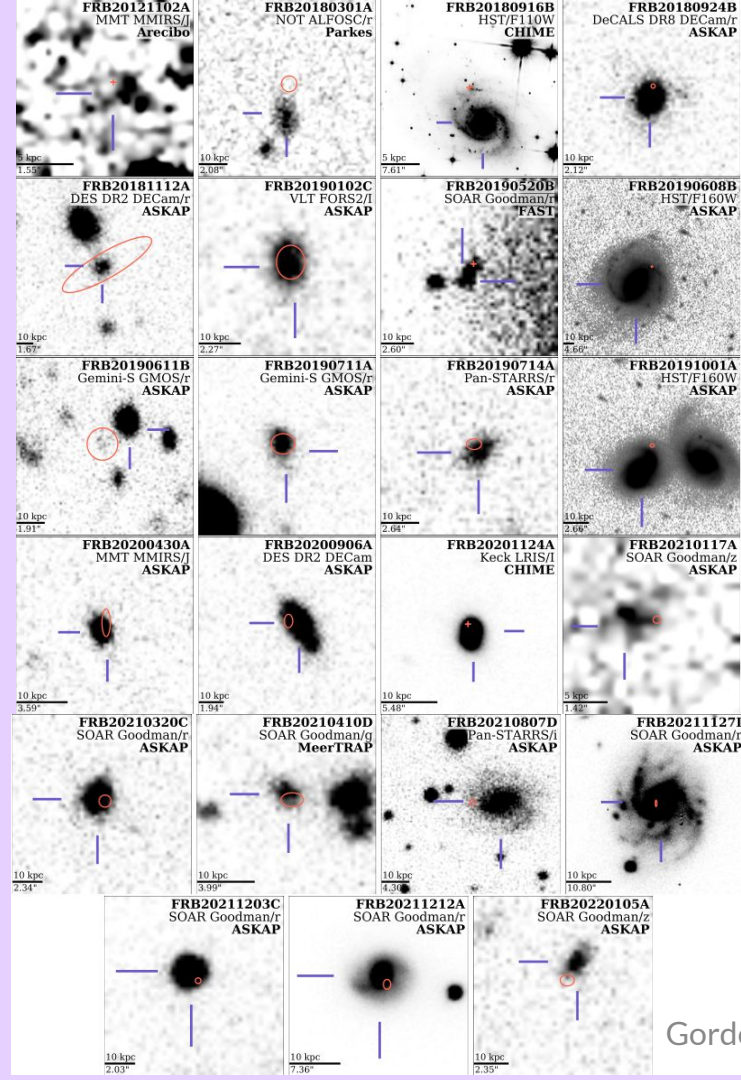# The Host Galaxies

of

Fast Radio Bursts

Alexa Gordon, Wen-fai Fong,

Charlie Kilpatrick, & collaborators

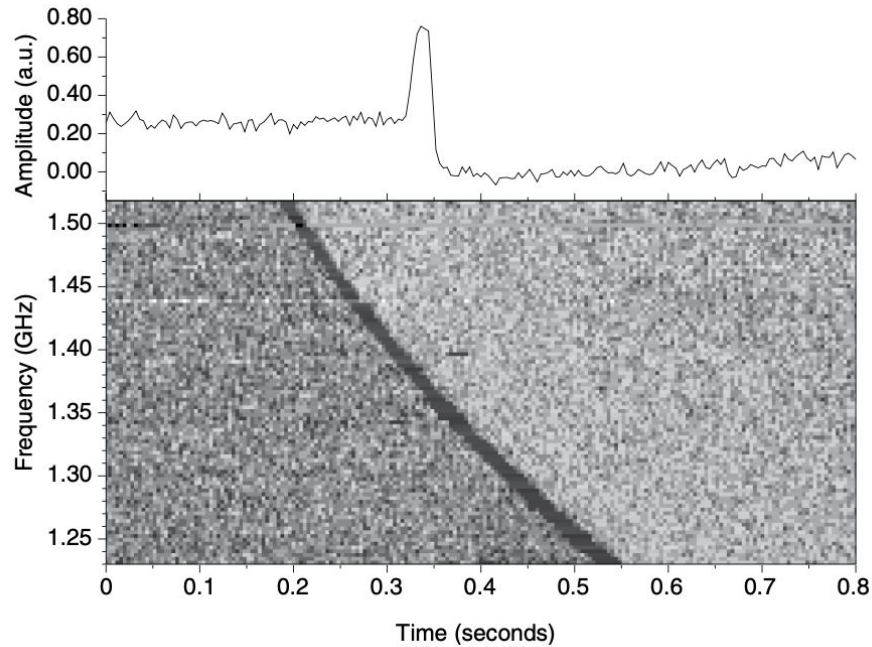**arXiv:2302.05465**

The Transient and Variable Universe

2023

CRAFT

FAST & FORTUNATE
FRB FOLLOW-UP

Gordon+23 Fig 1

Fast Radio Bursts

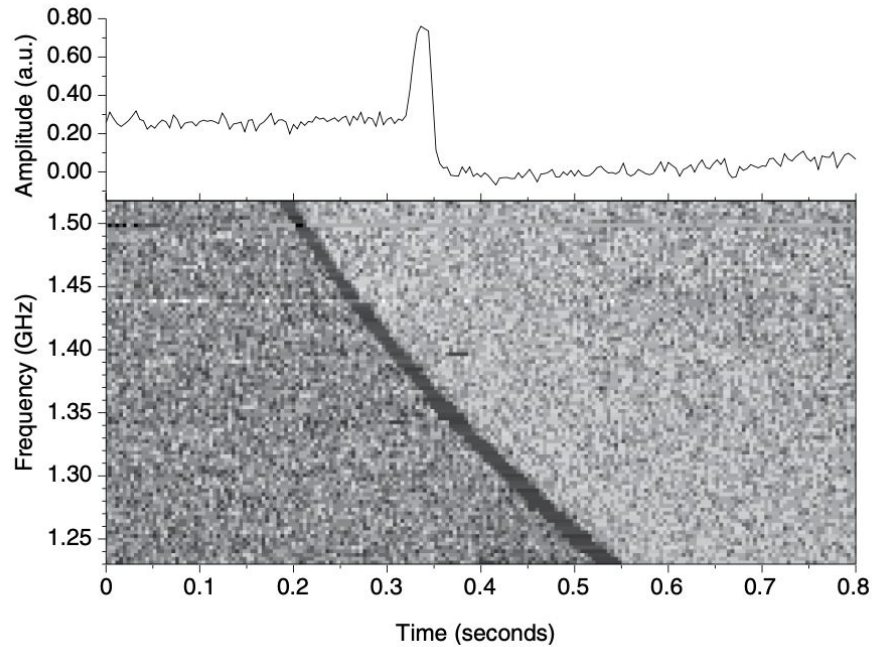**FRB 20010724**; Lorimer+07, Lorimer+18

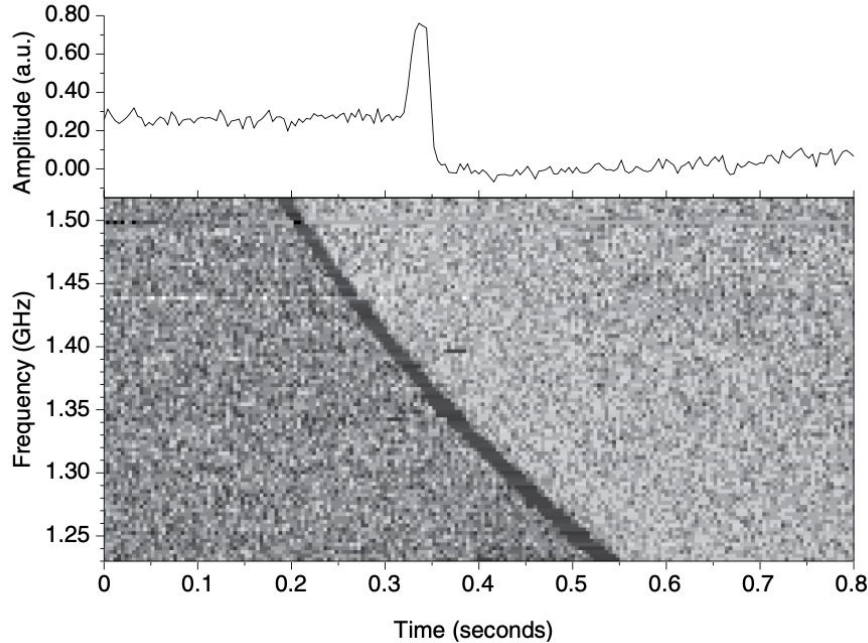Dispersion measure

$$DM = \int_0^d n_e \, dl$$

Fast Radio Bursts

FRB 20010724; Lorimer+07, Lorimer+18

$$DM = \int_{0}^{d} n_e dl$$

What causes them?

