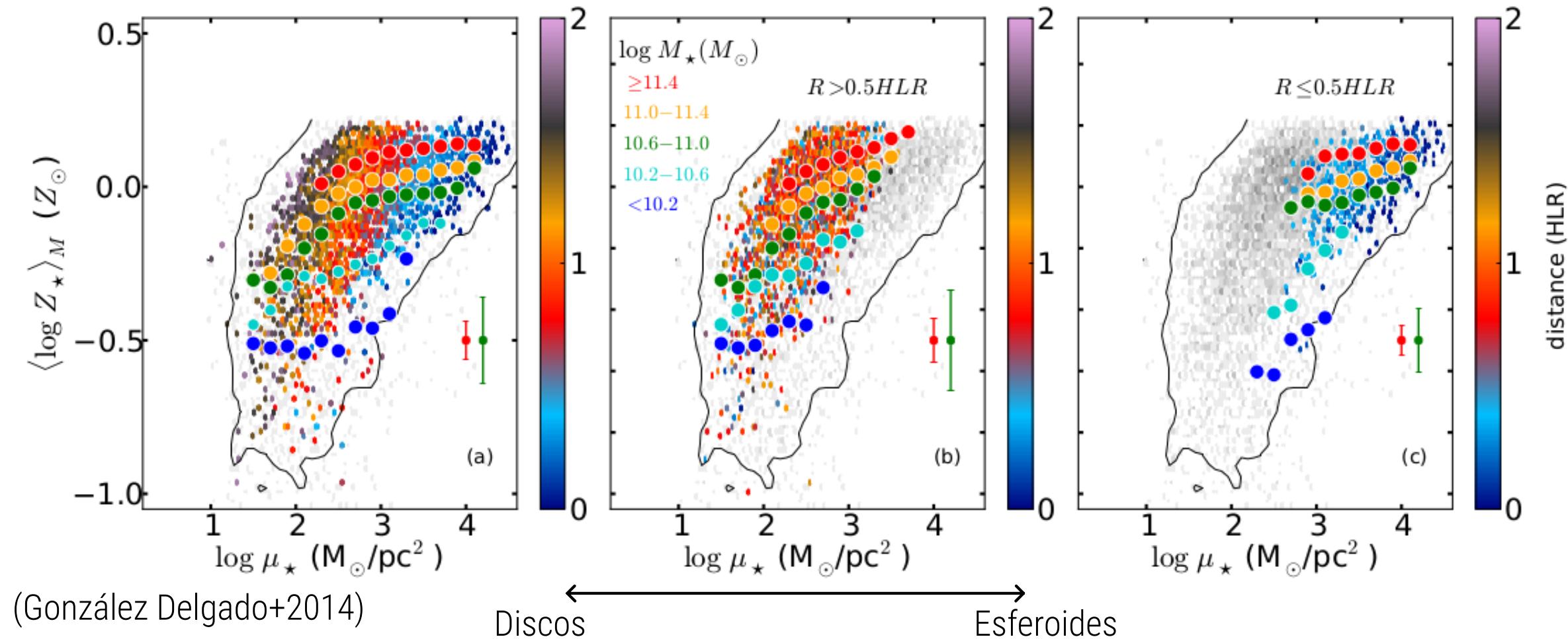


CICLO DE MASA VISTO POR CALIFA: RELACIÓN MASA – METALICIDAD

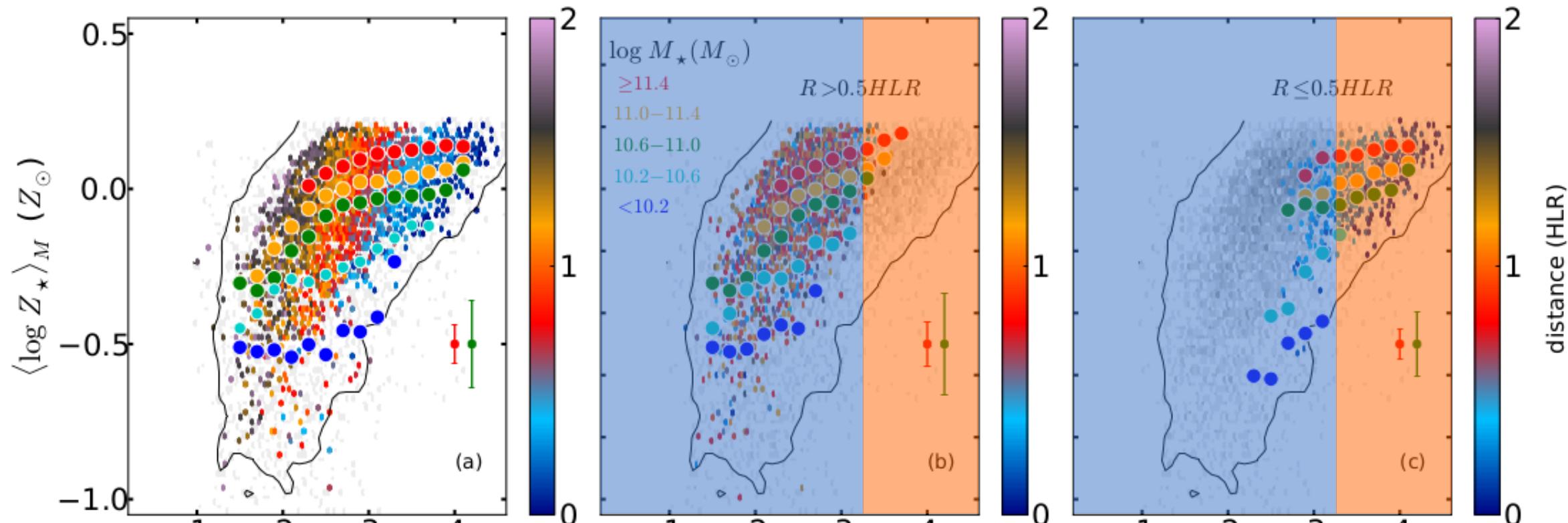


(González Delgado+2014)

CICLO DE MASA VISTO POR CALIFA: RELACIÓN MASA – METALICIDAD



CICLO DE MASA VISTO POR CALIFA: RELACIÓN MASA – METALICIDAD



(González Delgado+2014)

