The Chemical Evolution of Fluorine in the Milky Way

XIII Estallidos Workshop

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Why fluorine?

- Evolution of fluorine is still poorly understood.
- We hope that by tracing its evolution, we can better understand which stars are the dominant contributors.

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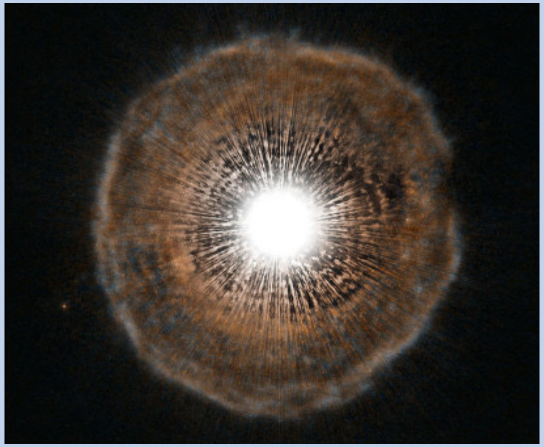
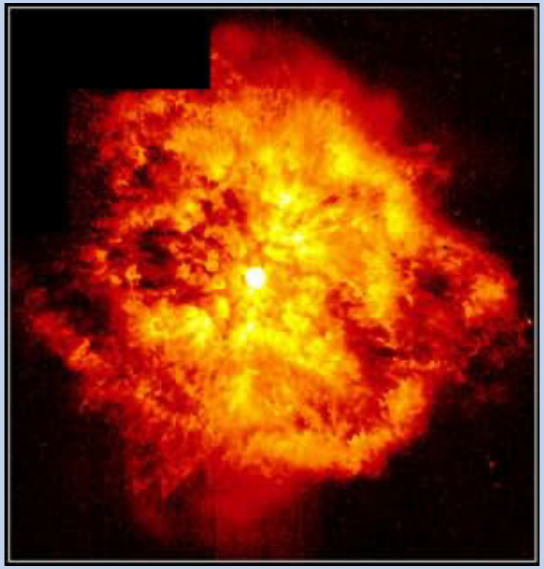
Sites of Fluorine Production

- **AGB stars**
- **Wolf-Rayet stars**
- **Rotating massive stars**
- ν-process in CCSNe
- Novae



ESA/Hubble, NASA and H. Olofsson (Onsala Space Observatory)