Fast Radio Bursts

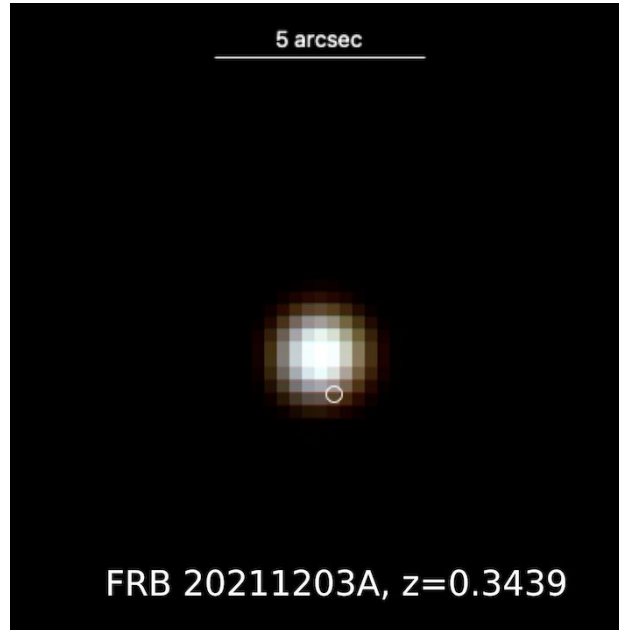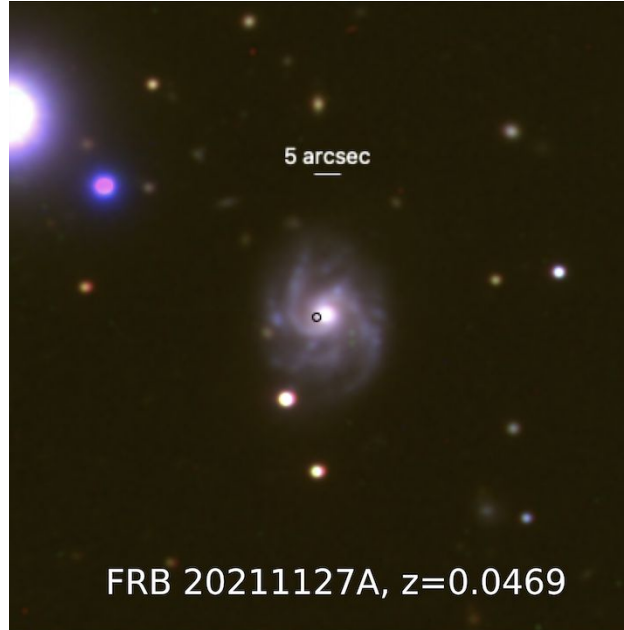**FRB 20010724**; Lorimer+07, Lorimer+18

Dispersion measure

$$DM = \int_0^d n_e dl$$

What causes them?

Coherence + Energetics = Magnetars?

3

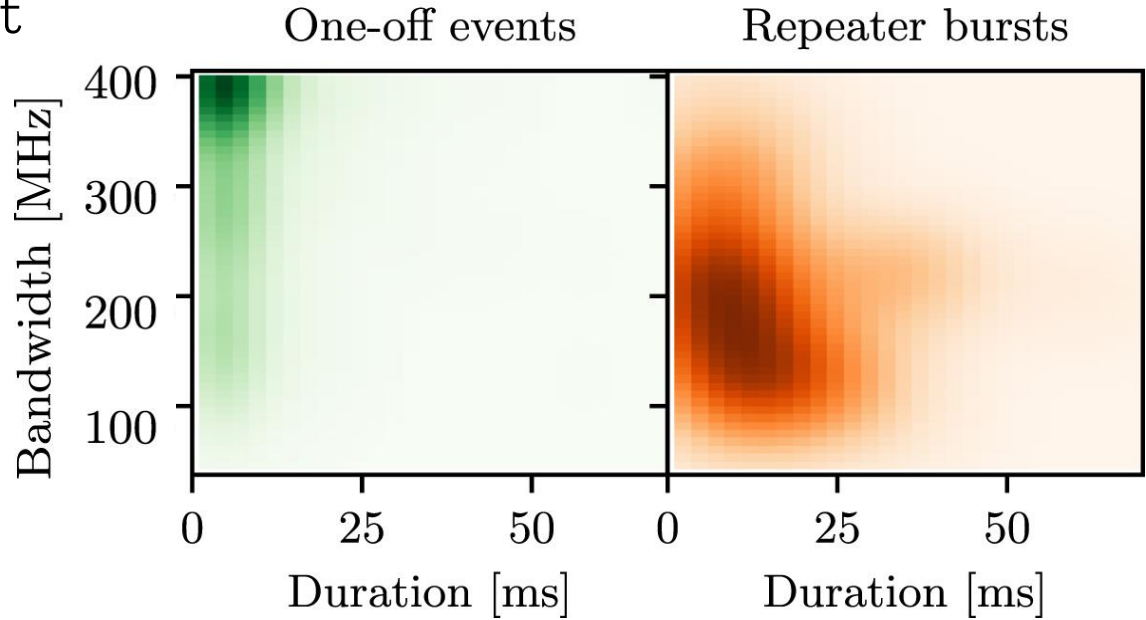# Host Galaxies Reveal
the Local Environment

~27 FRBs localized to <1-2 arcseconds

FRB 20211127A, z=0.0469

FRB 20211203A, z=0.3439

FRB 20211212A, z=0.0707

Some FRBs repeat, others (apparently) don't

Multiple progenitors?
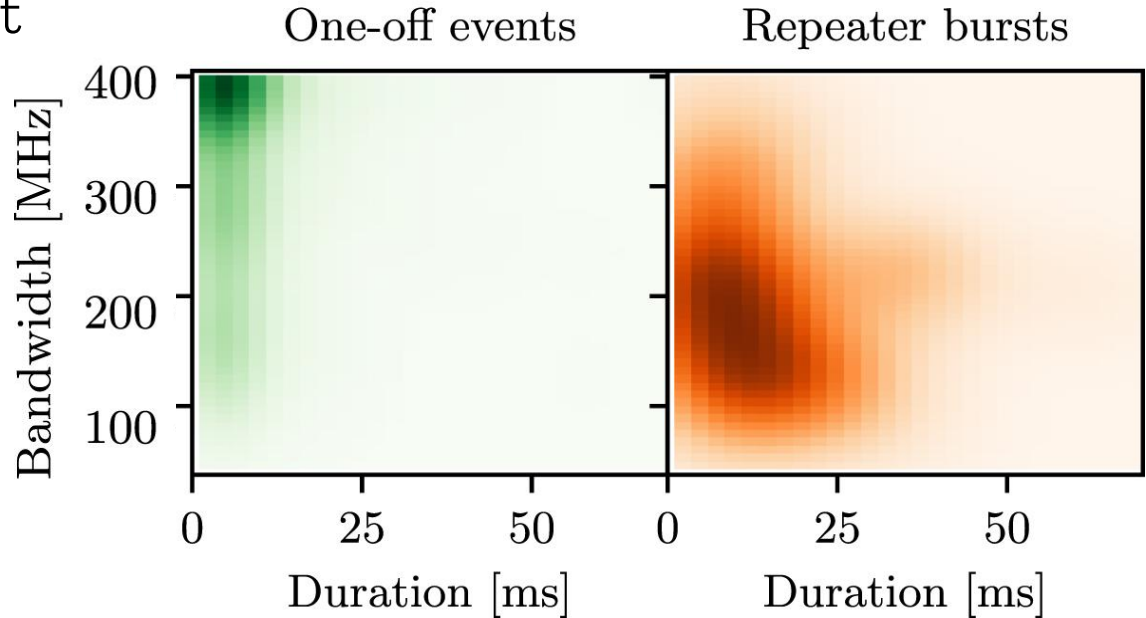
Multiple formation channels?

