

銀河の SED 進化・分化と円盤銀河形成

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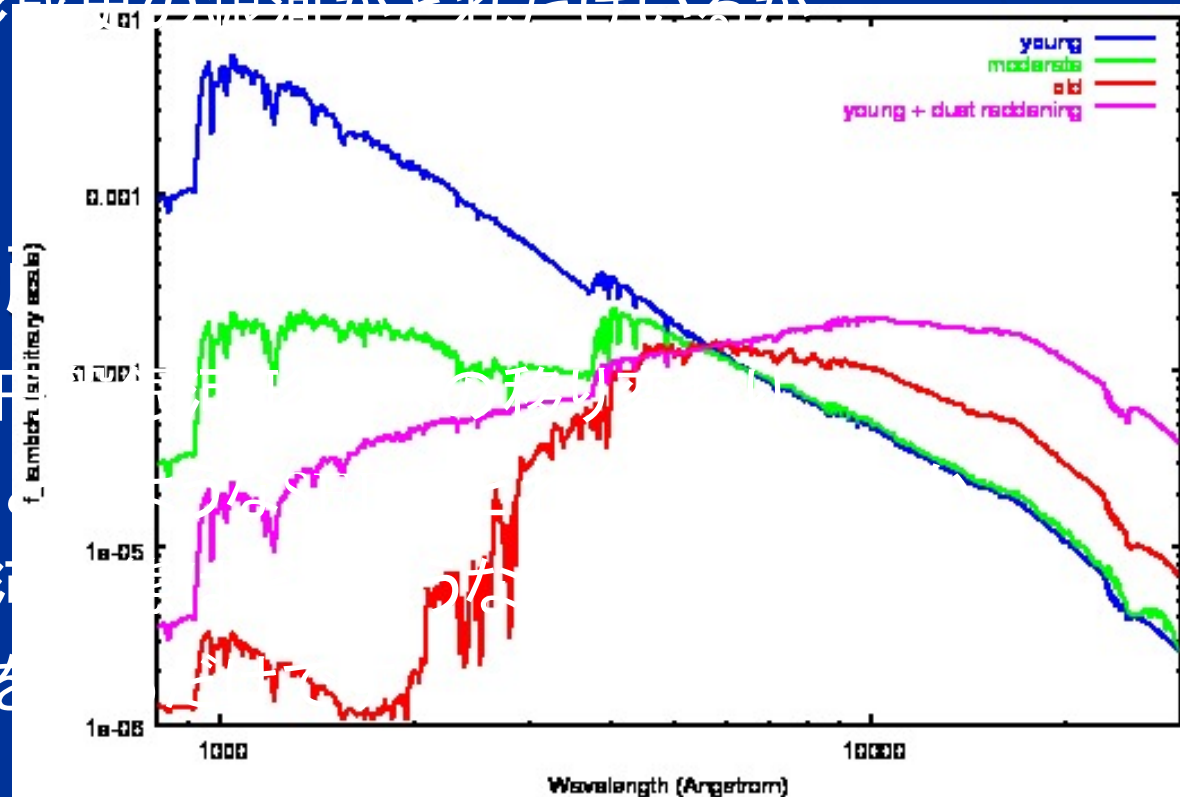
概要