← Discos → Esferoides

FE/EQ tardía

$Z_* \propto \mu_*$

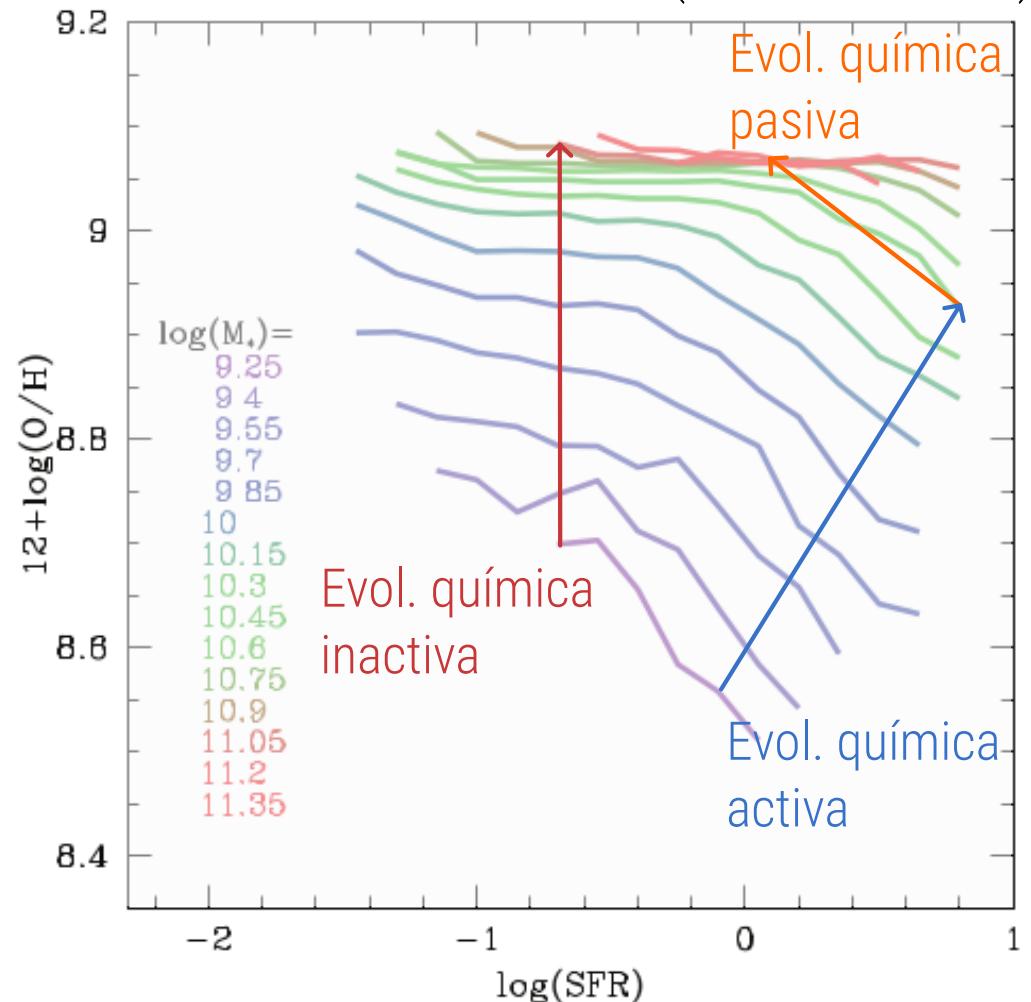