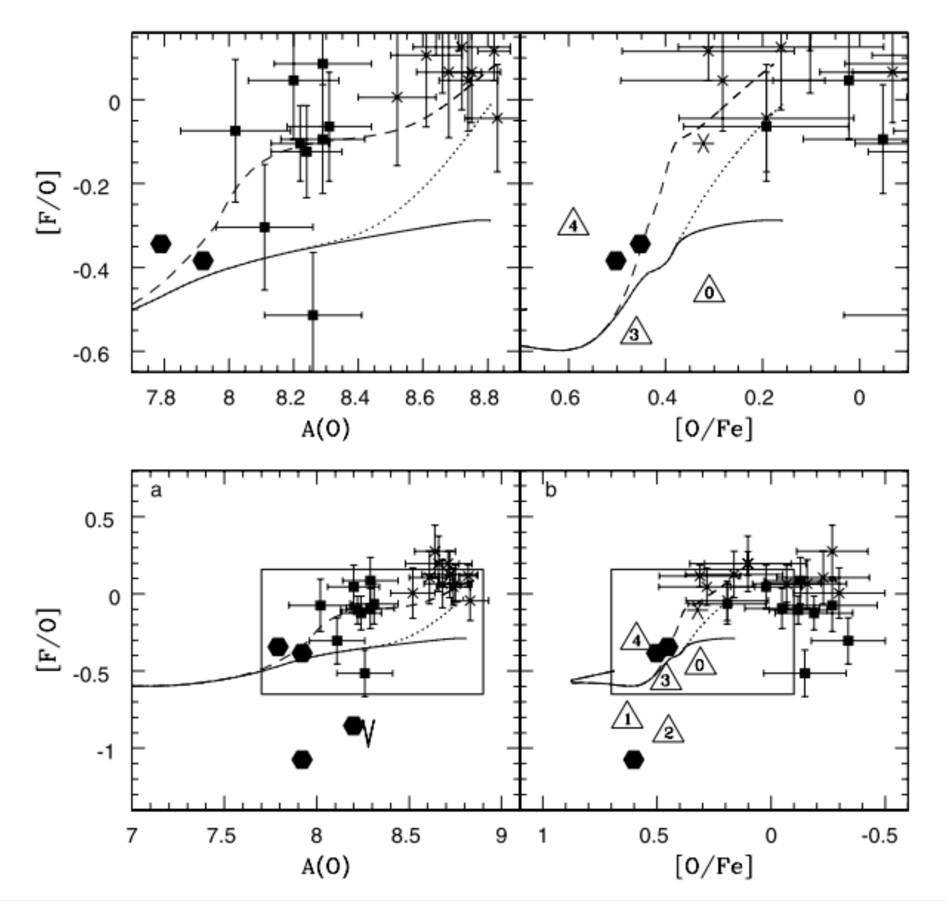


Yves Grosdidier, Anthony Moffat, Gilles Joncas, Agnes Acker and NASA

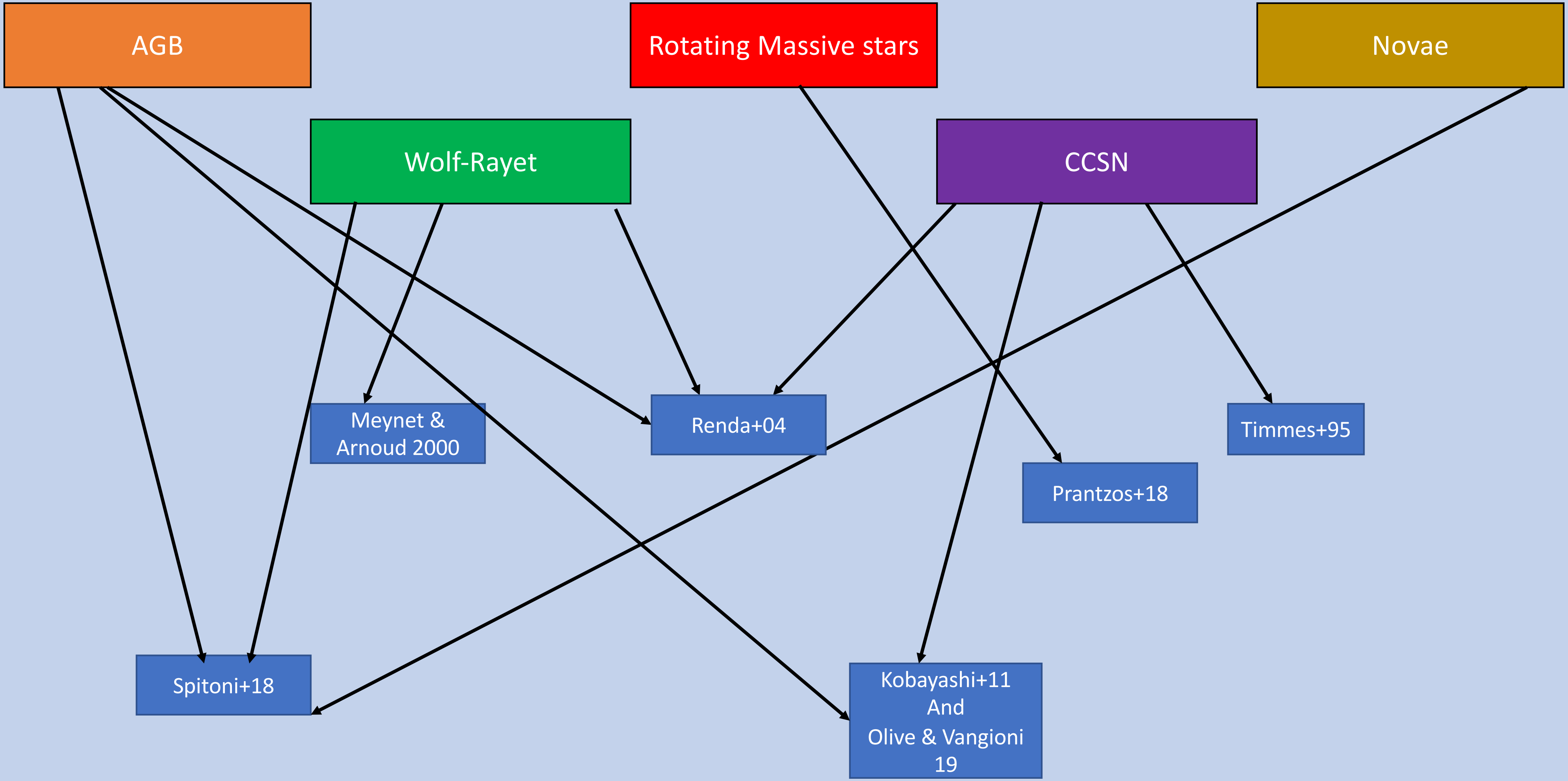
Renda et al. 2004

- Galactic chemical evolution model using AGB and WR yields

- Found that AGB stars dominated the fluorine production at low metallicities and WR stars at solar and super-solar metallicities



Renda et al. 2004

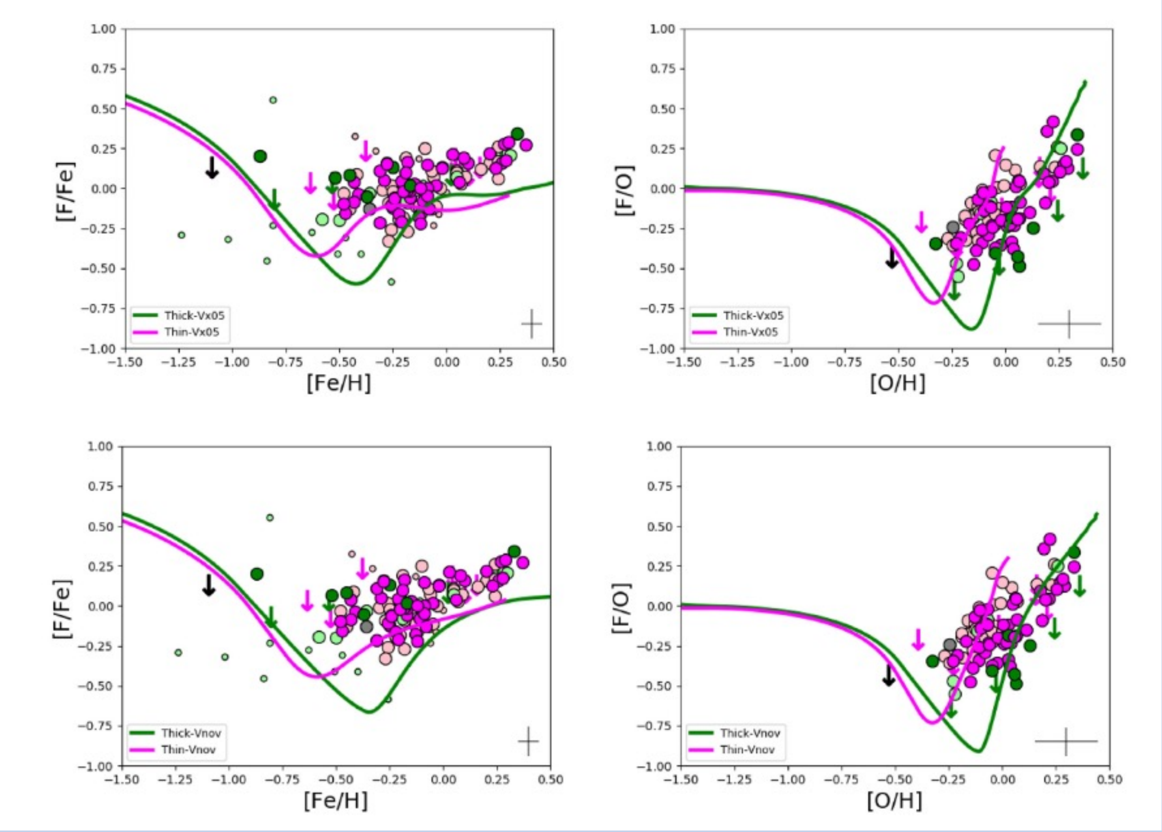

AGB
Rotating Massive stars
Novae
Wolf-Rayet
CCSN
Meynet & Arnoud 2000
Renda+04
Timmes+95
Prantzos+18
Spitoni+18
Kobayashi+11 And Olive & Vangioni 19

Grisoni et al 2020

- Galactic chemical evolution model that separately modelled the thick and thin disk

- Found thick disk evolved faster than the thin disk. Best two models were:
1) Yields from LIMS and super-AGB multiplied by a factor of 5.
2) Novae are also included