Adapted from Pleunis+21

5

Some FRBs repeat, others (apparently) don't
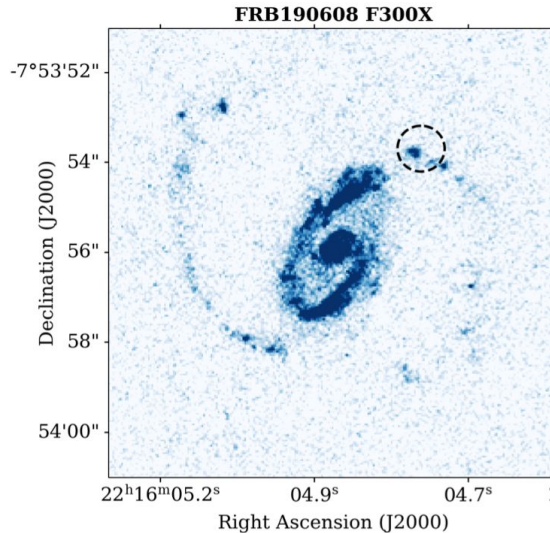
Multiple progenitors?

Multiple formation channels?

Can host studies solve the mystery?

One-off events   Repeater bursts

Adapted from Pleunis+21

Star Formation Connection?

Tentative correlation

with spiral arms

Oddly fall in "green valley"

below the star forming

main sequence
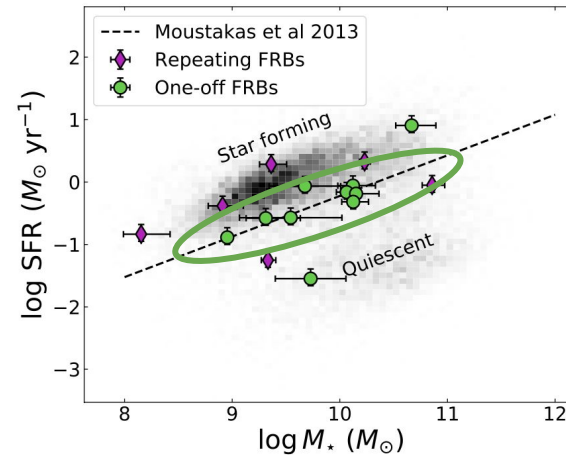
Heintz+20, Bhandari+21, Chittidi+21,
Fong+21, Mannings+21, Tendulkar+21

Bhandari+21

7

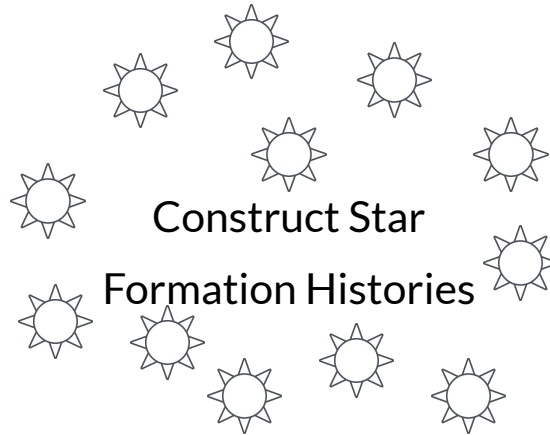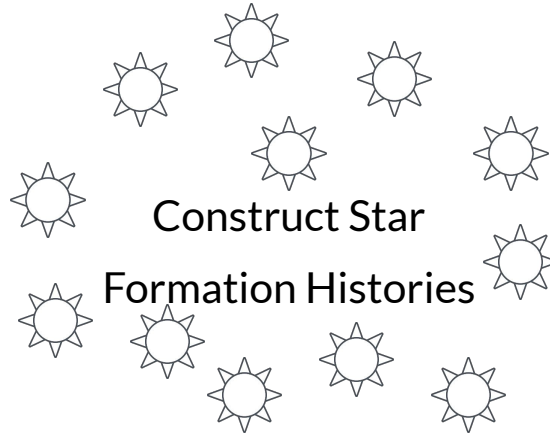# Goal - Model all Highly Secure FRB Hosts

Mass Age

Derive Stellar

Population Properties

Metallicity

Goal - Model all Highly Secure FRB Hosts

Mass **Age**

Derive Stellar

Population Properties

Metallicity

Construct Star

Formation Histories

Goal - Model all Highly Secure FRB Hosts

Mass Age

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Construct Star

Formation Histories

Investigate

correlations between

FRB & host properties

Goal - Model all Highly Secure FRB Hosts

Mass **Age**

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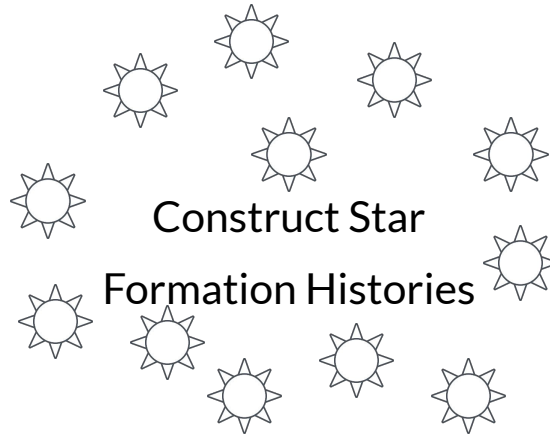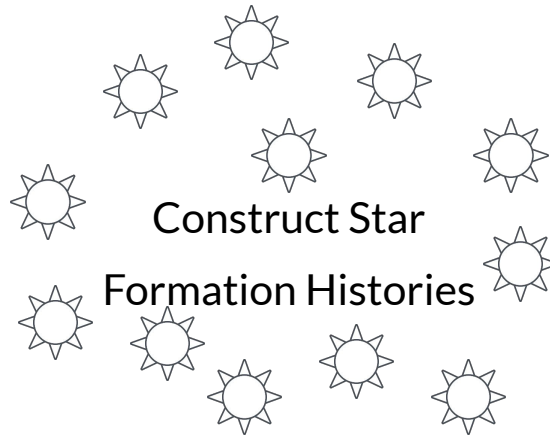
Investigate

correlations between

FRB & host properties

23 FRB hosts: 17 non-repeaters & 6 repeaters

Goal - Model all Highly Secure FRB Hosts

Mass
Age
Metallicity

Derive Stellar
Population Properties

Construct Star
Formation Histories

Investigate
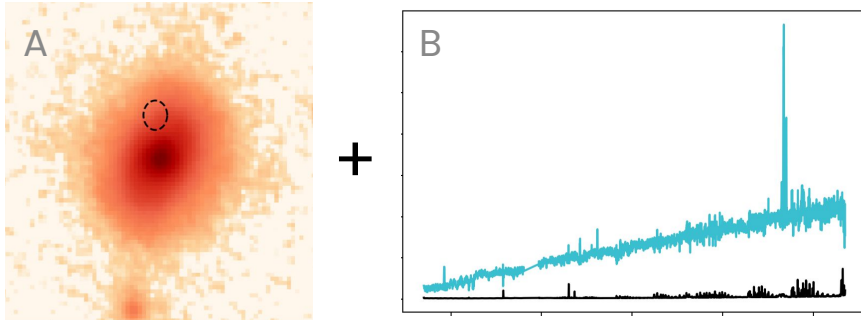correlations between
FRB & host properties

23 FRB hosts: 17 non-repeaters & 6 repeaters

Largest
uniformly-modeled
sample to date!