■ $0.5 < z < 3.5$ の銀河のSED進化

- ・ 銀河のSED → どの年齢の星がどれだけいるか
- ・ どのような星形成中の銀河がどれだけいるか

■ 静止系可視の

- ・ $z \sim 1$ → 現在の円盤銀河
- ・ clumpy disks は
- ・ 現在の円盤銀河
- ・ 今日は顔写真を



GOODS-North

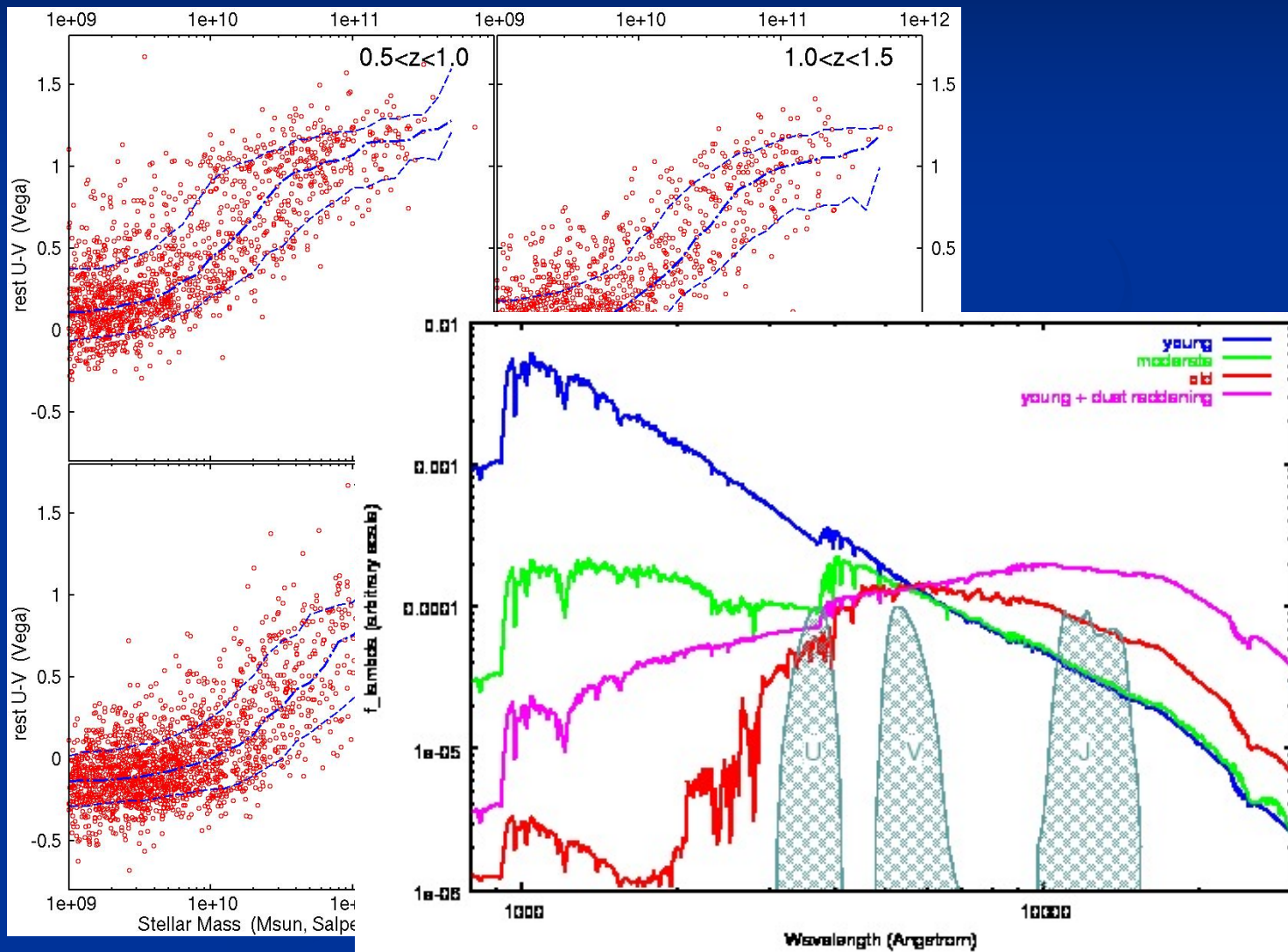
■ ~100平方分に渡る多波長データ

- ✓ Subaru/MOIRCS J, H, Ks bands
サンプルはKs-selected ($K_{\text{vega}} < 23$, 一部 $K_{\text{vega}} < 24$)
- ✓ HST ACS/B, V, i, z & WFC3/J, H bands
z, J, H バンドは静止系可視域で形態を見るのにも使用
- ✓ Spitzer/IRAC 3.6, 4.5, 5.8 μm bands
- ✓ KPNO/MOSAIC U band