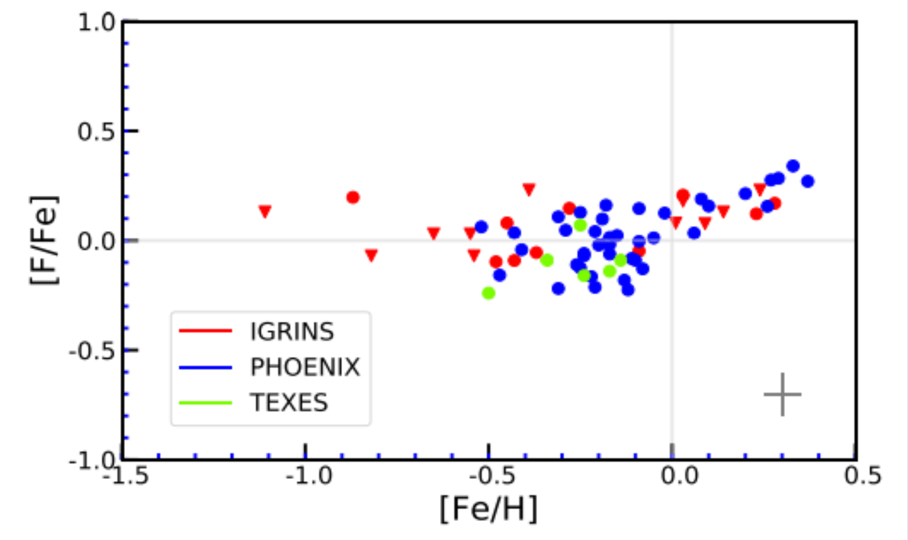
- Used the latest set of fluorine observations from Ryde et al. 2020

