狭範囲に限定された重力崩壊型超新星親星質量が示唆する銀河系化学進化と超新星頻度史

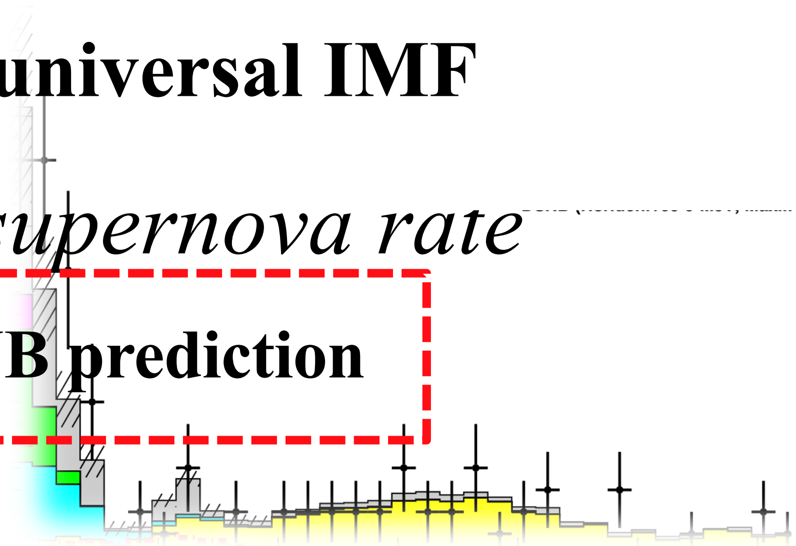
辻本拓司 (国立天文台)

- *The implied low maximum mass of core-collapse supernova (CCSN) progenitors*
- *Its impact on Galactic chemical evolution*