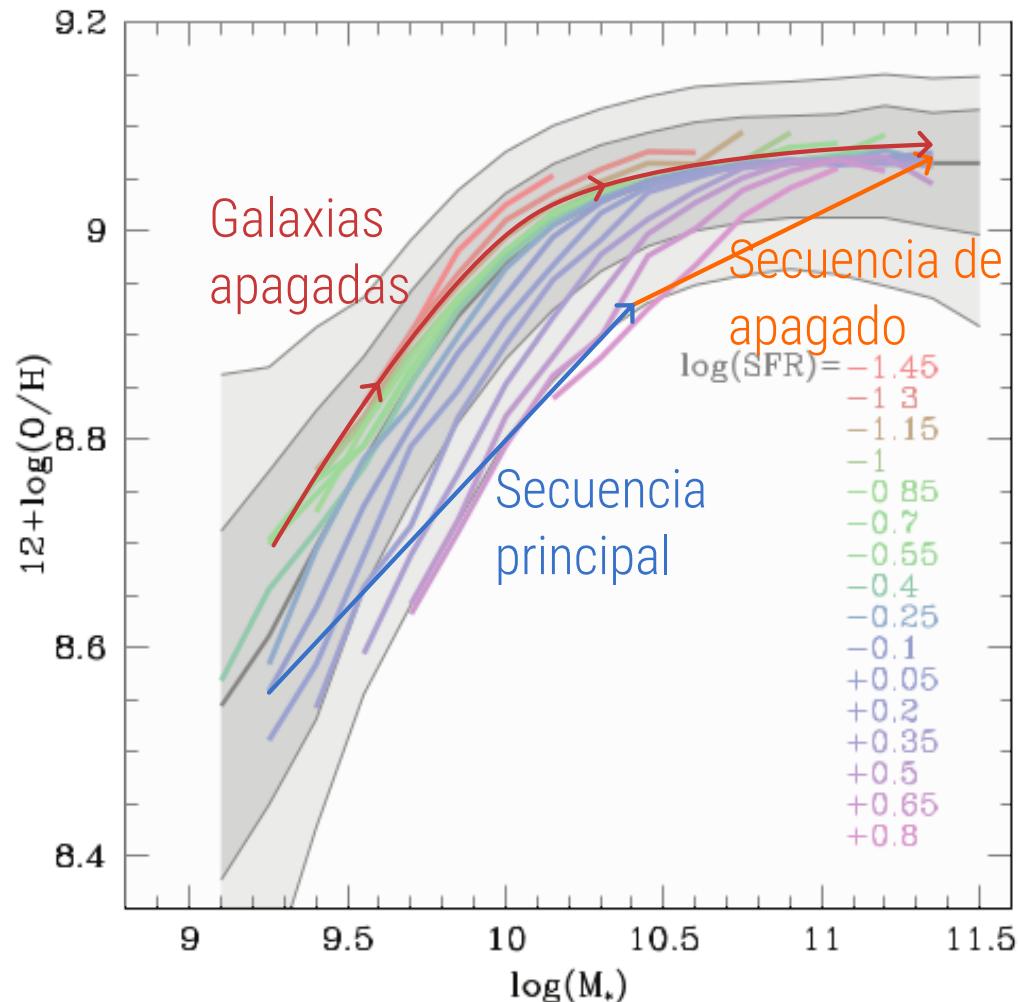
$\tau_Z \propto 1/M_*$