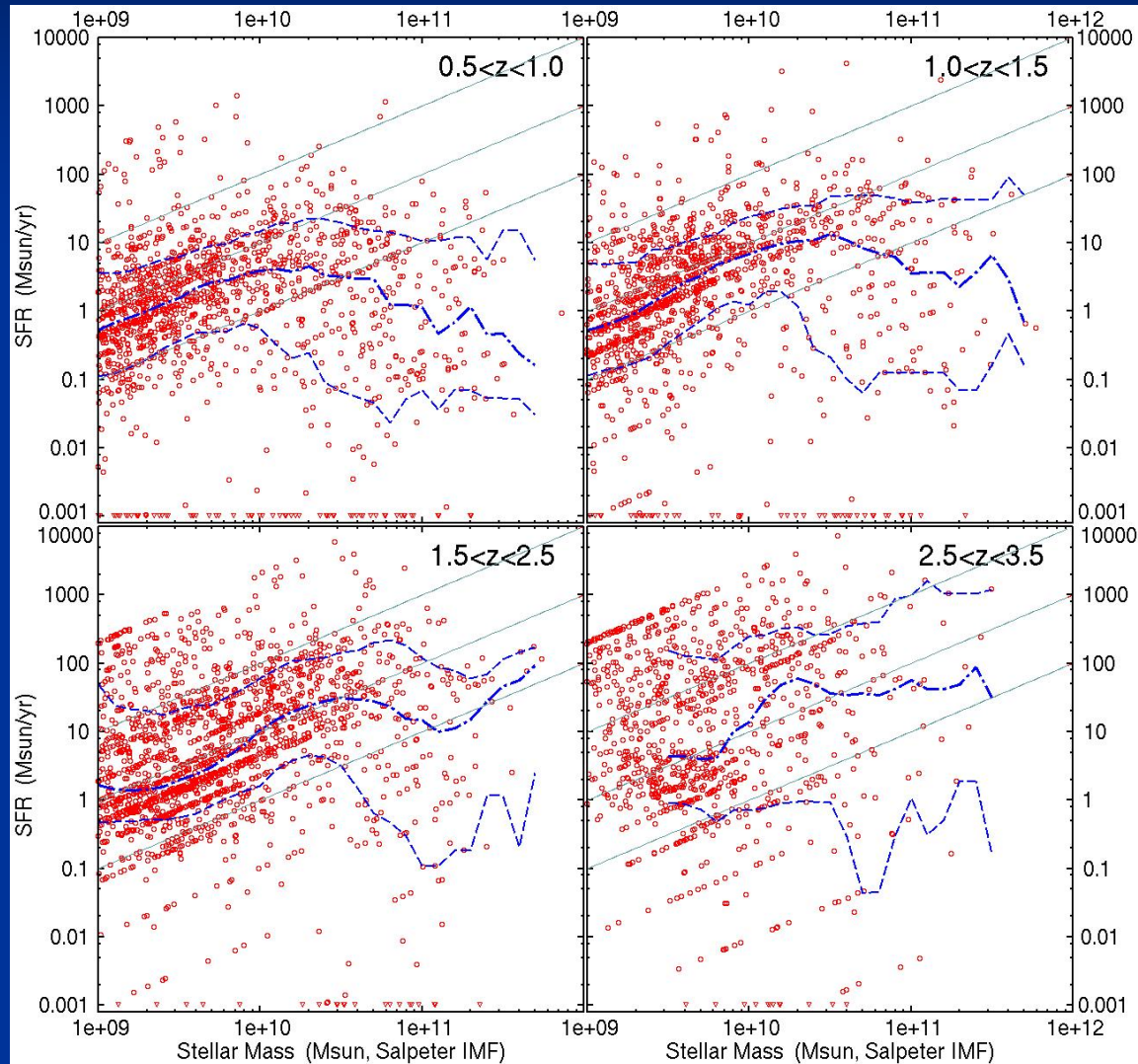
多色測光データを種族合成モデル(GALAXEV)でfitting

→ redshift, rest-frame colors, stellar mass, SFR

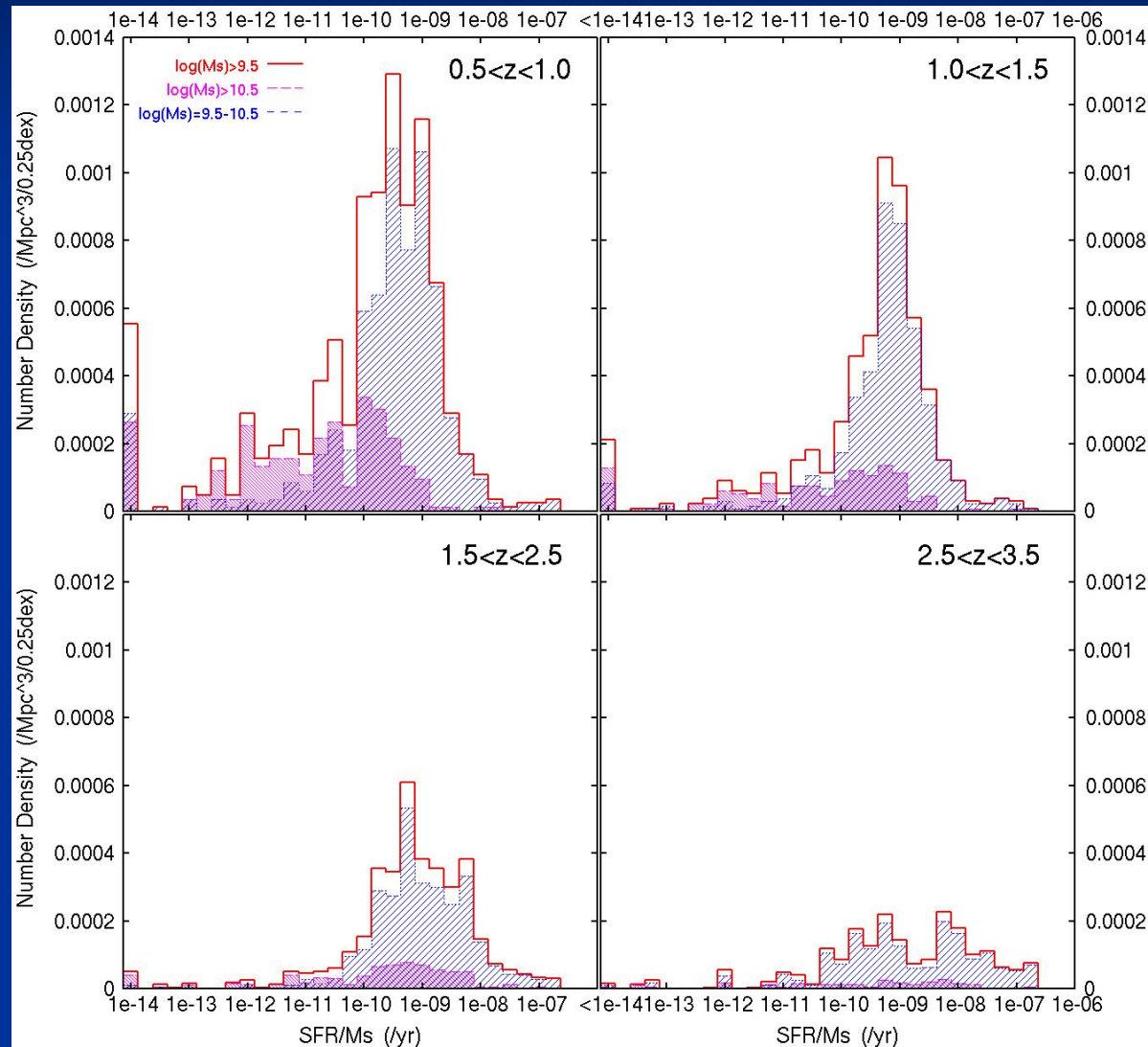
rest U-V vs 星質量(M_s)分布