  ⇨ **non-universal IMF**

- *Its impact on the cosmic supernova rate*

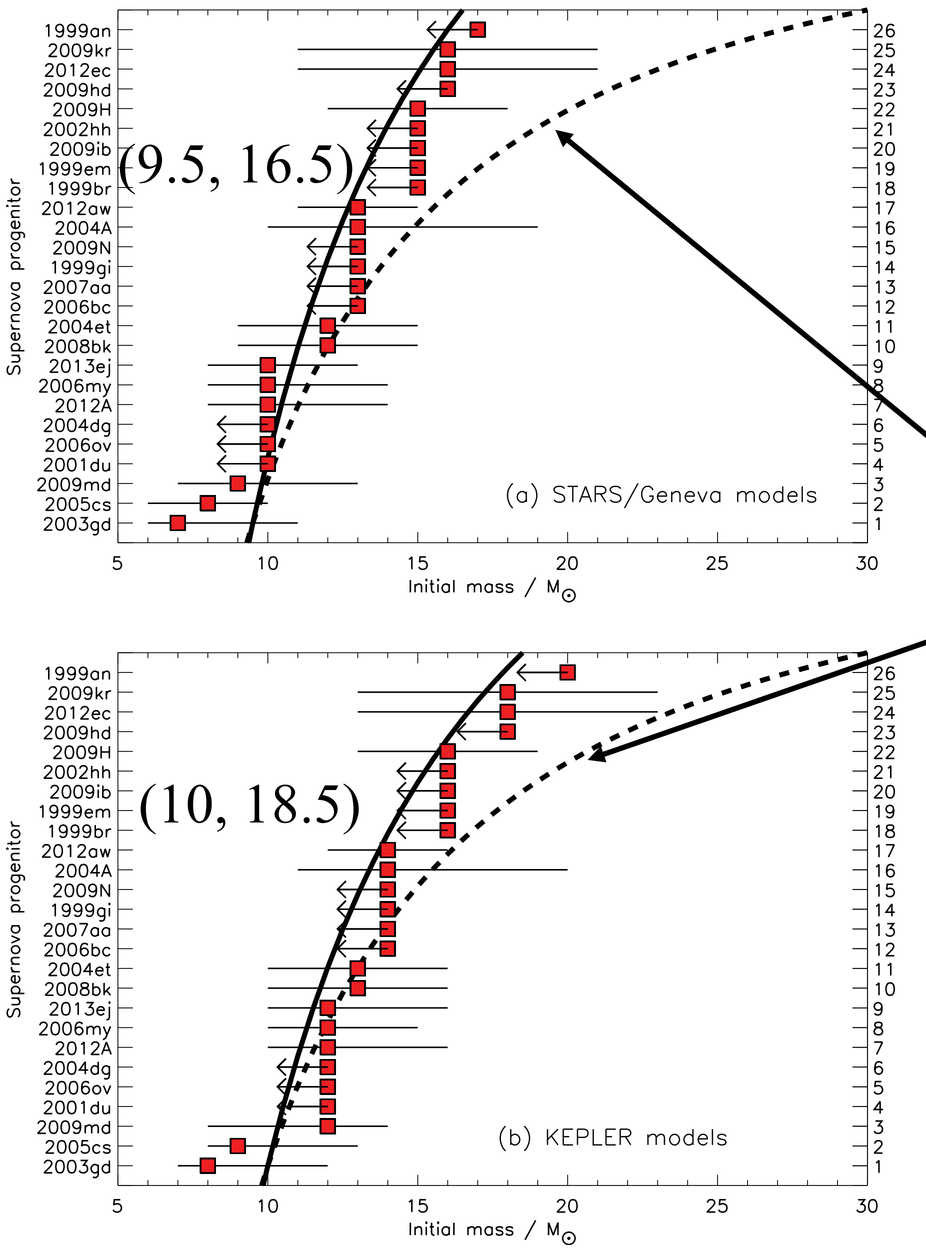
  ⇨ **DSNB prediction**



第９回超新星ニュートリノ研究会, ３月２−３日 at 九州大学

The observational evidence for the missing high-mass CCSN progenitors

Cumulative frequency of the progenitor masses with the Salpeter IMF



$m_{\rm max}$=30 $M_\odot$

,suggesting

$\boldsymbol{m_{\rm max} \approx 18\ M_\odot}$

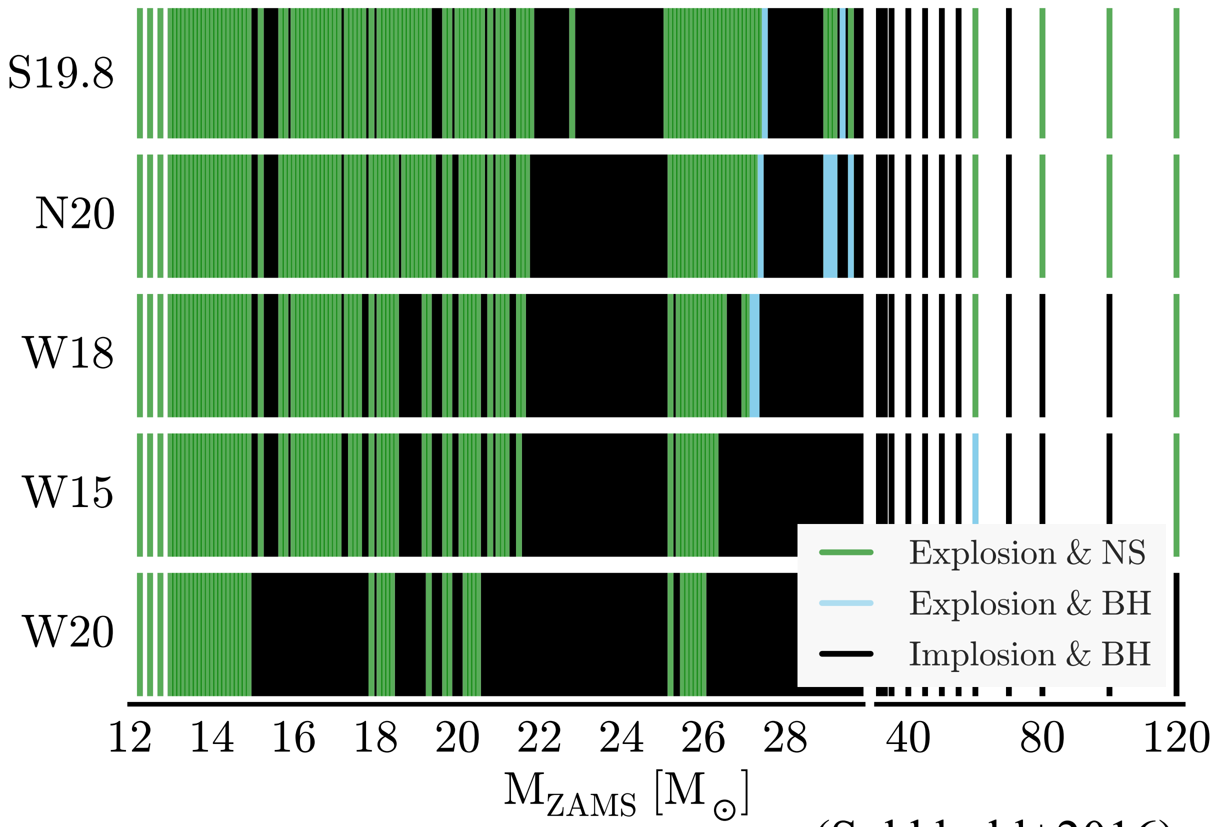
with

$\boldsymbol{m_{\rm min} \approx 8\ M_\odot}$

(Smartt 2015)

The theoretical modeling of CCSNe supports a low m_{max}

the complex explosion/BH landscape



(Sukhbold+2016)

an increase in the number of CCSNe, compared to a single mass range:8-18$M_\odot$