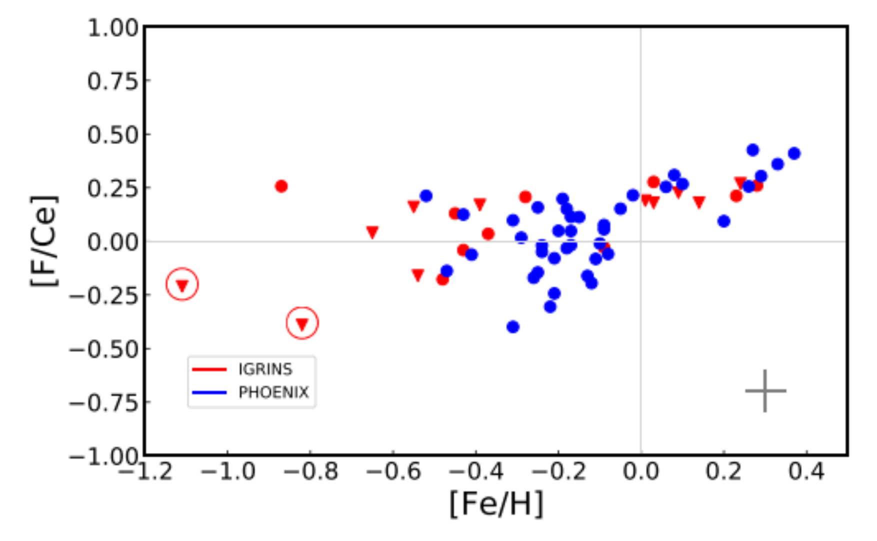


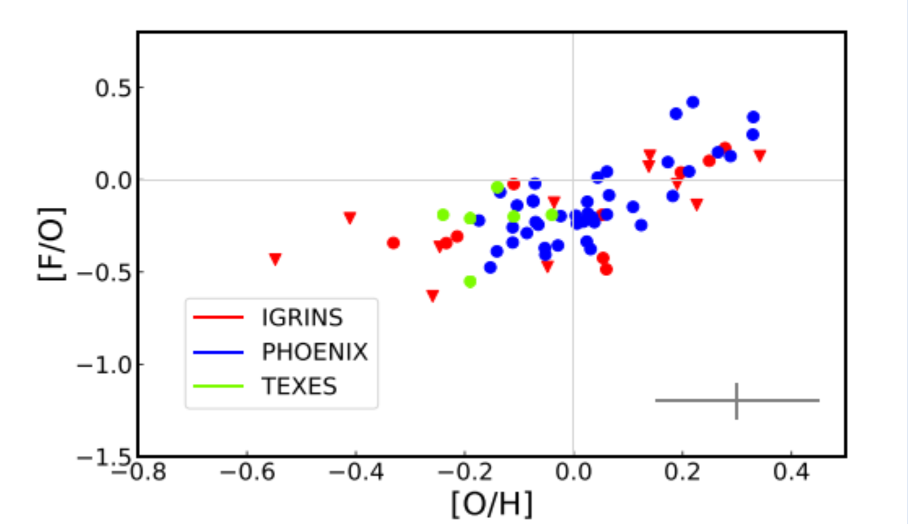
Grisoni et al. 2020

Ryde et al. 2020

- 66 K giants (25 observed with the IGRINS spectrograph and 41 with the Phoenix spectrograph).
- Expanded the metallicity range of fluorine observations to -1.1<[Fe/H]<0.4.







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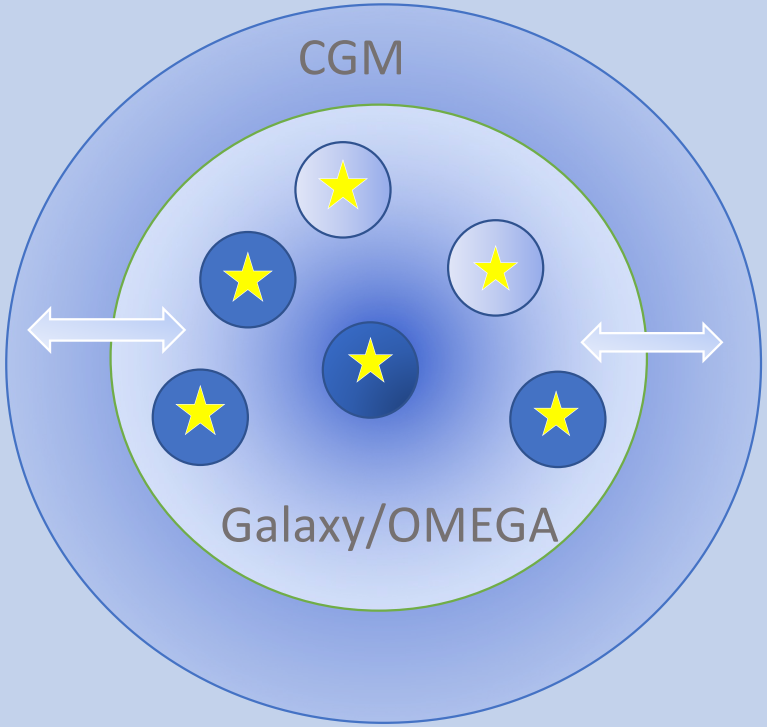
OMEGA+ GCE model

- Two-zone GCE model.
- Central Galaxy
- External Circumgalactic medium



Codes available at:
https://github.com/NuGrid/NuPyCEE
https://github.com/becot85/JINAPyCEE

Parameters of the model

- Dual infall model based on Chiappini et al. 1997
- Yields
  - SN1a Iwamoto et al. 1999
  - F.R.U.I.T.Y AGB yields from Cristallo et al. 2015
  - Massive star yields from Limongi and Chieffi 2018
- Kroupa 2001 IMF
- SFR