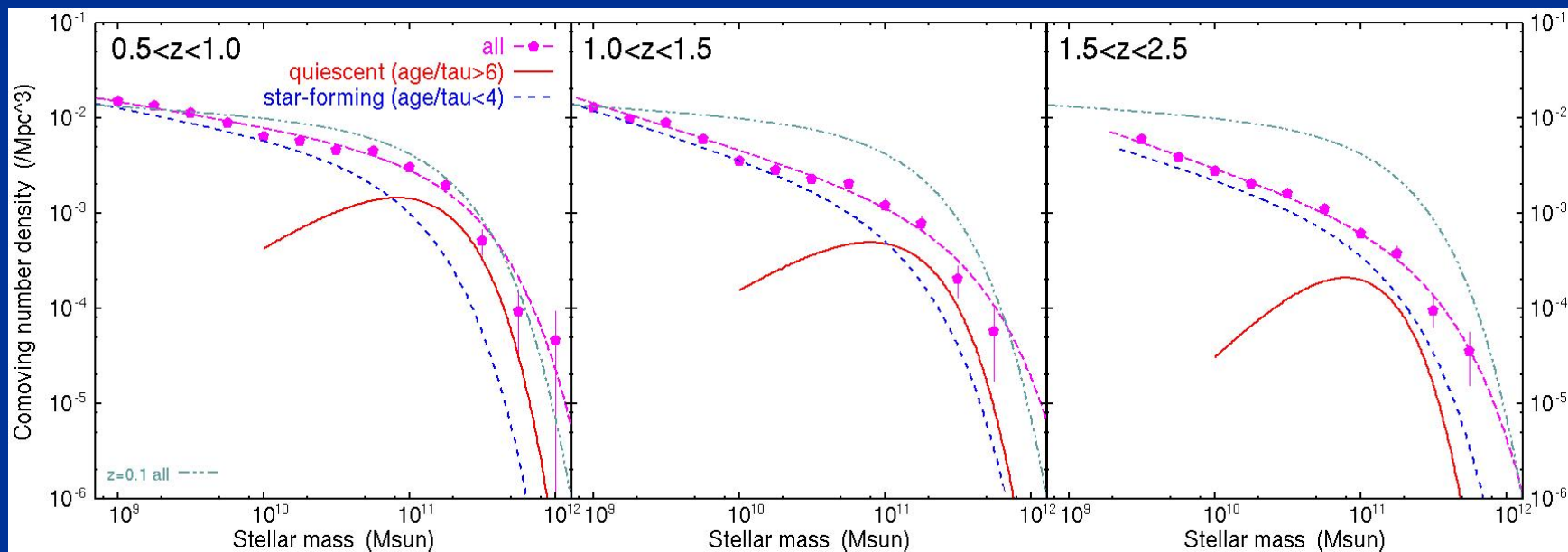
SFR vs M_s 分布の進化



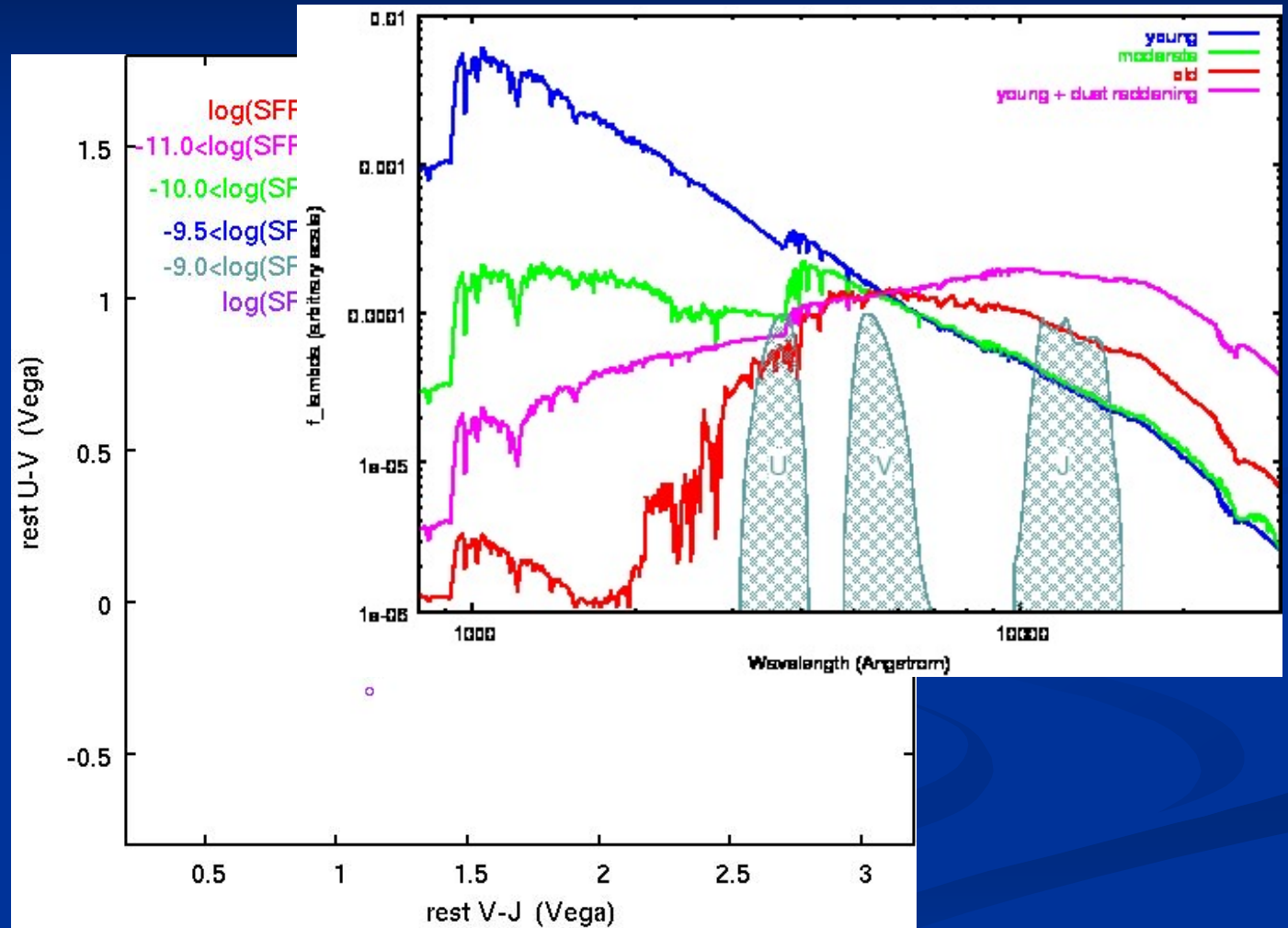
SFR/ M_s 分布の進化



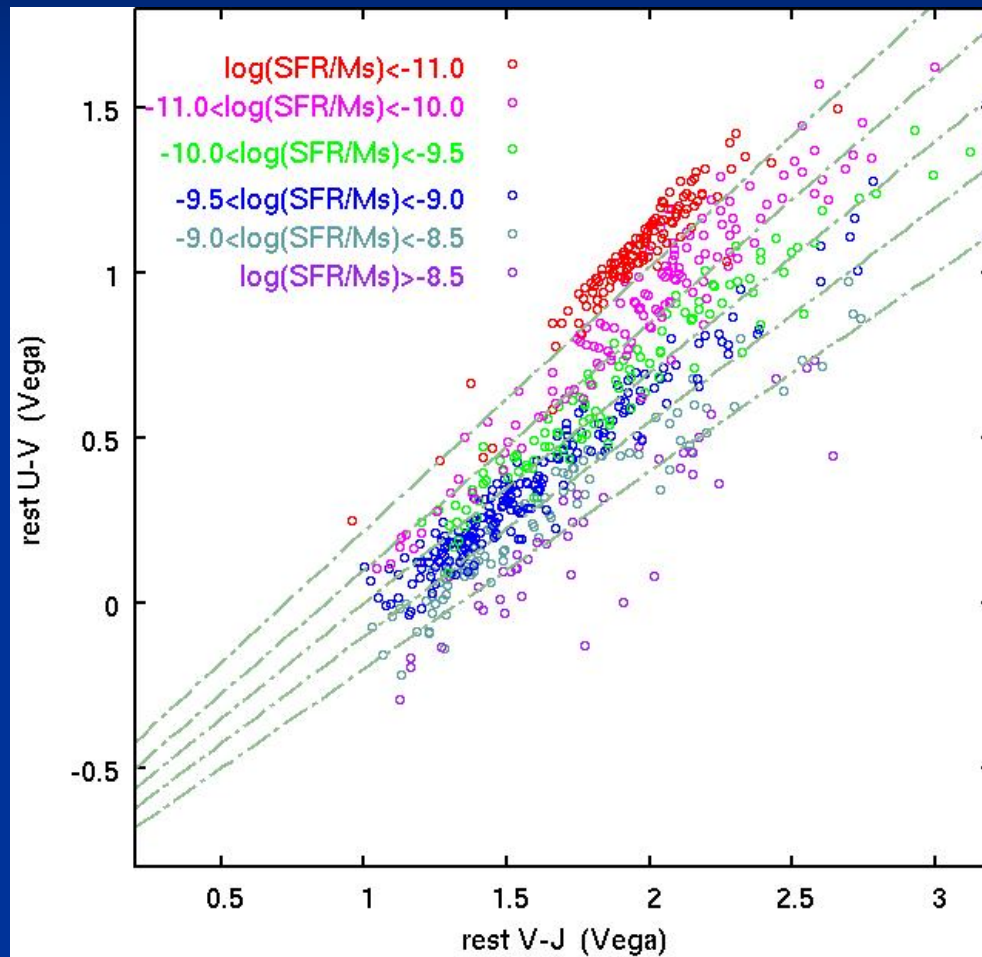
数密度進化 (passive & star-forming)