FE/EQ temprana

$Z_* \not\propto \mu_*$

$\tau_Z \propto 1/M_*$

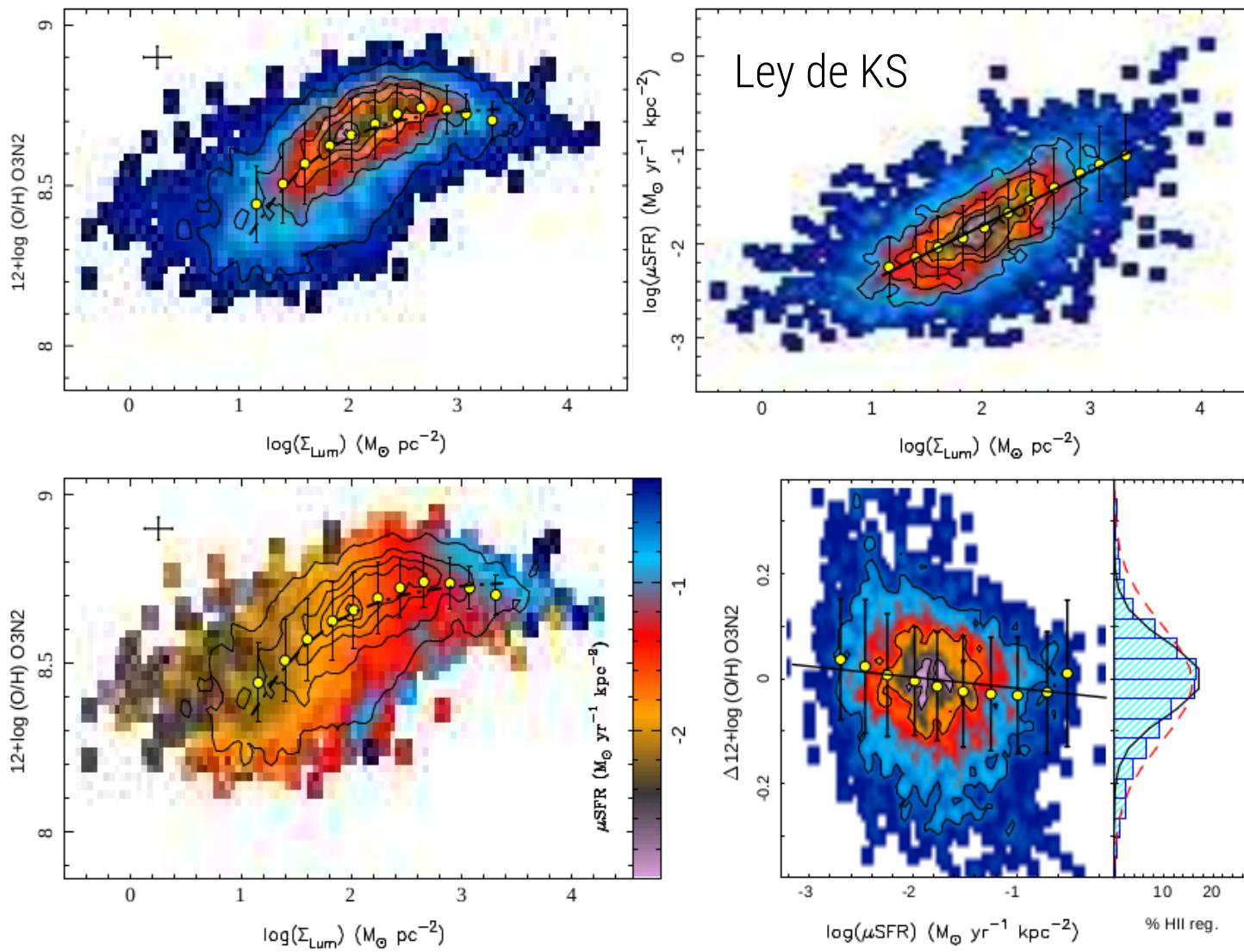
CICLO DE MASA VISTO POR CALIFA: RELACIÓN MASA – METALICIDAD – TFE



¿Es la relación con la TFE primaria?