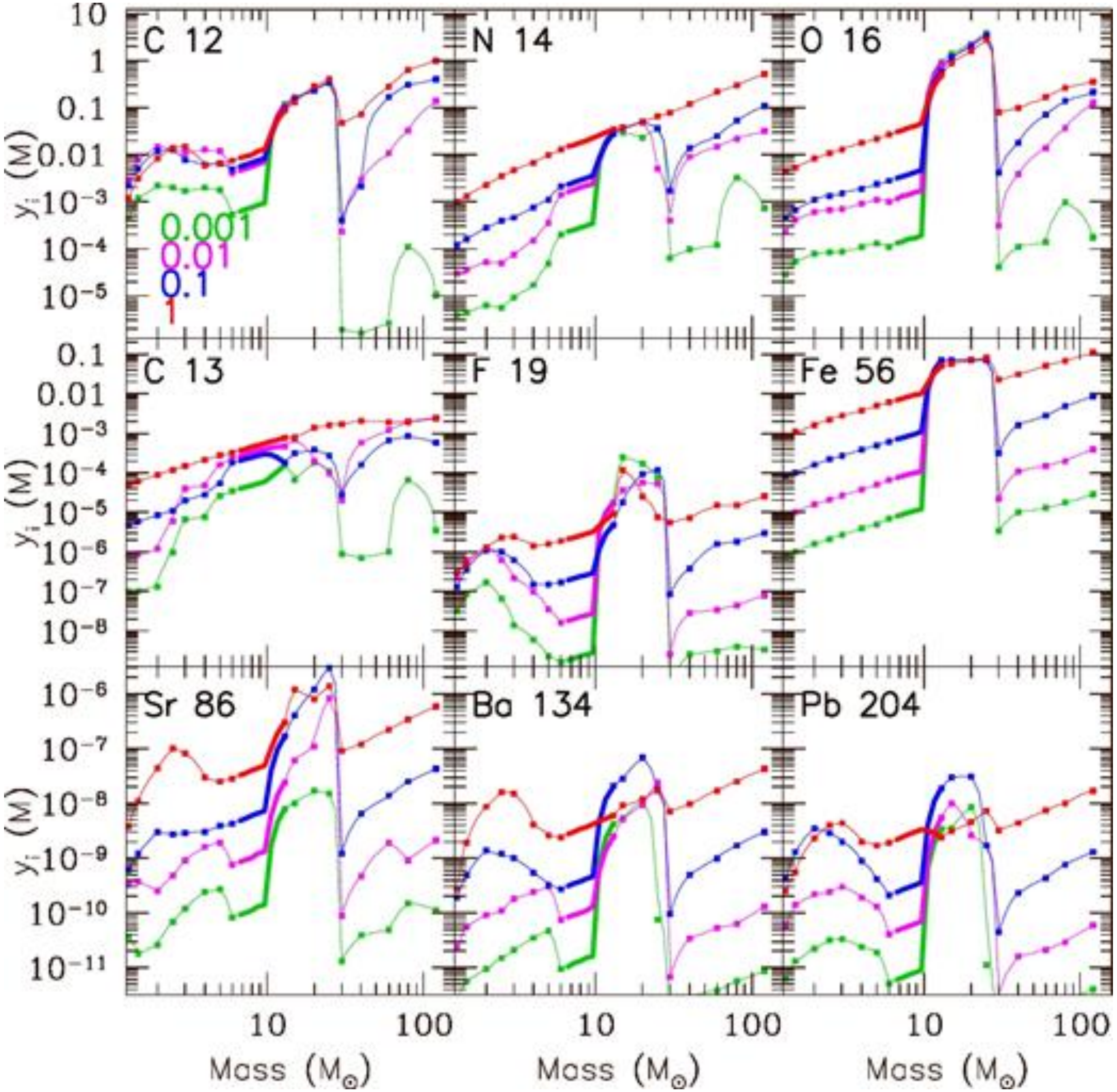
13% (m_{max}=22.6 $M_\odot$)

11% (m_{max}=21.2 $M_\odot$)

If a single mass range is assumed

It may be reasonable to assume the CCSN mass range=8-18$M_\odot$

The conventional Galactic chemical evolution scheme adopts a high $m_{\max}$ such as 100 $M_\odot$ (at least 50 $M_\odot$)



(Prantzos+2018)

If $m_{\max}$=18 $M_\odot$,

The CCSN number **reduces to ~70%**

The reduction in the total amount of heavy element is more serious

$m_{\rm star}$ ↗ $m_{element}$ ↗

reduces to ~50%

果たして銀河系化学進化は超新星親星上限質量:18~20 $M_{\odot}$ を受け入れられるのか？

SFR　　IMF

化学進化は**星形成率**と**星の初期質量関数**で大方が決まる

↓

効率の悪くなった化学進化をある程度は星形成率を高めることで、埋め合わせはできそう

↓

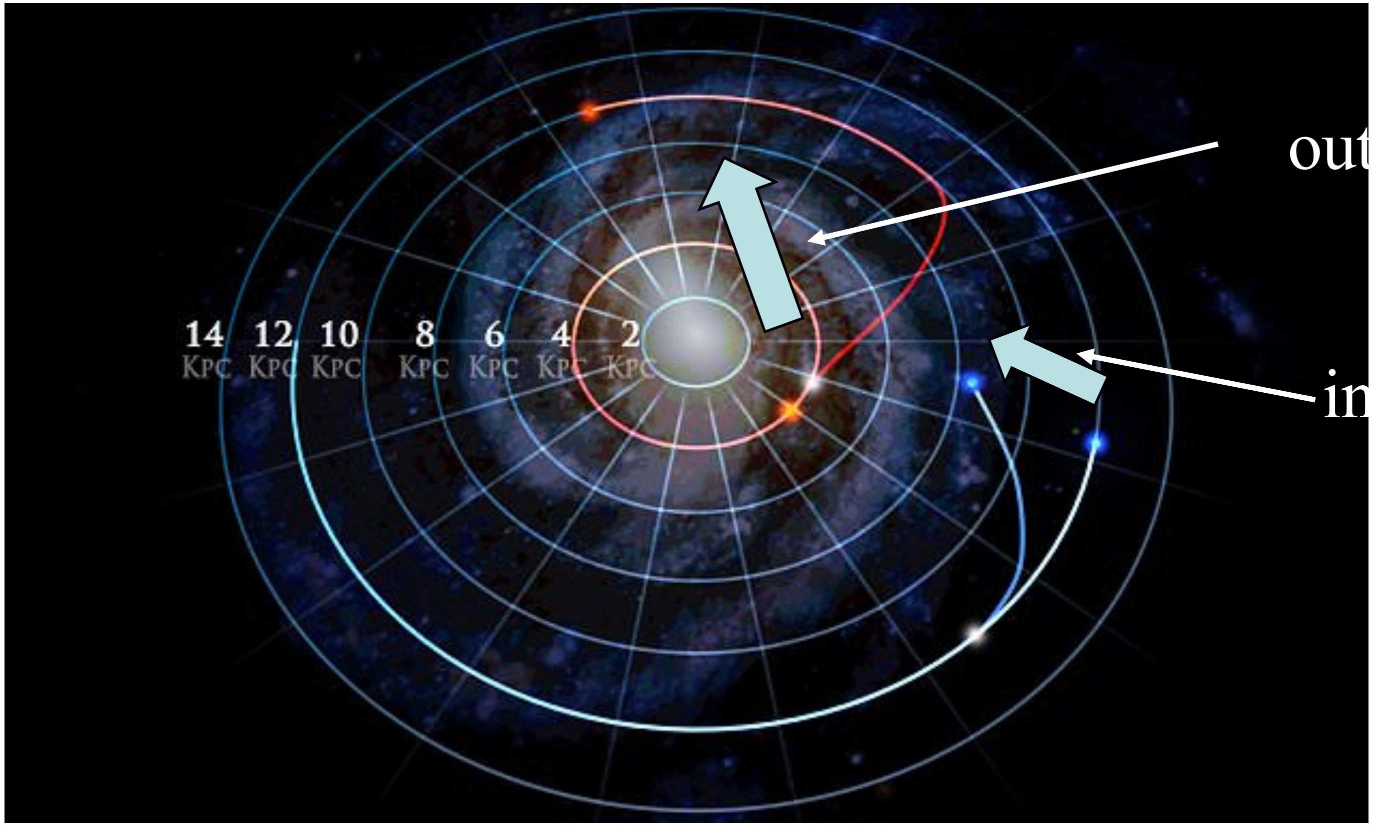
とは言え、難しそう （当初は相容れないという趣旨の論文を書くつもりでこの仕事を開始した）