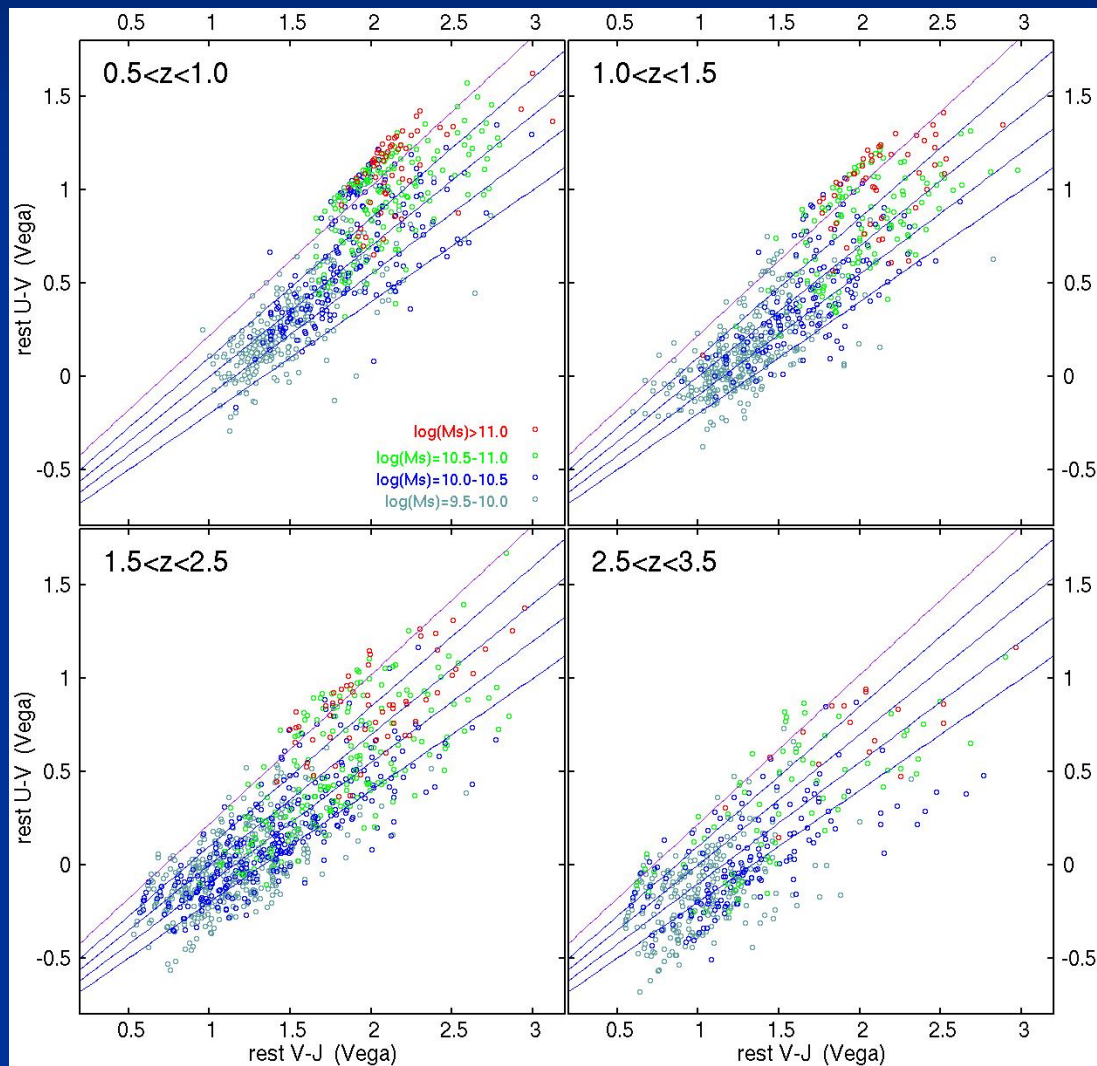
U-V vs V-J 分布



U-V vs V-J 分布



U-V vs V-J 分布の進化



静止系Bバンドの形態

- HST ACS/z-band, WFC3/J&H-bands data

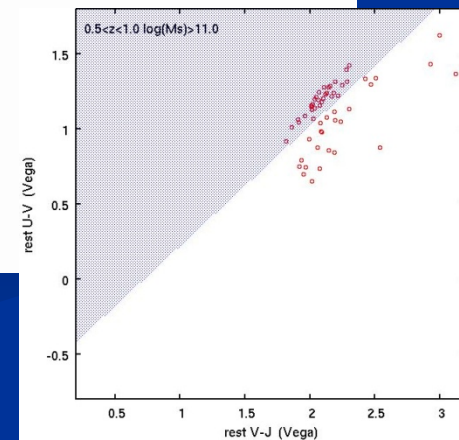
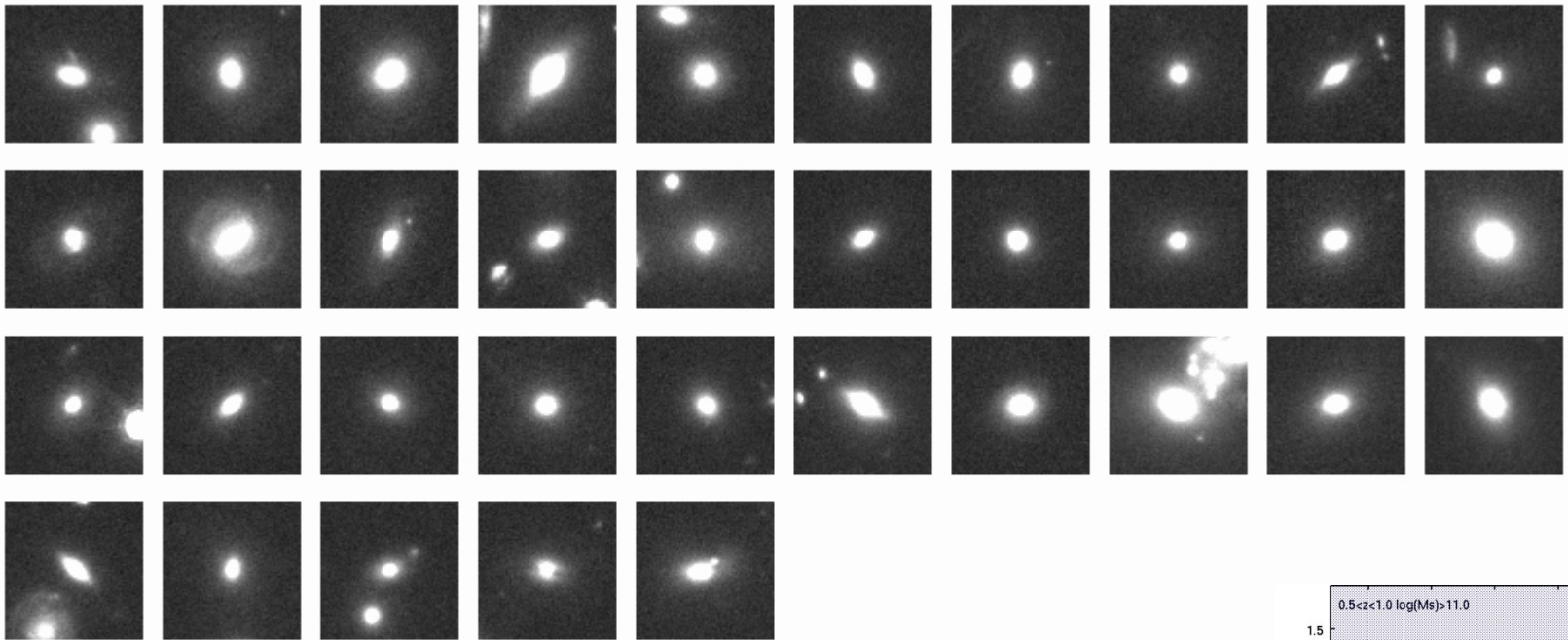
- SEDと形態の関係

- ✓ U-V vs V-J 2色図を使ってSSFR (SFR/M_s) ごとに見る