$$\dot{M}_{\star} = \frac{\epsilon_{\star}}{\tau_{\star}} M_{gas}(t)$$

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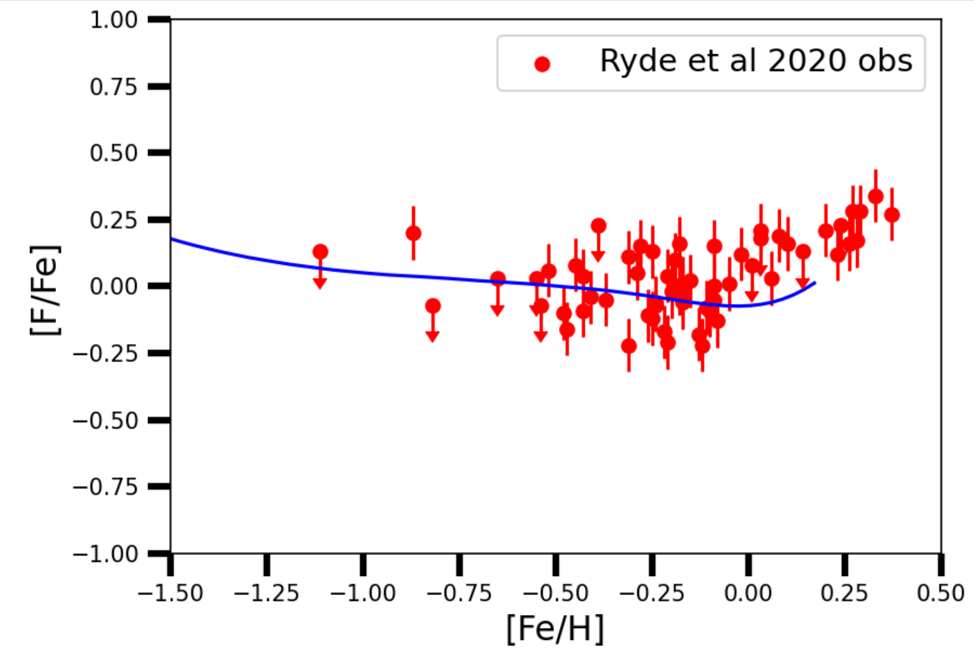
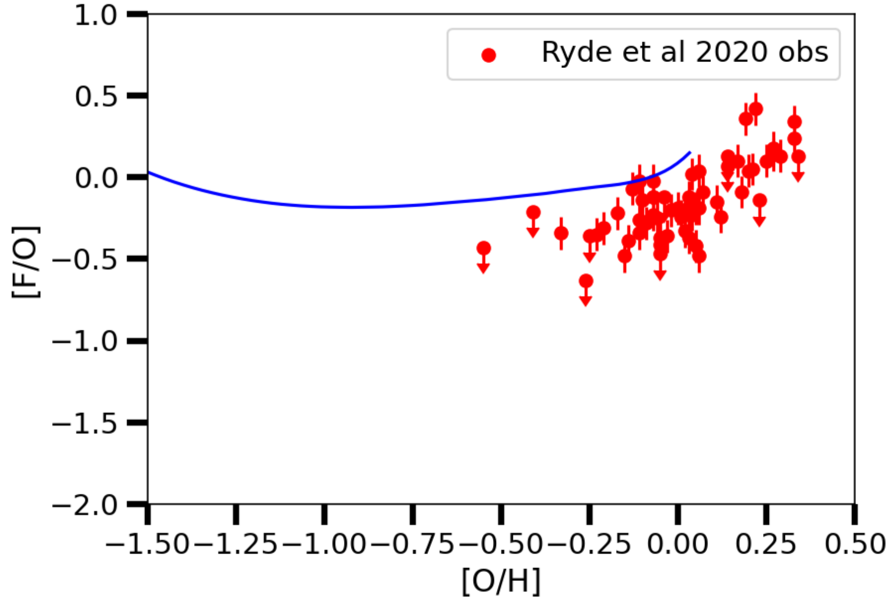
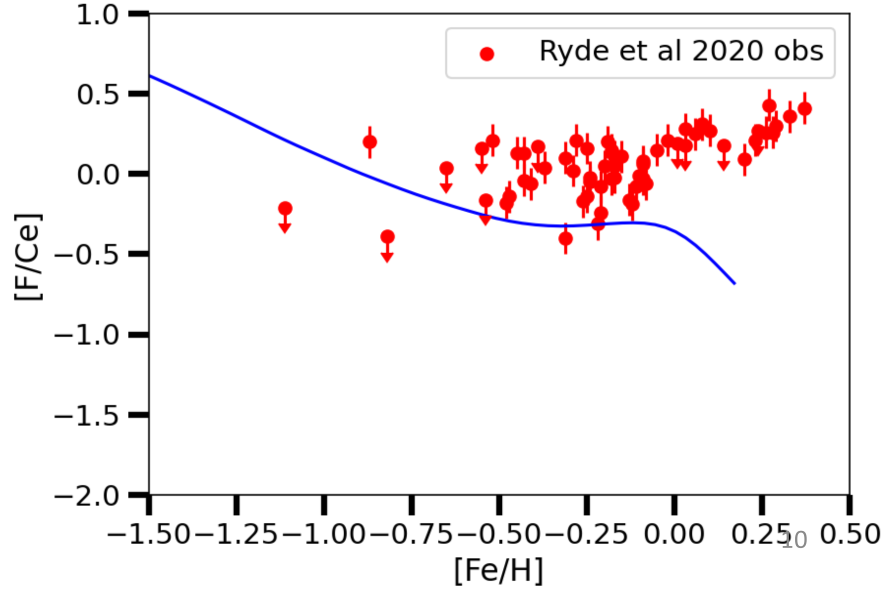
Results