↓

いや待てよ。新たな銀河化学力学進化の枠組みがあるではないか

A new paradigm of Galactic dynamics

Stars radially move on the Galactic disk : ***radial migration***

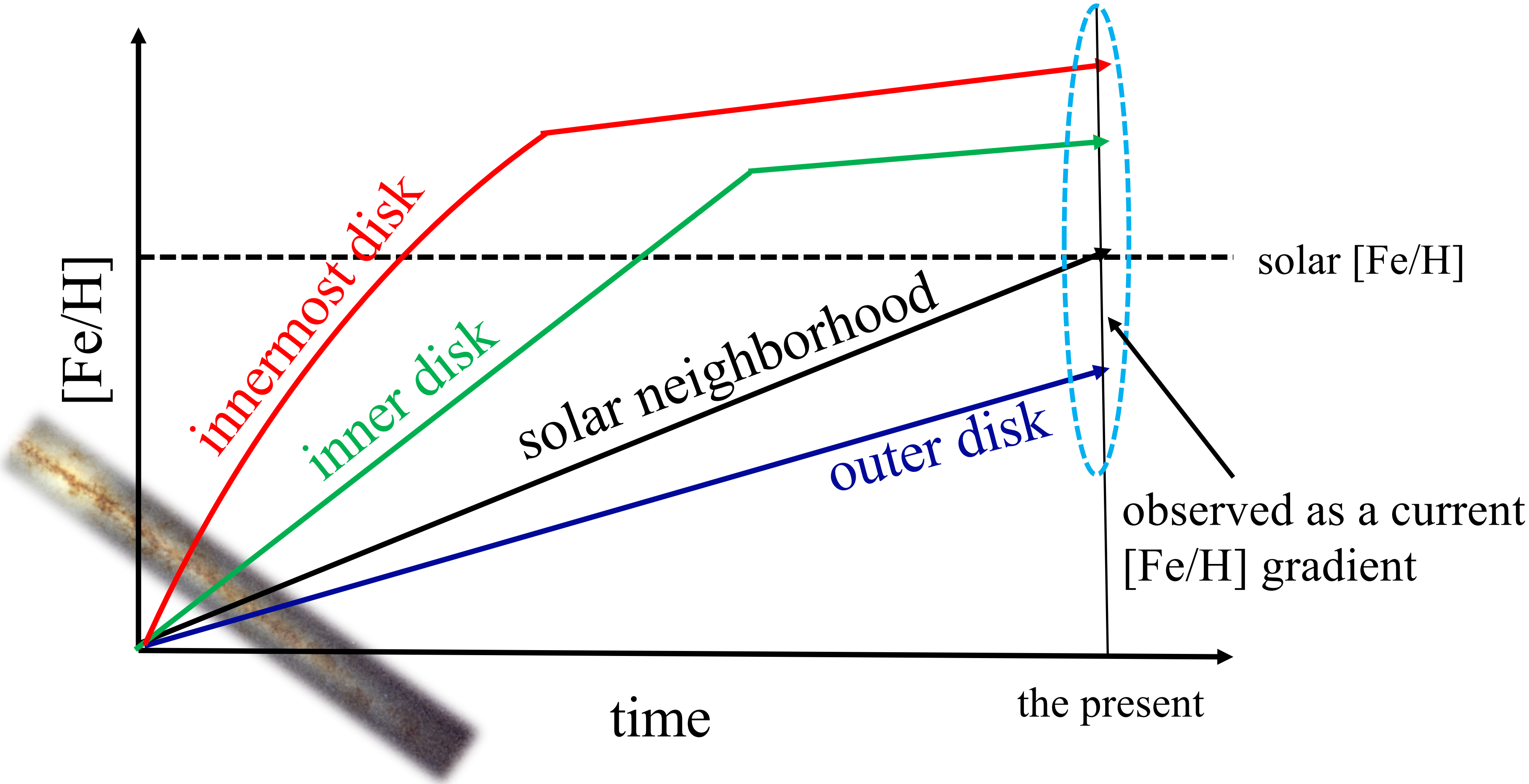


@Danna Berry

via a gravitational **interaction with** transient recurrent **spirals**
by losing or gaining angular momentum