Prospector

Photometry   Spectroscopy
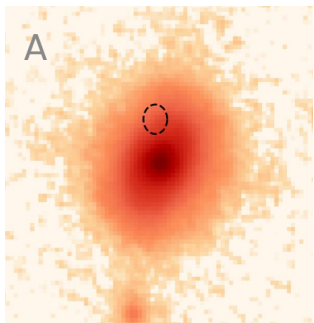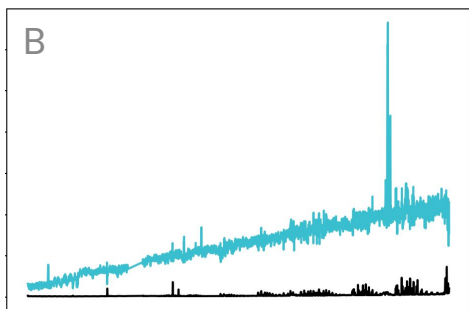

+

(+Prior Assumptions)

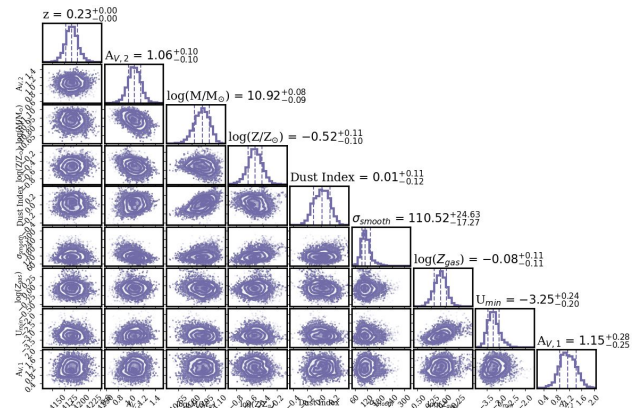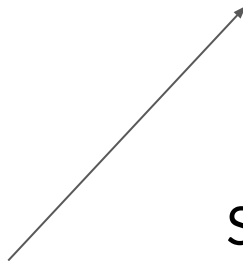Photometry   Spectroscopy

+

(+Prior Assumptions)

Stellar Population Properties

Photometry

Spectroscopy

+
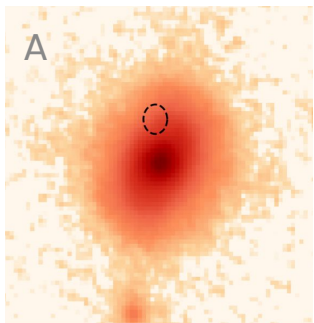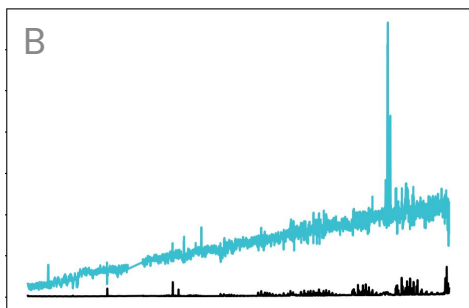
(+Prior Assumptions)
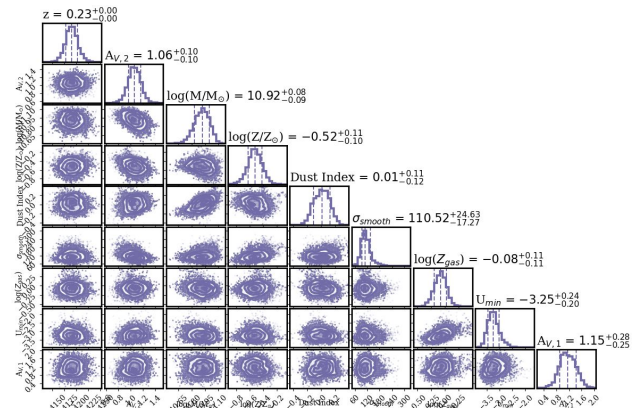
Stellar Population Properties
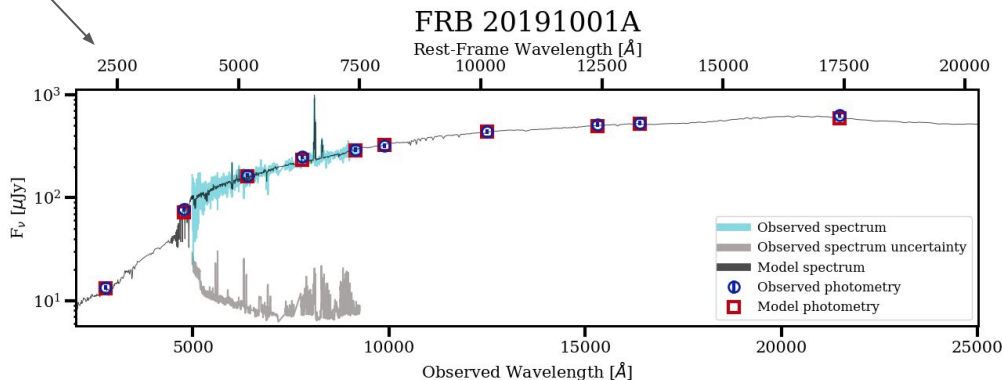
Spectral Energy Distribution (SED)

15

No Statistical Differences between

Repeaters & Non-repeaters (currently)