たとえば clumpy diskがgas mass fractionが高い状態での不安定性起源だとすると、SSFRが高かったりするの？

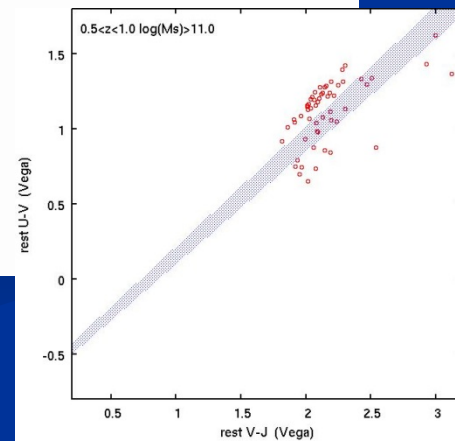
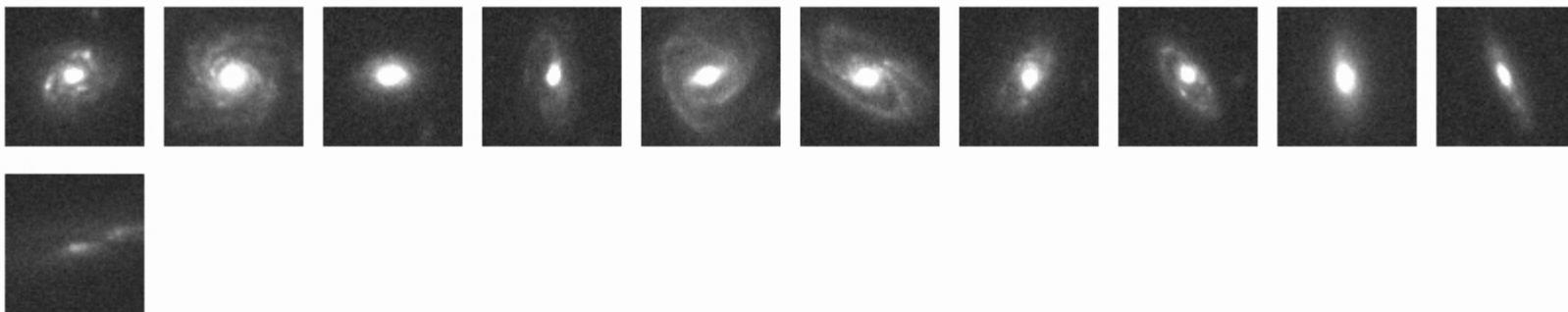
$0.5 < z < 1.0$

$\log(M_s) > 11$ $\log(SSFR) < -11$



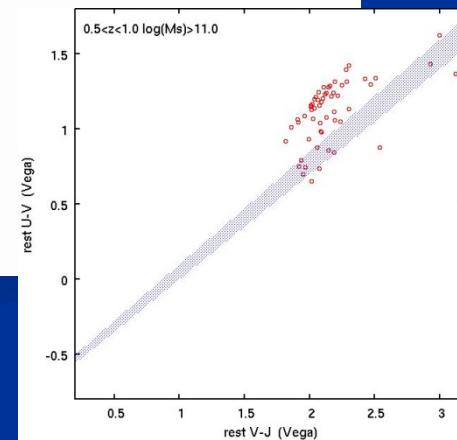
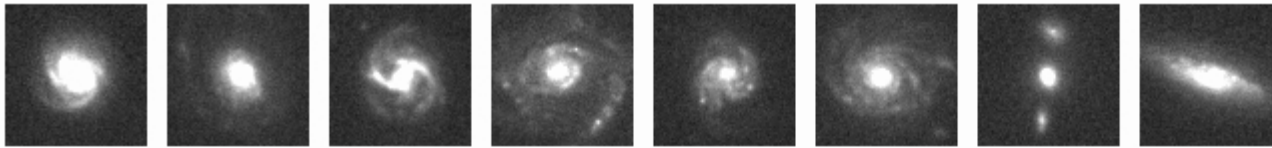
$0.5 < z < 1.0$