This theory predicts :

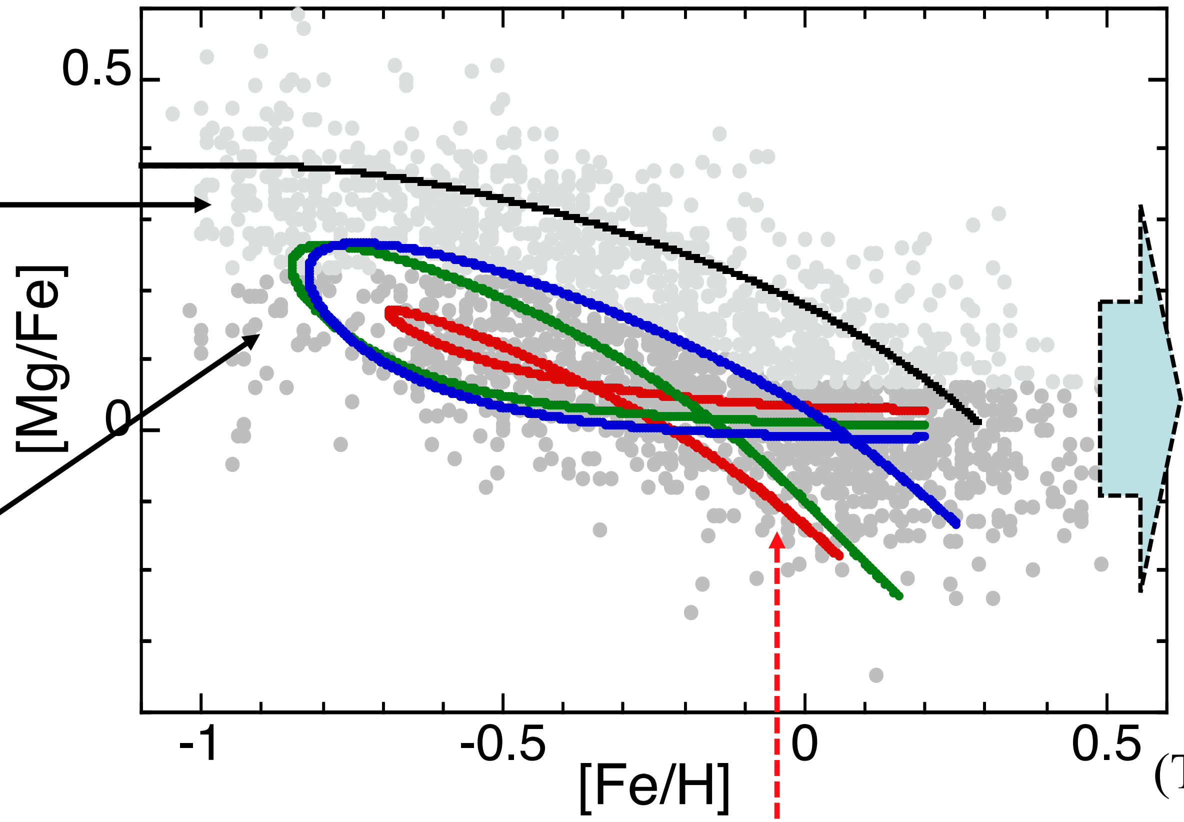
the stars in the solar vicinity represent
the mixture of stars born at
various Galactocentric distances over the disk



Local Galactic chemical evolution accepts a 8-18 $M_\odot$ mass range

thick disk

thin disk



(TT 2023)