p = 0.060

Gordon+23 Fig 4
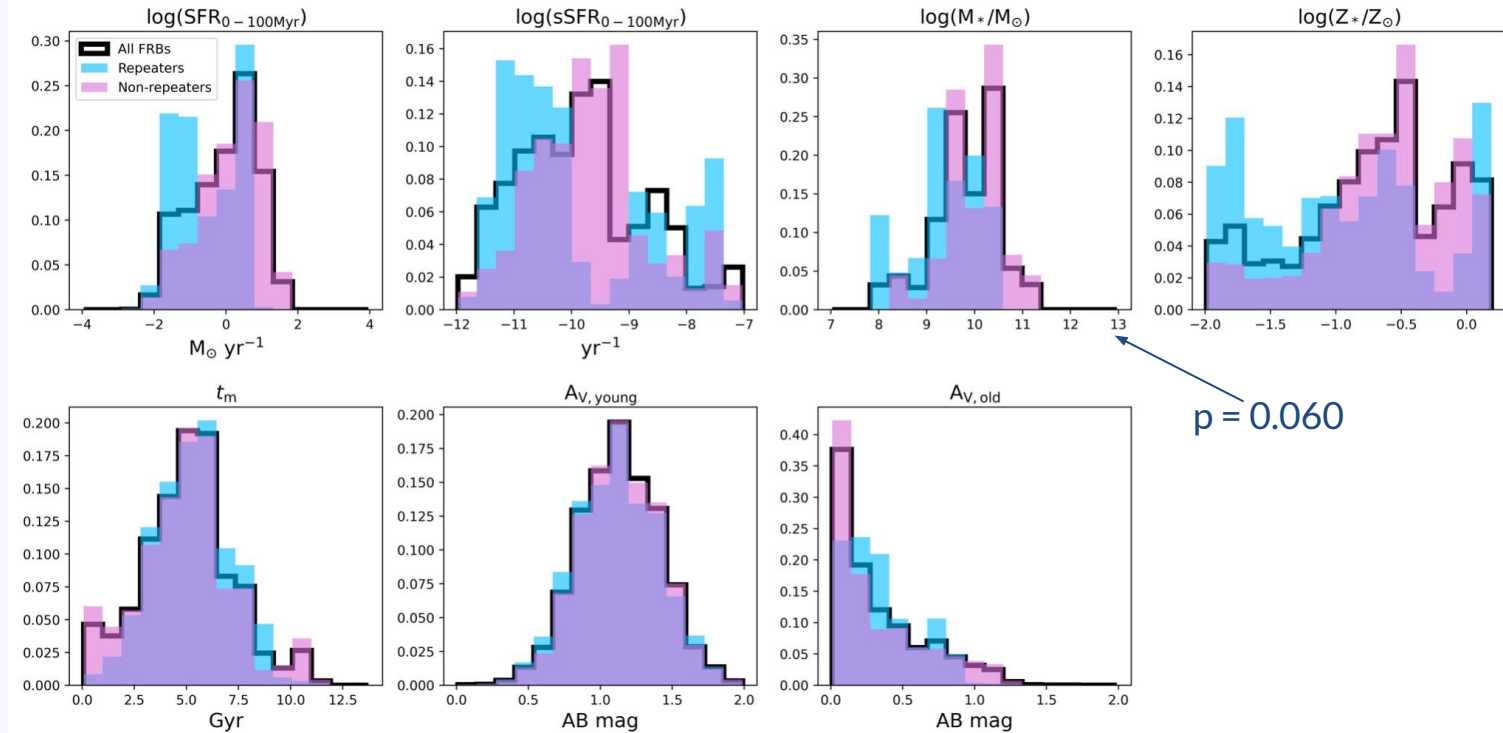
Non-parametric

Star Formation Histories

Five "classes" of SFHs

Rising
Exponentially-declining
    delayed-tau
    tau-linear
Post-starburst
Rejuvenating

FRB 20121102A **(R)**

SFR (Msun/yr)

Lookback time (Gyr)

present day

17

FRB Hosts have <u>diverse</u> Star Formation Histories

SFR $[M_\odot yr^{-1}]$

$t_{lookback}$ (Gyr)

18

Gordon+23 Fig 8

FRB Hosts have <u>diverse</u> Star Formation Histories

Repeaters tend to show rising star formation histories

Connection between activity level and recent star formation?

19

Gordon+23 Fig 8

FRB Hosts have <u>diverse</u> Star Formation Histories

Repeaters tend to show rising star formation histories

Connection between activity level and recent star formation?

(one non-repeater is rising)

20

Gordon+23 Fig 8

FRB Hosts have <u>diverse</u> Star Formation Histories

Repeaters tend to show rising star formation histories

Connection between activity level and recent star formation?

(one non-repeater is rising)

(one repeater is tau-linear exponentially declining)

21

Gordon+23 Fig 8

FRB 20121102A **(R)**   FRB 20180301A **(R)**   FRB 20180916B **(R)**   FRB 20180924B

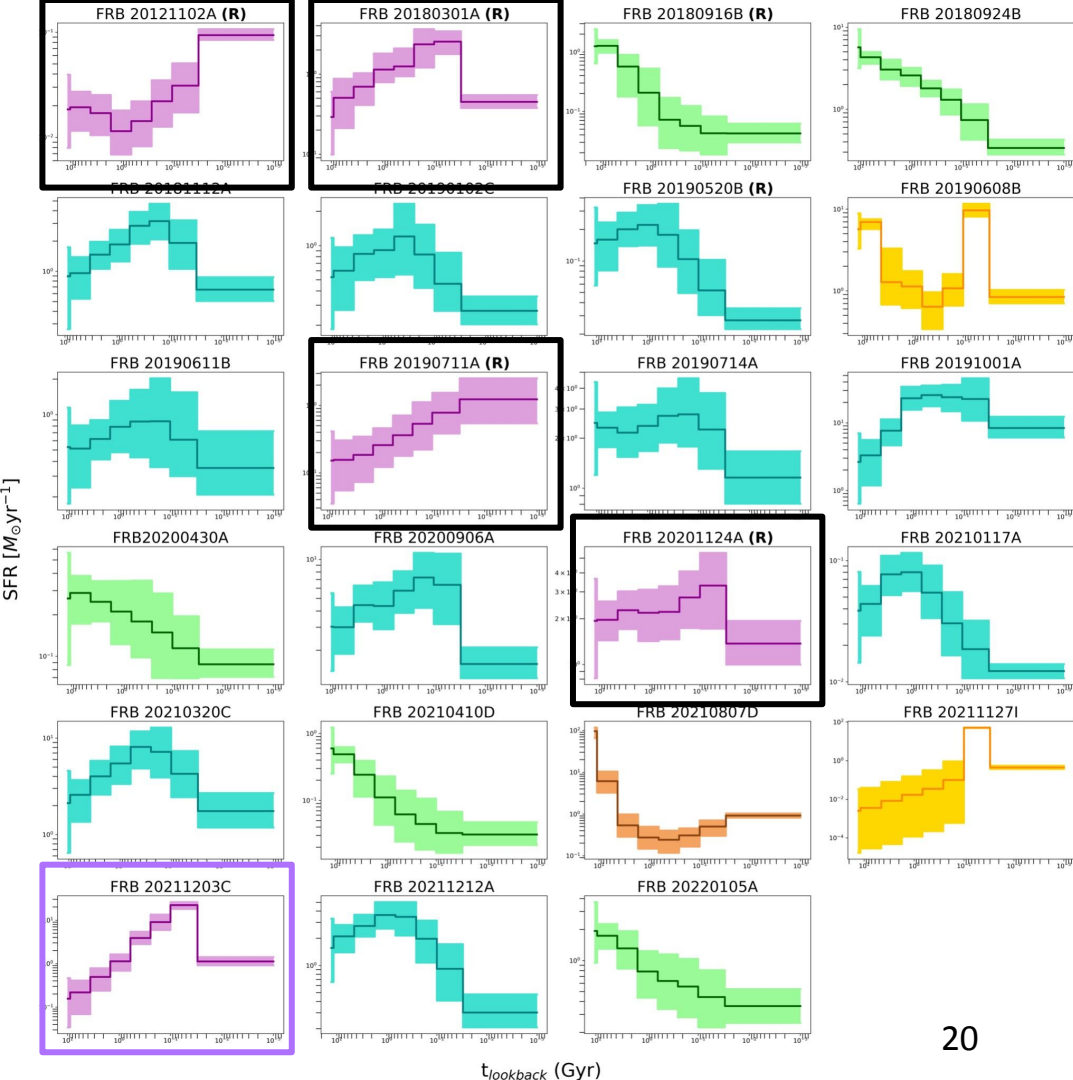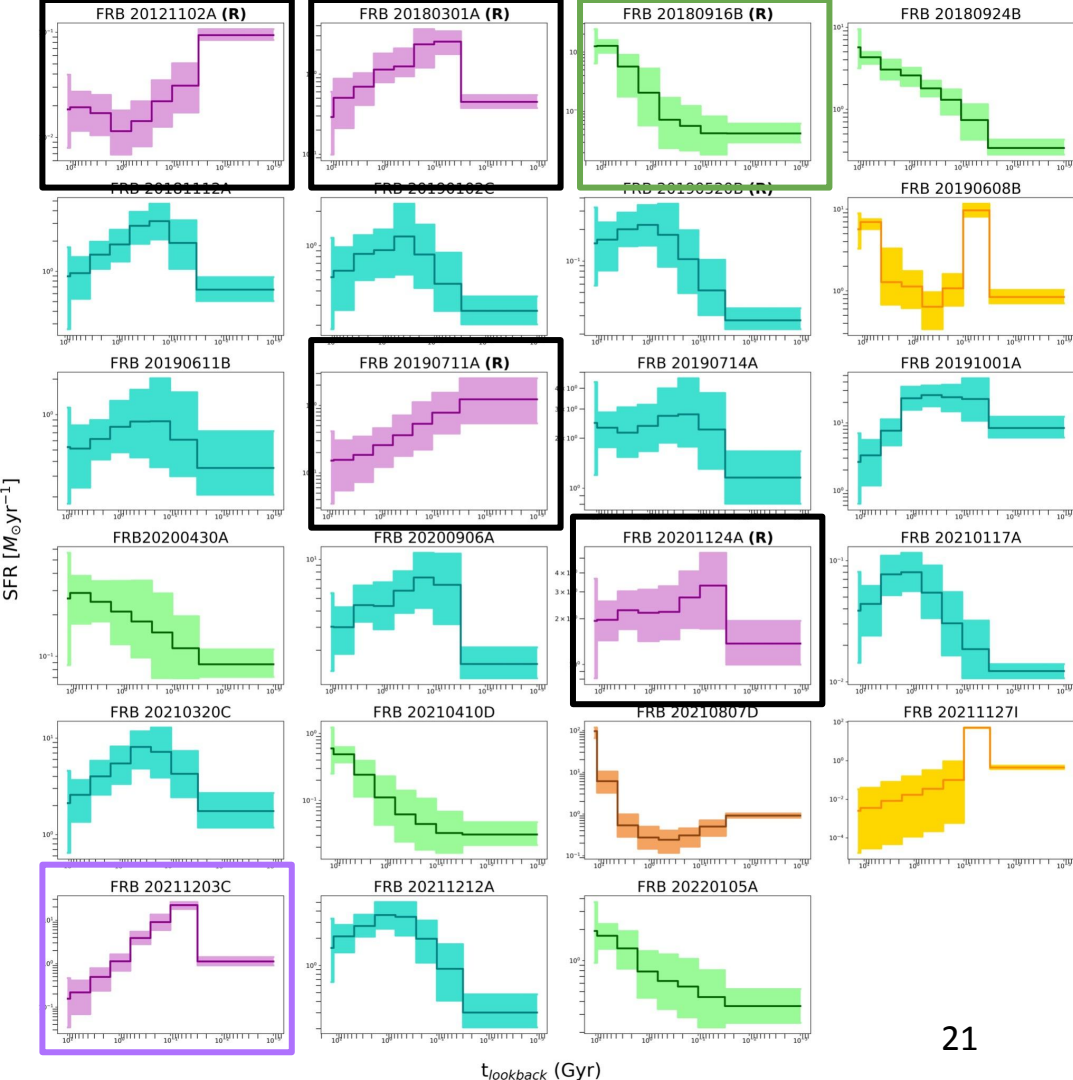FRB 20181112A   FRB 20190102C   FRB 20190523B (R)   FRB 20190608B