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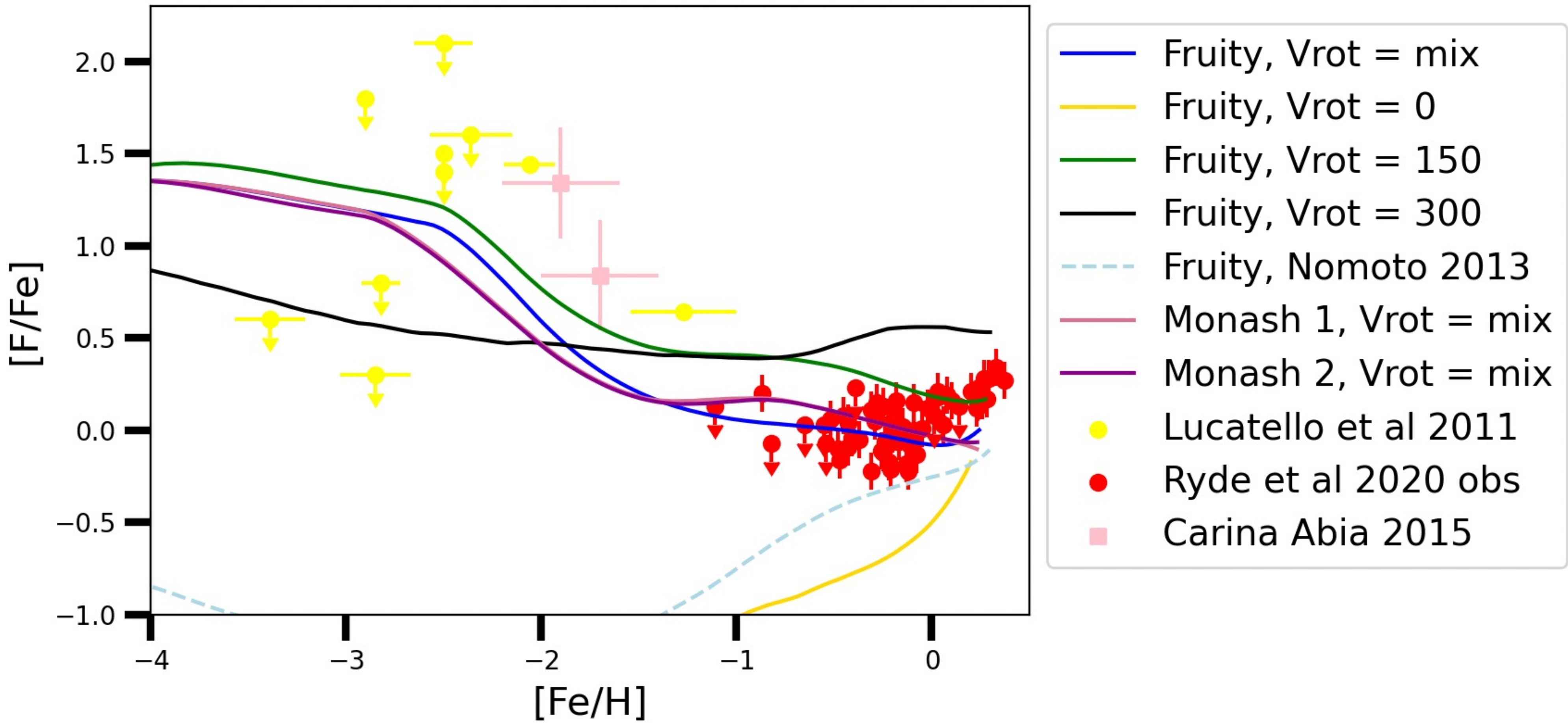
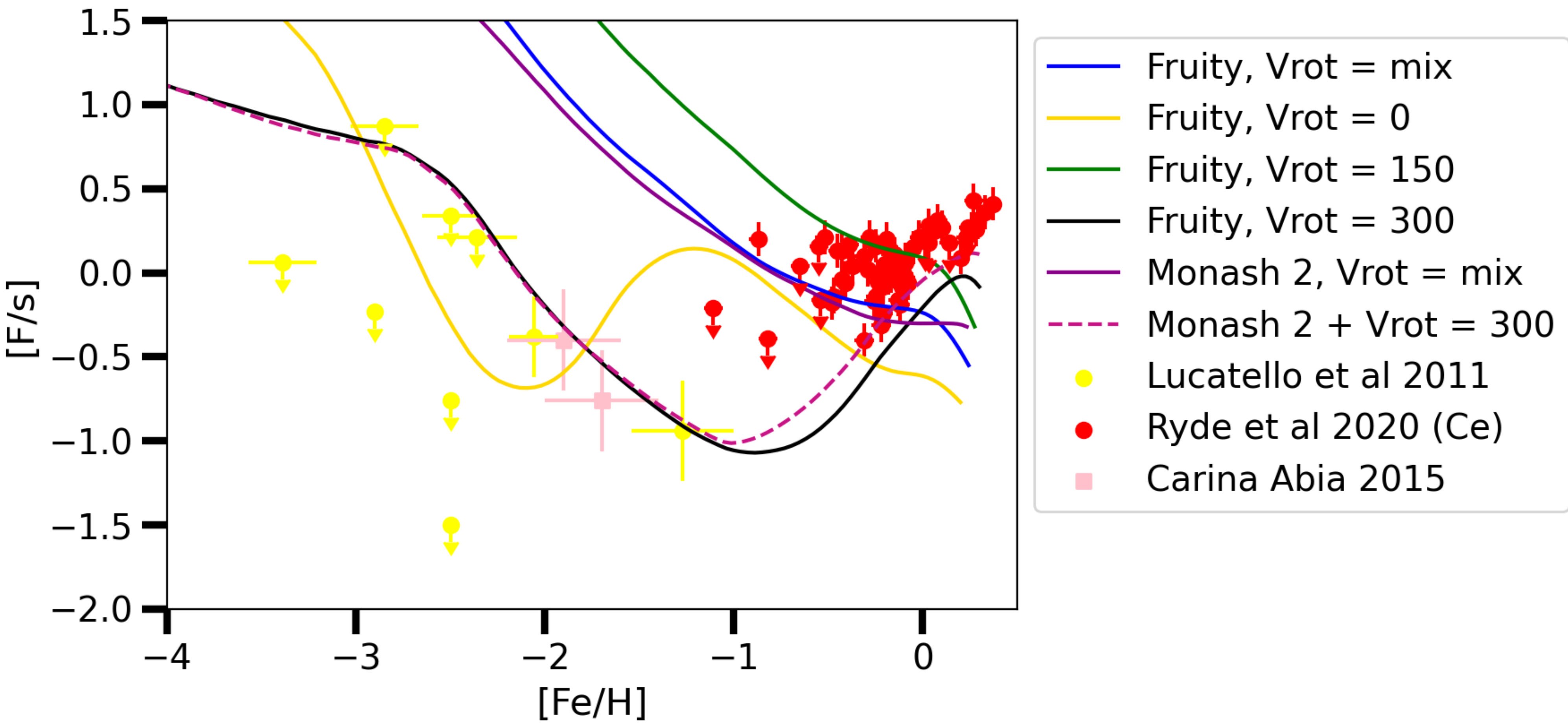


[F/Fe]
[Fe/H]
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−4
−3
−2
−1
0
Fruity, Vrot = mix
Fruity, Vrot = 0
Fruity, Vrot = 150
Fruity, Vrot = 300
Fruity, Nomoto 2013
Monash 1, Vrot = mix
Monash 2, Vrot = mix
Lucatello et al 2011
Ryde et al 2020 obs
Carina Abia 2015



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Future Development

- Explore the fluorine yields from other rotating massive star models (e.g. Choplin et al. 2018)

- Explore how the fluorine yield from WR models has changed since Meynet and Arnoud 2000 – can we rule it out as a source?

Conclusions

- Understanding the evolution of fluorine continues to pose a challenge for the community.
- By looking at the enhancement of both fluorine and s-process elements we can begin to understand the evolution of fluorine at low metallicity.
- We need a contribution from rapidly rotating massive stars in order to reproduce the [F/s] trends but more investigation needs to be done before making any firm conclusions.