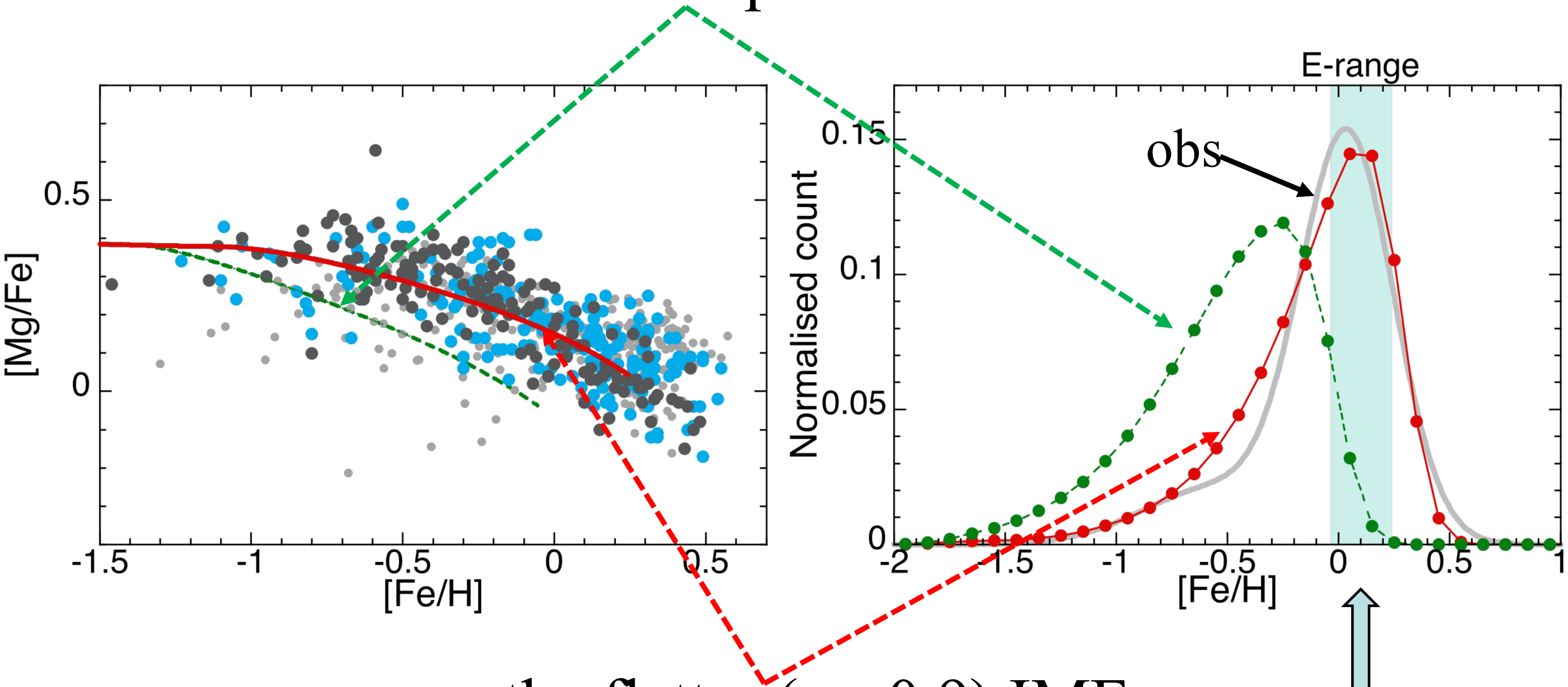
occupies a wider data-populated area

encompasses only a relatively small part of data

On the other hand,

The Galactic bulge demands more CCSNe than that expected from a 8-18 $M_\odot$ mass range with the Salpeter (x=-1.35) IMF

the Salpeter IMF



the flatter (x=-0.9) IMF

This argument for **a flat IMF** in the Galactic bulge can be extended to an insight into the form of **the IMFs in elliptical galaxies**.

a flat IMF

Galactic chemical evolution suggests

the variable IMF in the Universe

How star formation proceeds?

moderate mode

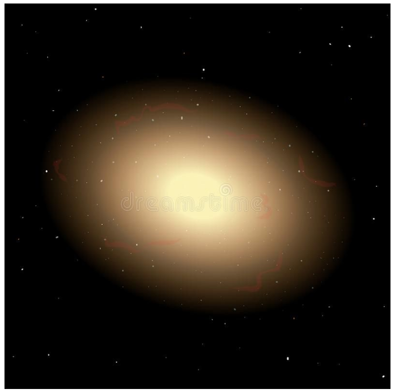
||

late-type galaxies

bursting mode

|| (Pouteau+2022)

early-type galaxies



the IMF

the Salpeter

(x=-1.35)

the one generating numerous CCSNe

(x=-0.9)

If the IMF is universal

proportional

Cosmic star formation rate $\propto$ Cosmic CCSN rate

If the IMF is non-universal

a break in the proportionality

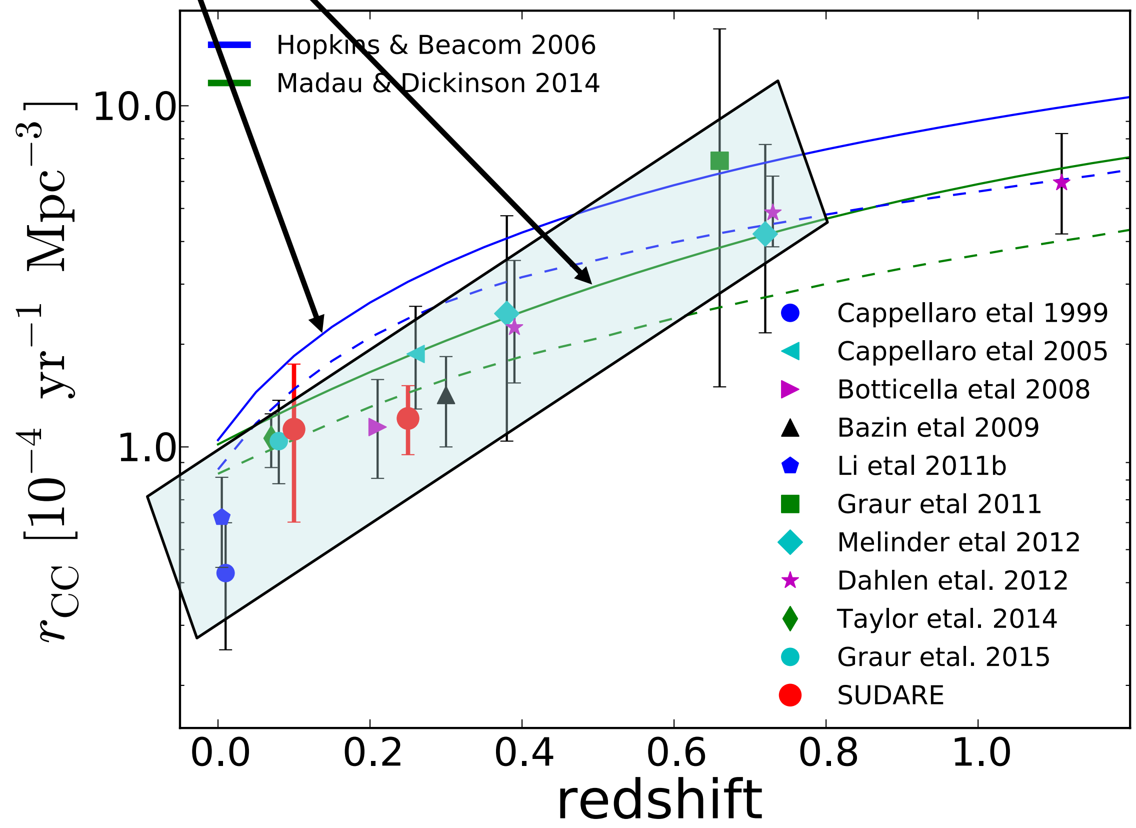
Cosmic star formation rate $\not\propto$ Cosmic CCSN rate