FRB 20190...   FRB20200...

FRB 20210320C   FRB 20210410D   FRB 20210807D   FRB 20211127I

FRB 20211203C   FRB 20211212A   FRB 20220105A
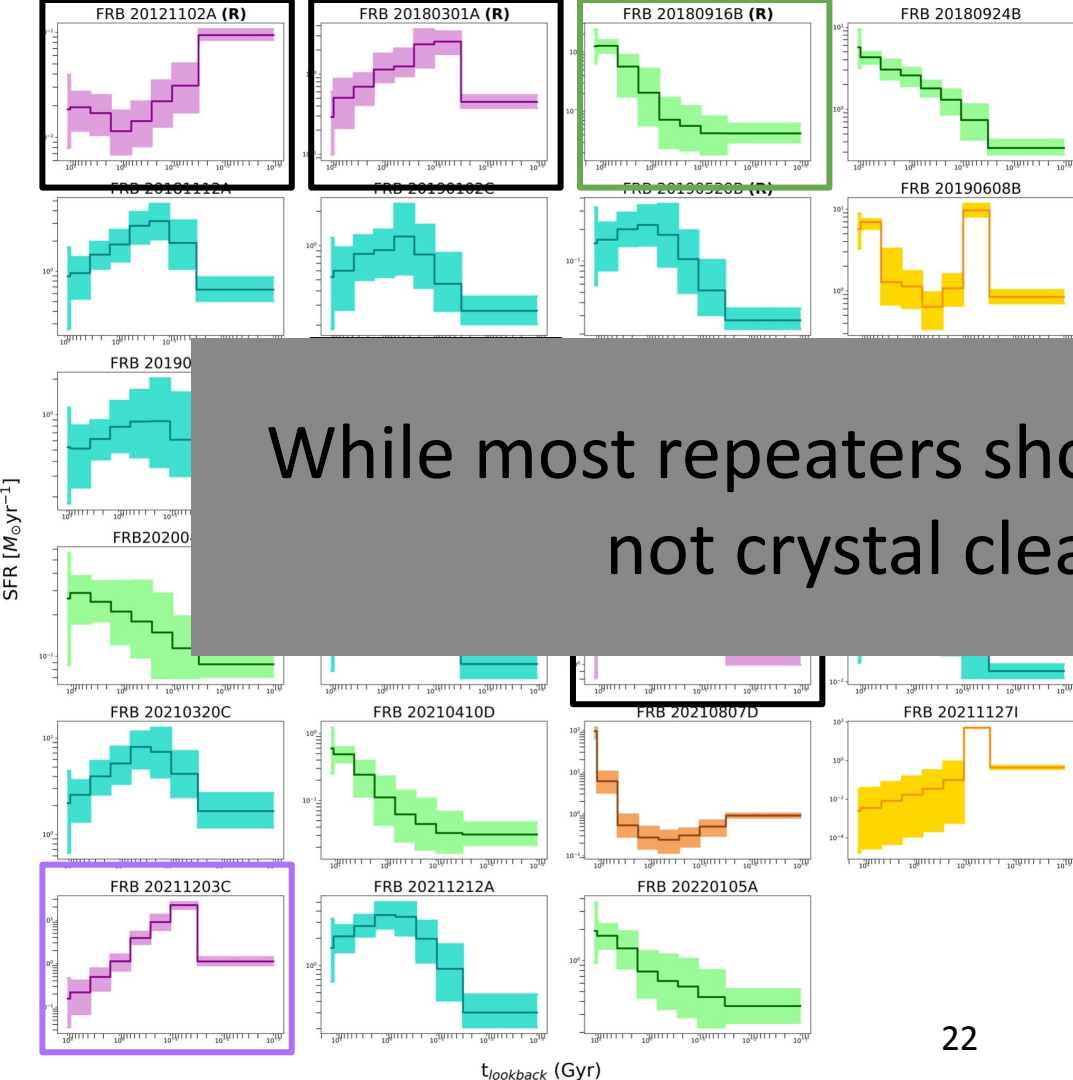
$t_{lookback}$ (Gyr)

SFR [$M_\odot yr^{-1}$]

FRB Hosts have <u>diverse</u> Star
Formation Histories

Repeaters tend to show

While most repeaters show rising SFHs, it's
not crystal clear (yet!)

(one non-repeater is
rising)

(one repeater is tau-linear
exponentially declining)