CICLO DE MASA VISTO POR CALIFA: RELACIÓN MASA – METALICIDAD – TFE

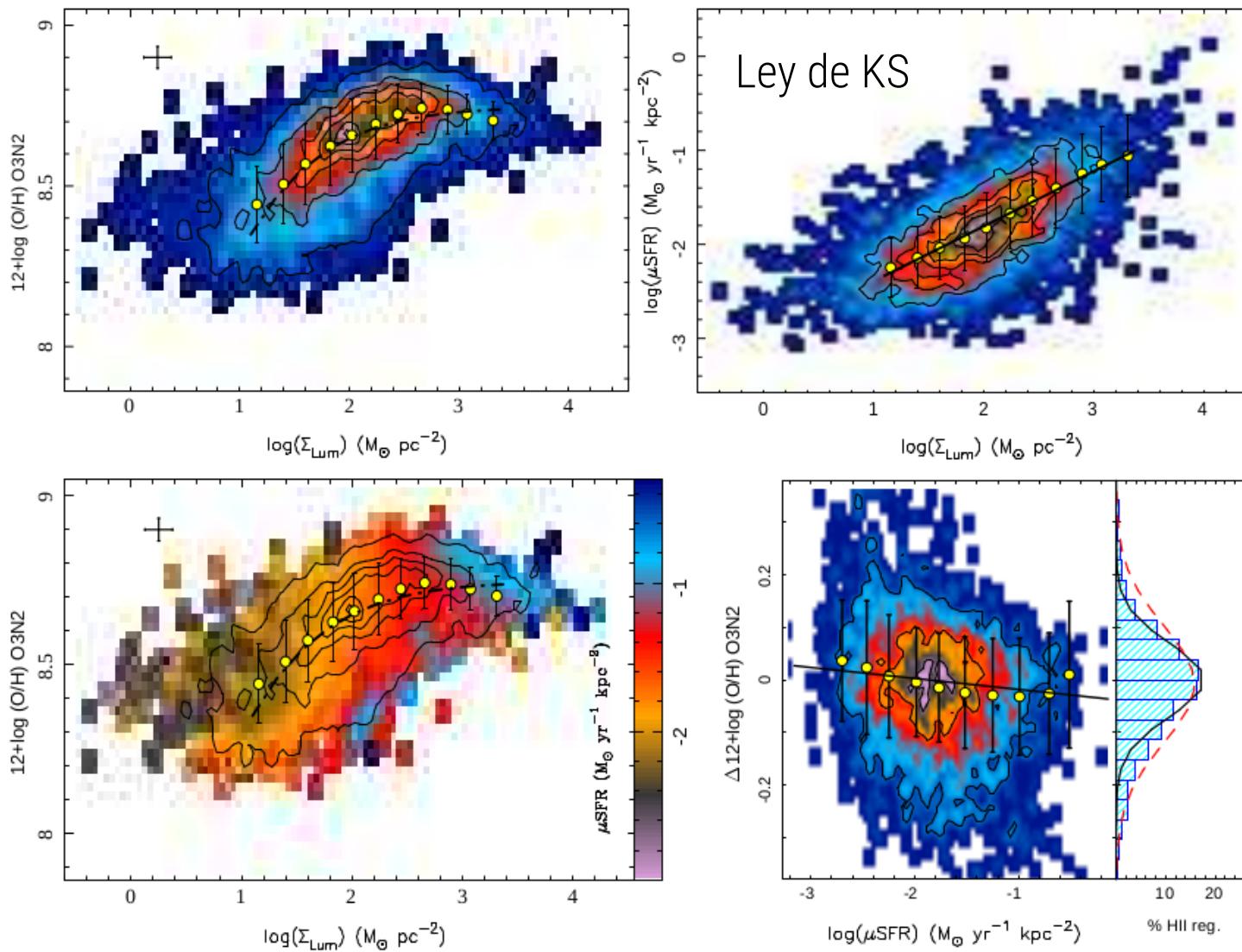
(Sánchez+2013)



Al remover la dependencia con Σ_* queda una **correlación débil** entre metalicidad y densidad de TFE.