The observed CCSN rate's slope is steeper than the predictions from the observed cosmic star formation rate

with the Universal IMF

$$r_{cc}(z) = k_{cc}\, h^2\, \Psi(z)$$

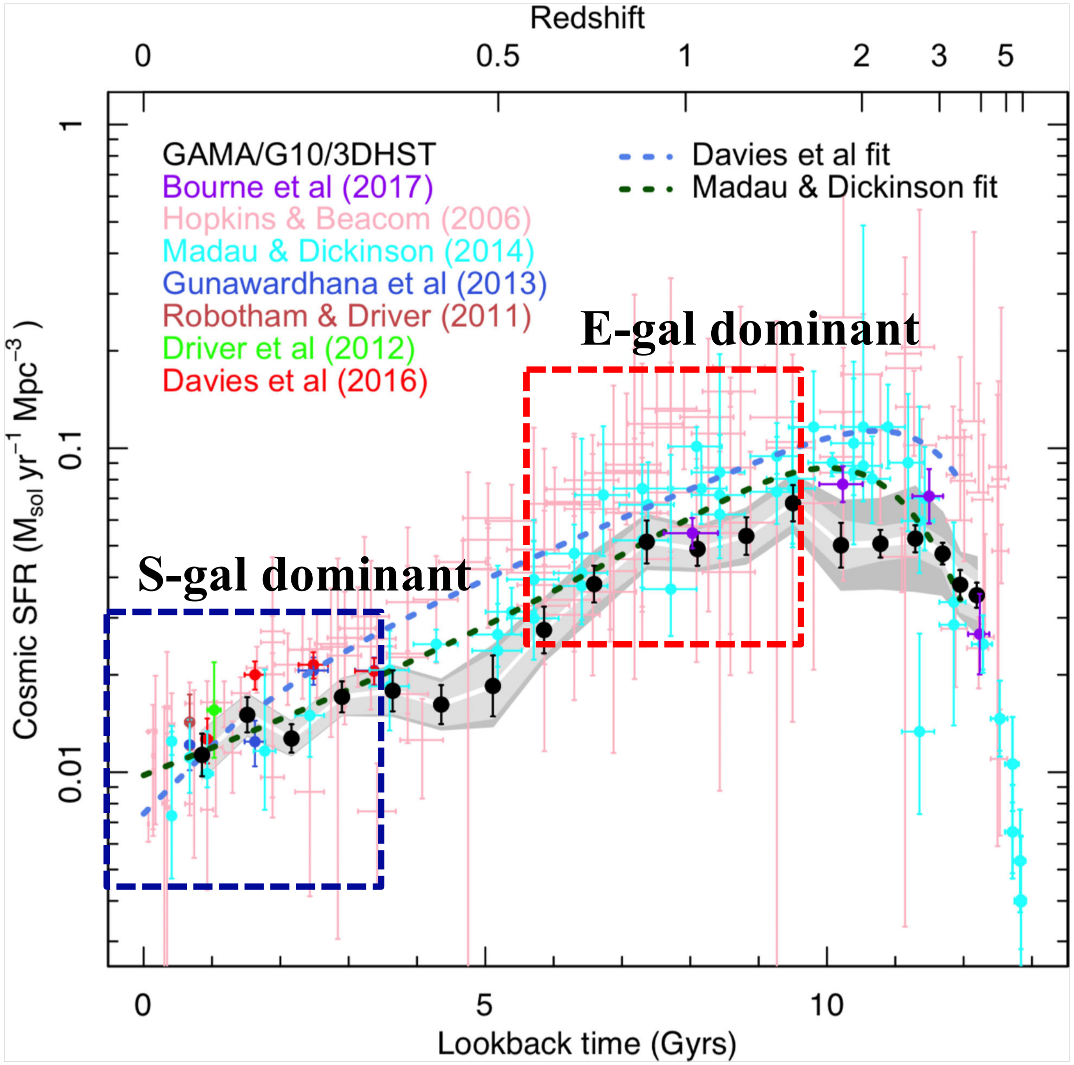
k_{cc} = a scale factor of massive stars that explode as CCSNe per unit mass of the IMF



(Cappellaro+2015)

Assuming, k_{cc} = const.