22

Gordon+23 Fig 8

Most FRB hosts are star-forming

and <u>not distinct</u> from field galaxies
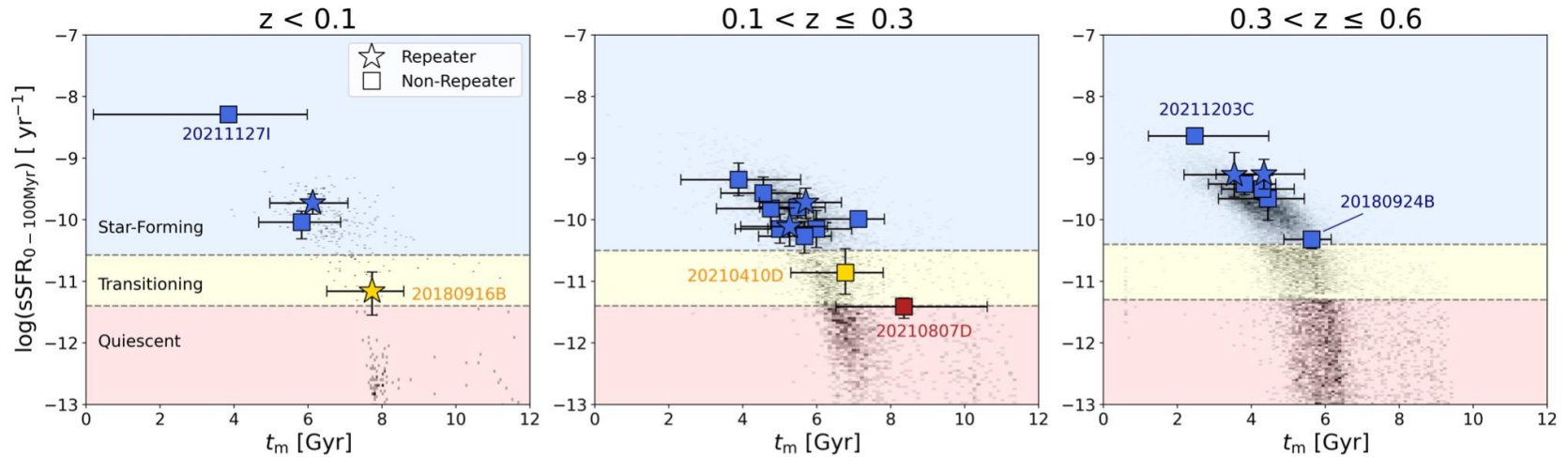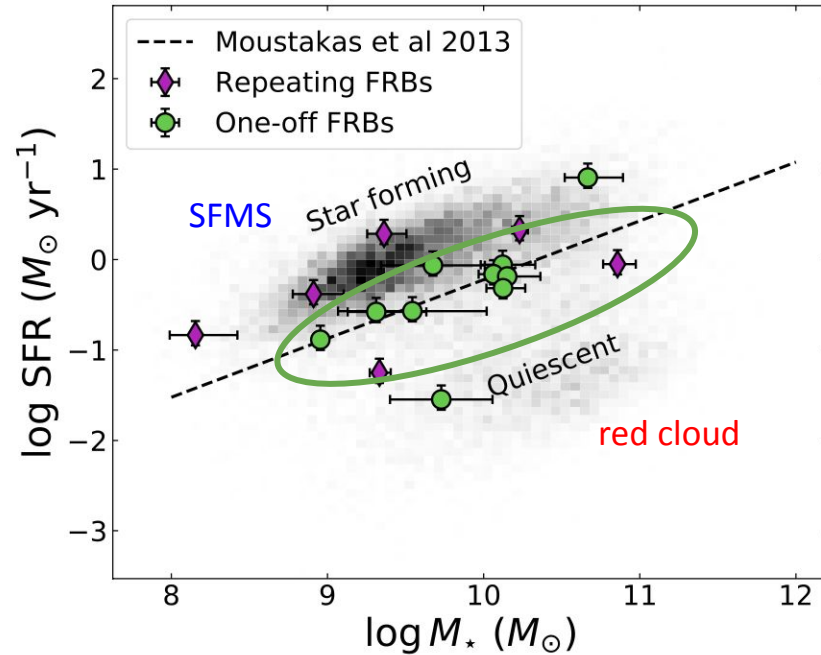

Repeaters associated with present-day star-formation

2/3 of less active hosts are non-repeaters -
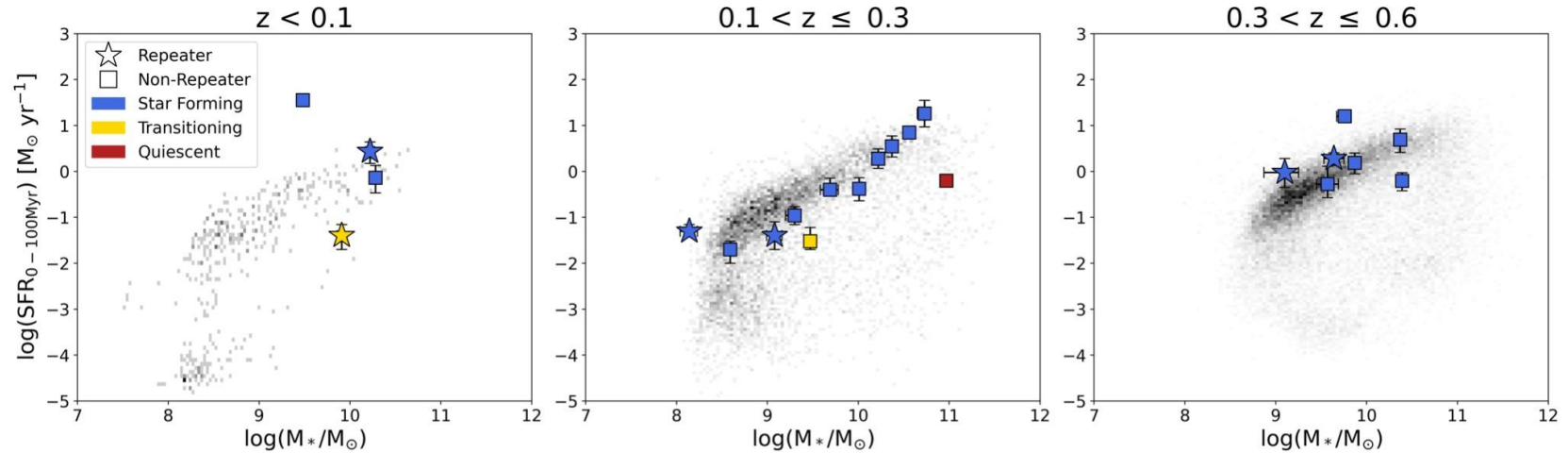preference for more evolved galaxies?

Gordon+23 Fig 7

Revisiting the "green valley" question
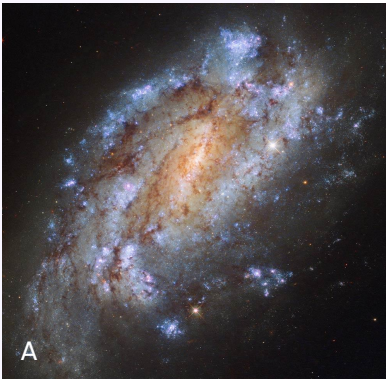

Bhandari+21

Uniformly-modeled FRB hosts <u>trace</u> the Star-Forming Main Sequence

Make sure to compare apples to apples!

Gordon+23 Fig 6

Star-forming environment supports a young progenitor; FRB properties support magnetars

Actively
star-forming galaxy
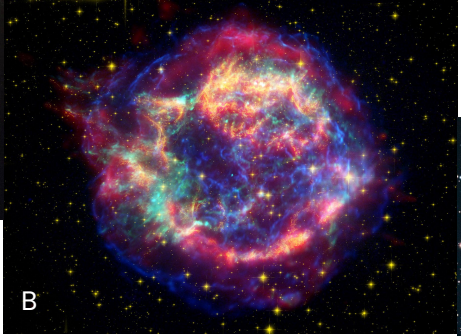
Core-collapse
supernova
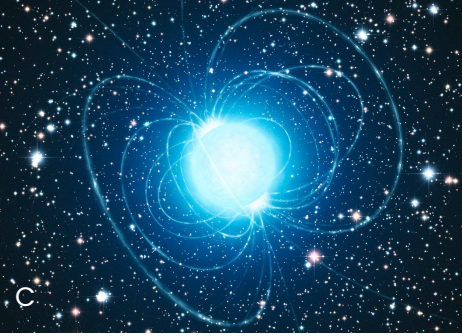
Young magnetar

FRB?

What's next for hosts?

50% larger sample (9 R, 25 NR) - stellar mass statistically distinct

2x larger sample (12 R, 34 NR) - SFR statistically distinct

3x larger sample (18 R, 51 NR) - stellar metallicity statistically distinct

(assuming current distributions are representative of true distributions)

What's next for hosts?

A modest increase in sample size will have the statistical power to distinguish the hosts of repeaters and non-repeaters!

What's next for hosts?

ASKAP/CRACO

CHIME Outriggers

1 sub-arcsec FRB/day by end of 2023!

Credit: Alex Cherney

Credit: Z22/Wikipedia

What's next for hosts?