$\log(M_s) > 11$ $-11 < \log(SSFR) < -10$



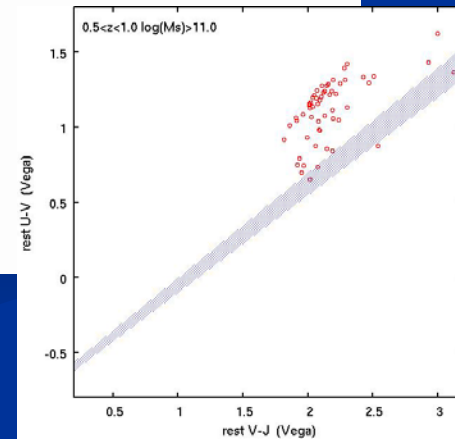
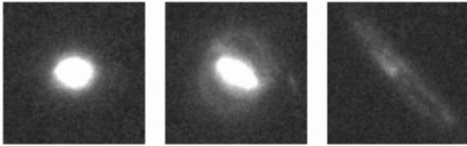
$0.5 < z < 1.0$

$\log(M_s) > 11$ $-10 < \log(\text{SSFR}) < -9.5$



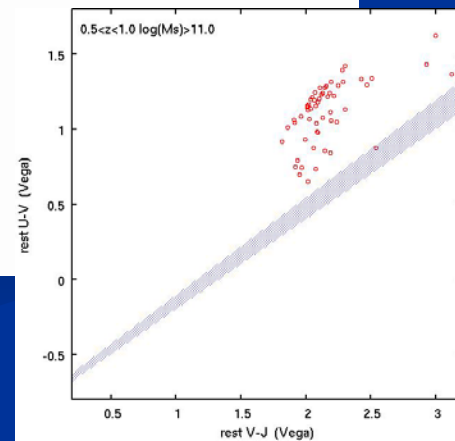
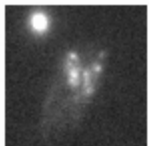
$$0.5 < z < 1.0$$

$$\log(M_s) > 11 \quad -9.5 < \log(\text{SSFR}) < -9$$

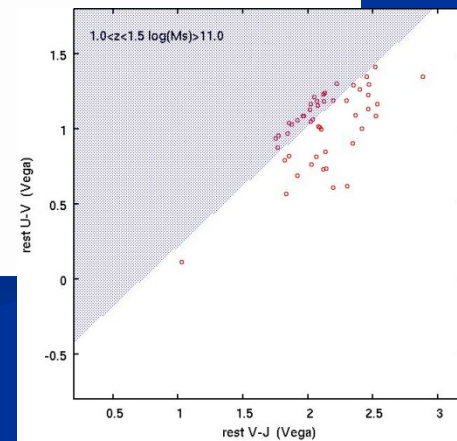
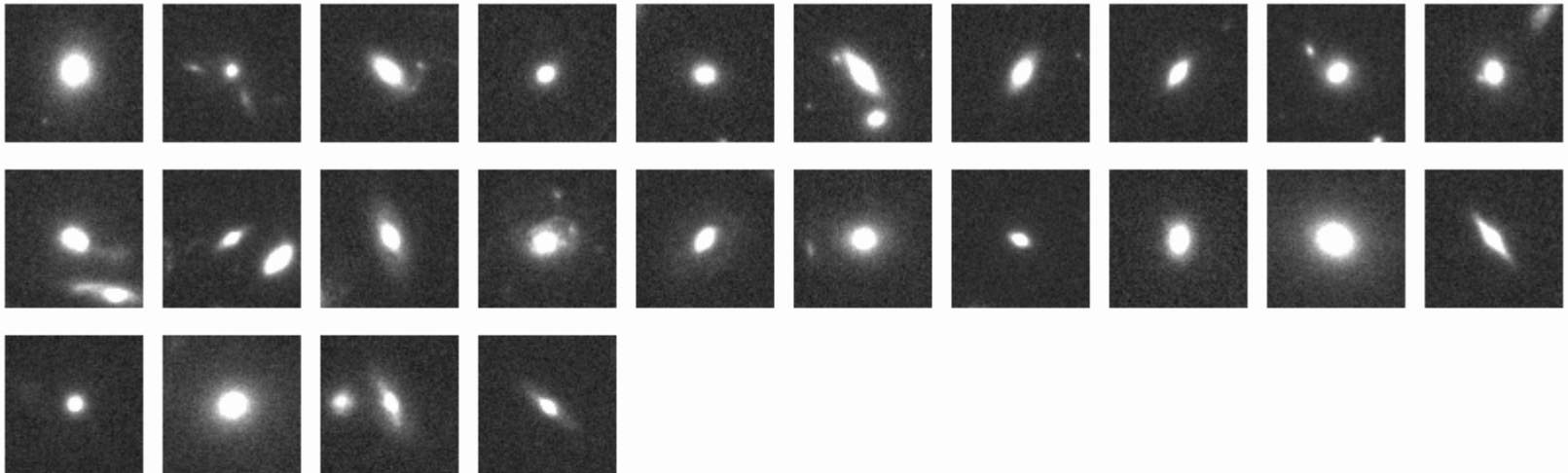


$$0.5 < z < 1.0$$

$$\log(M_s) > 11 \quad -9 < \log(\text{SSFR}) < -8.5$$

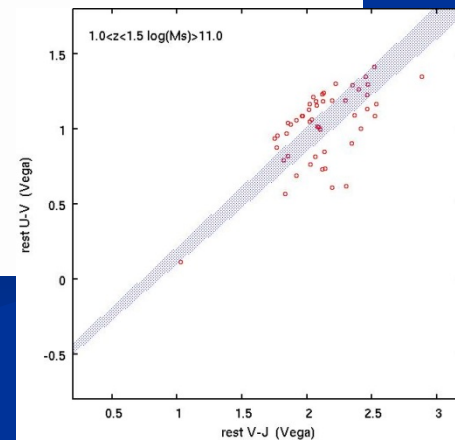
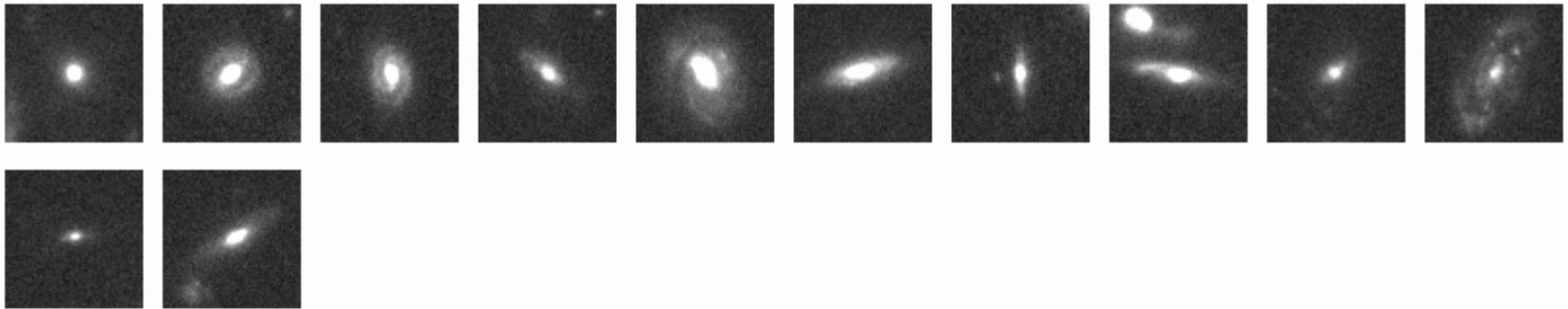