CICLO DE MASA VISTO POR CALIFA: RELACIÓN MASA – METALICIDAD – TFE

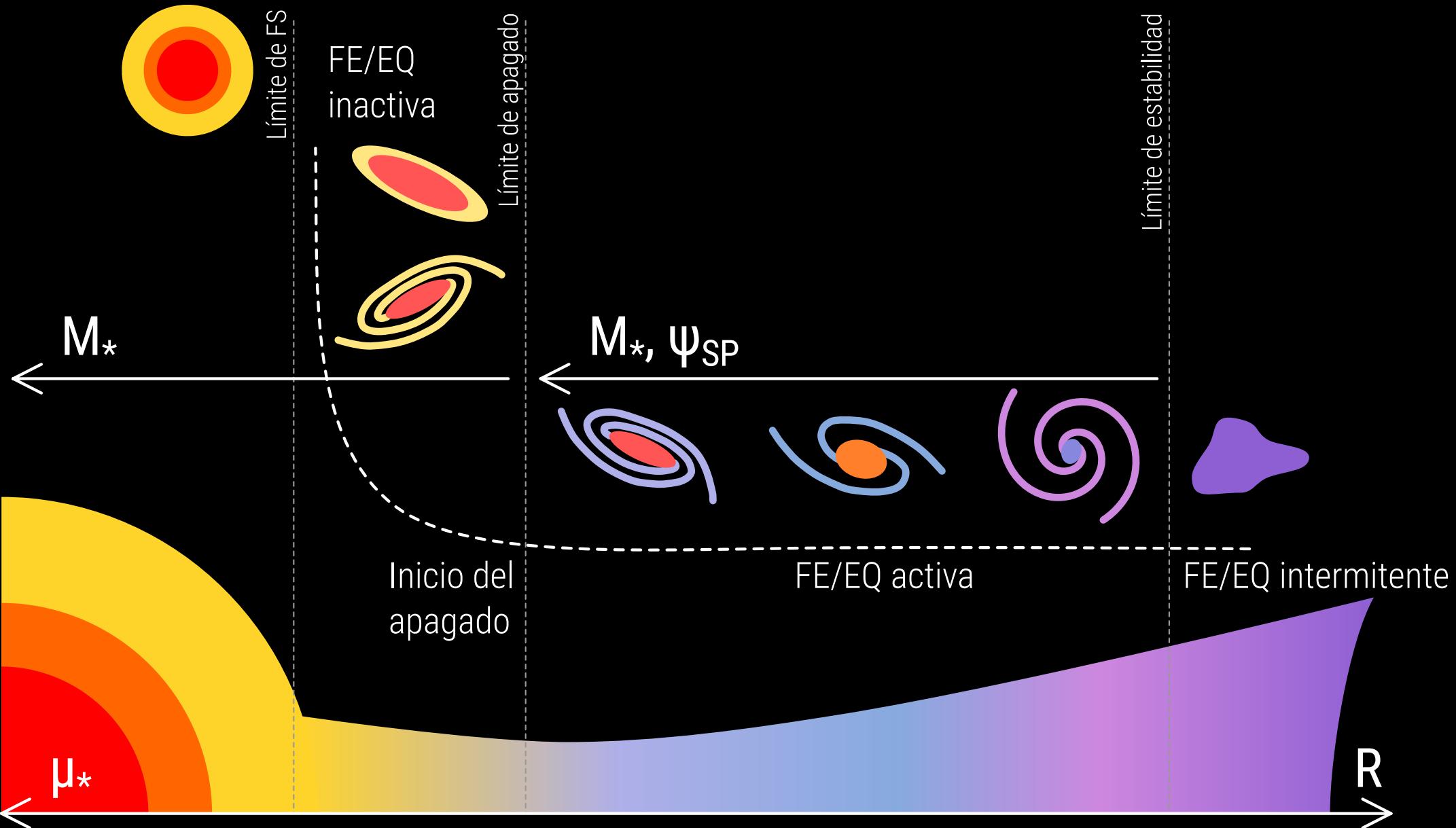
(Sánchez+2013)



¿Es la relación con la TFE primaria?
De acuerdo con Sánchez+2013 y
González Delgado+2014,
probablemente no.

Al remover la dependencia con Σ_*
queda una **correlación débil** entre
metalidad y densidad de TFE.

RESUMEN



RESUMEN

- Las relaciones de apertura son **equivalentes** a relaciones globales.
- Las relaciones locales representan un acercamiento de las relaciones globales.
- La masa estelar es el principal regulador de las escalas temporales:
 - Galaxias/regiones masivas/densas, **evolucionan primero**.
 - Galaxias/regiones poco masivas/densas, **evolucionan después**.
- La masa estelar como *proxy* del potencial galáctico define la fracción de gas:
 - Galaxias con mayor fracción de gas tienen **FE/EQ continua** en el tiempo.
 - Galaxias con menor fracción de gas tienen **FE/EQ intermitente** en el tiempo.
- Las galaxias menos masivas probablemente se ven más afectadas por el *feedback* estelar.