ASKAP/CRACO

VLT Large Programme - 180 hrs
PI: Shannon

CHIME Outriggers

Gemini LLP - 200 hrs
PI: Eftekhari
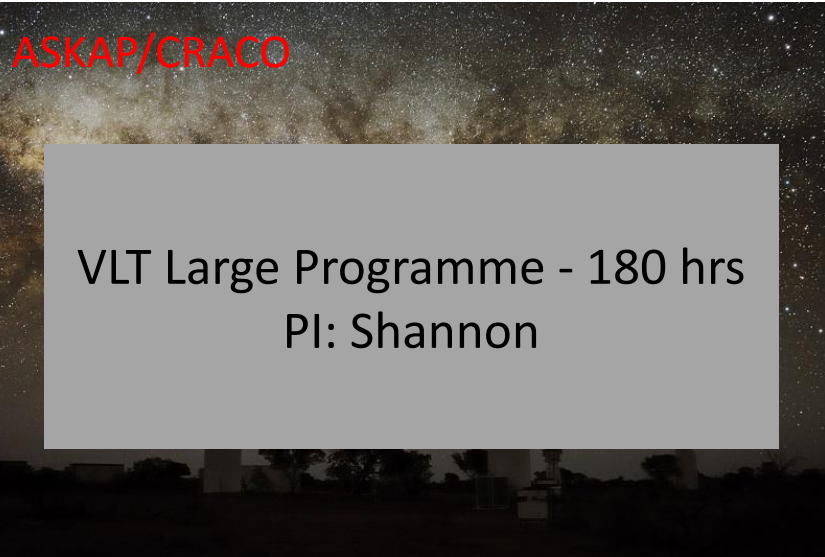
100-1000s new hosts in next few years!

30

Summary

- Largest sample of FRB hosts to date show majority of hosts are **star-forming** and trace star formation and stellar mass in galaxies, consistent with magnetars born from CCSNe

- A growing population of **less active** **hosts point toward more delayed progenitor** channels

- They have **diverse star formation histories** and are not distinct from field galaxies

- **Repeaters tend to show an increase in SFR** towards present day, perhaps indicating a connection between FRB activity level and galaxies still building up their mass

- There is no current statistical distinction in host properties between R/NR, but **repeater hosts extend to lower stellar masses**

- Only need a 50% larger sample to **start finding statistically significant distinctions** between repeaters and non-repeaters!

Questions? alexagordon2026 [at] u.northwestern.edu or Slack!
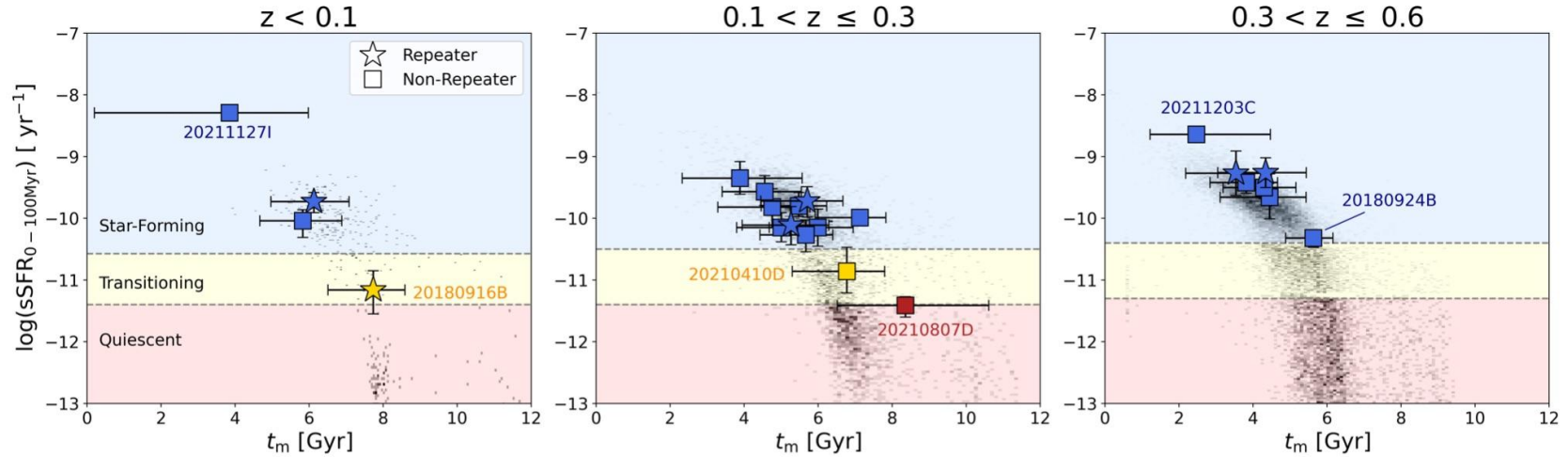
Bonus slides!
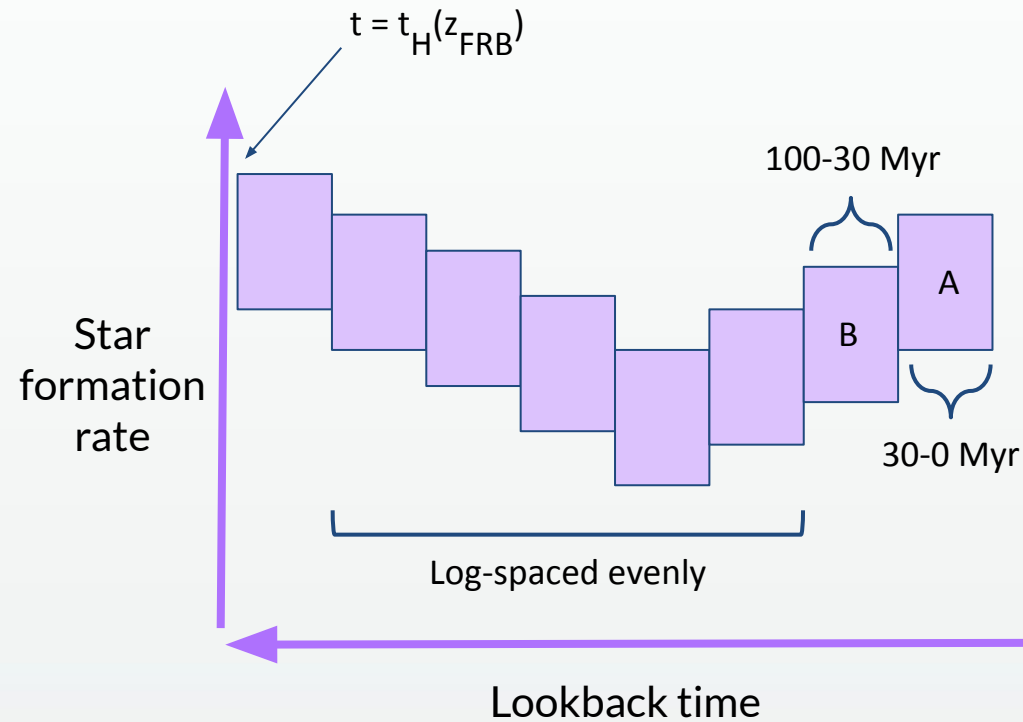
A Non-Parametric

Star Formation History

N=8 agebins

Fix start of first age bin

Specify length of last two bins

SFR(0-100 Myr) = (B*0.7 + A*0.3)/2

The Majority of FRB Hosts are Star-Forming

$$D(z) = sSFR(z) \times t_H(z) \qquad \text{Tacchella+22 mass-doubling number}$$

$$sSFR = SFR/M_*$$

$D(z) > 1/3$
star-forming
$1/3 < D(z) < 1/20$ transitioning
$D(z) < 1/20$ quiescent

FRB Host Properties

Stellar mass = 10^9.86 M$_\odot$

Mass-weighted age = 5.12 Gyr

log(Stellar metallicity) = -0.63

Specific SFR (SFR/M*) = 10^-9.86