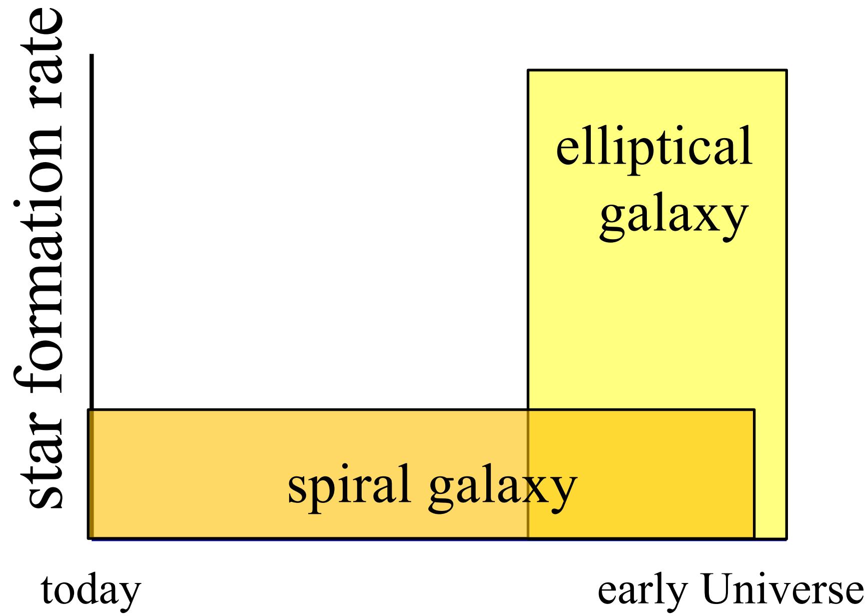
Cosmic star formation history



(Driver+2018)

Star formation history

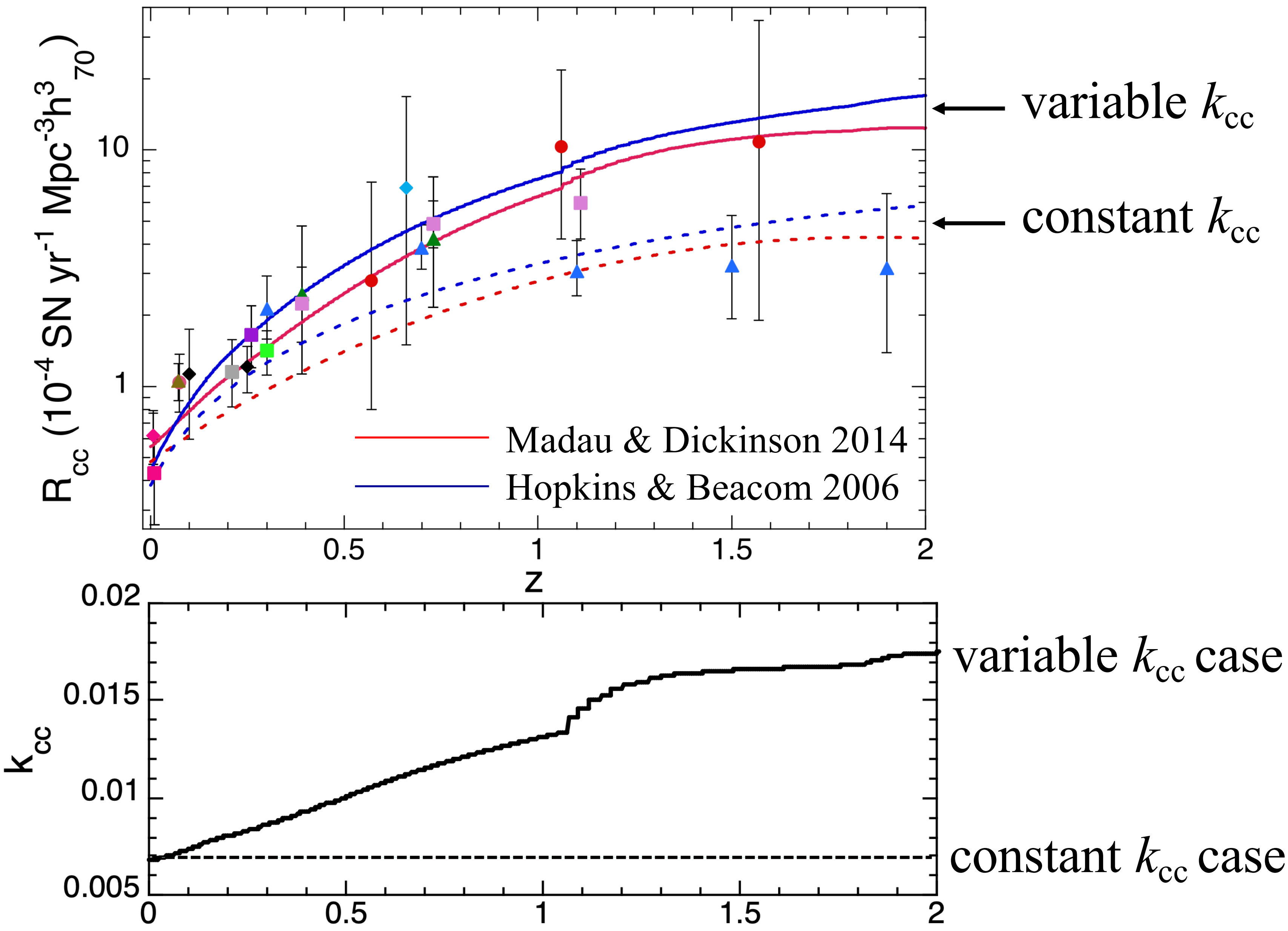
Ellipticals vs. Spirals



k_{cc}

CCSN rate contrast

The evolution of cosmic CCSN rate with redshift



Summary

- The narrow mass range (8-18 $M_{\odot}$) for CCSN progenitors is found to accepted by Galactic chemical evolution
- This narrow mass range strongly supports a variable IMF among different type of galaxies
- This variable IMF well explains an observed large contrast in the cosmic CCSN rates
- Our result **predicts a high rate of BH formation**, which must greatly influence the count of DBSN neutrinos

(中里さんの講演へ)