$1.0 < z < 1.5$
 $\log(M_s) > 11$ $\log(\text{SSFR}) < -11$



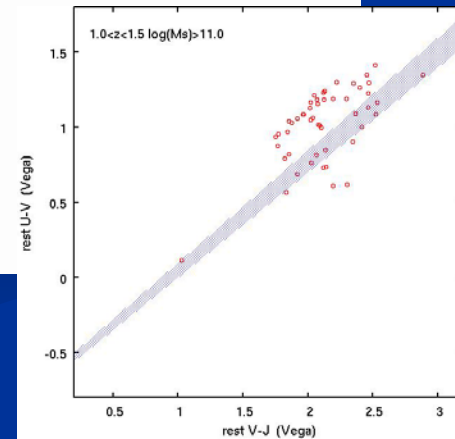
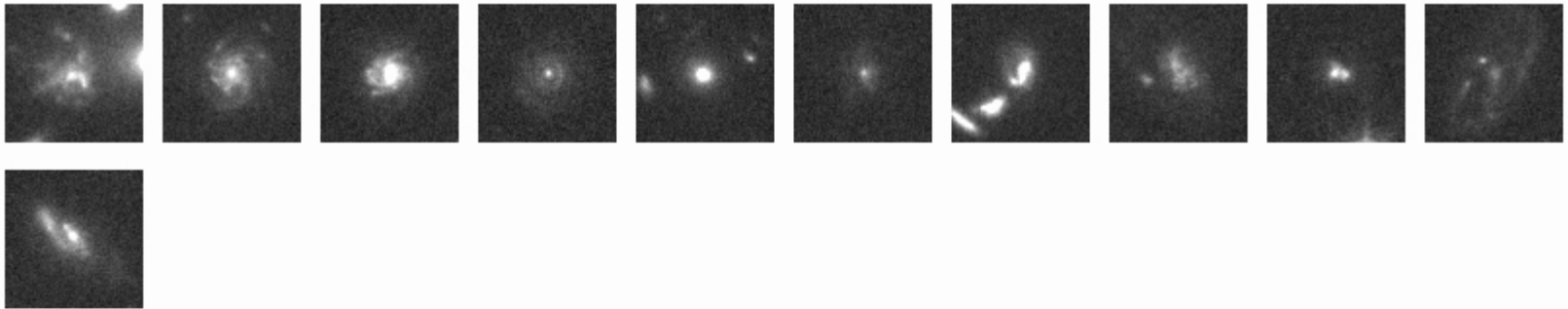
$1.0 < z < 1.5$

$\log(M_s) > 11$ $-11 < \log(SSFR) < -10$



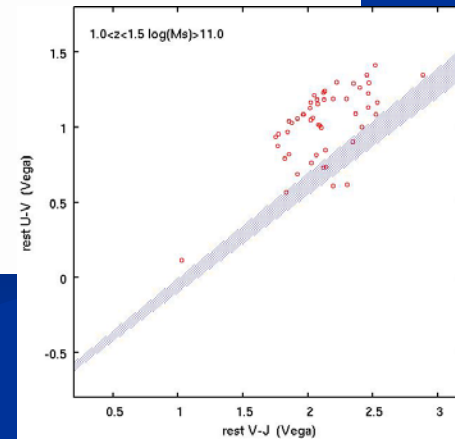
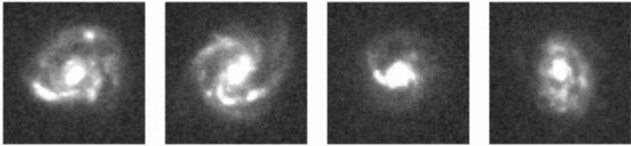
$1.0 < z < 1.5$

$\log(M_s) > 11$ $-10 < \log(\text{SSFR}) < -9.5$



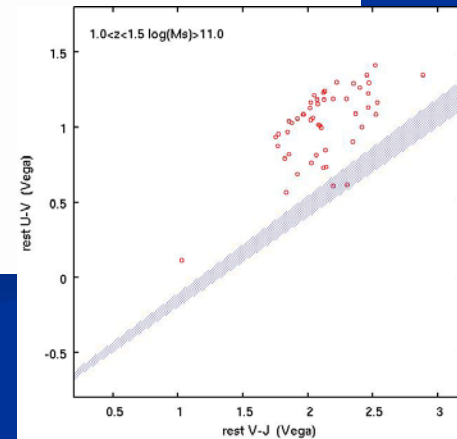
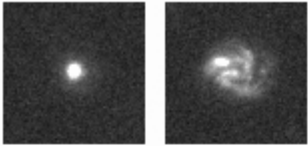
$1.0 < z < 1.5$

$\log(M_s) > 11$ $-9.5 < \log(SSFR) < -9$



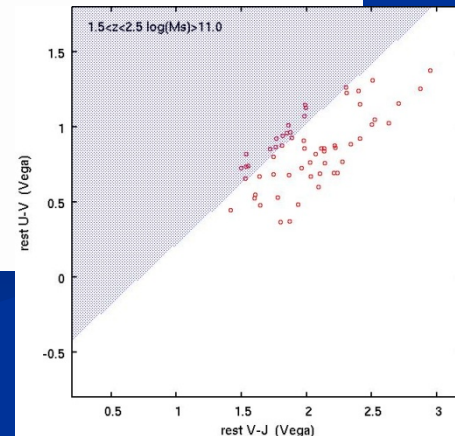
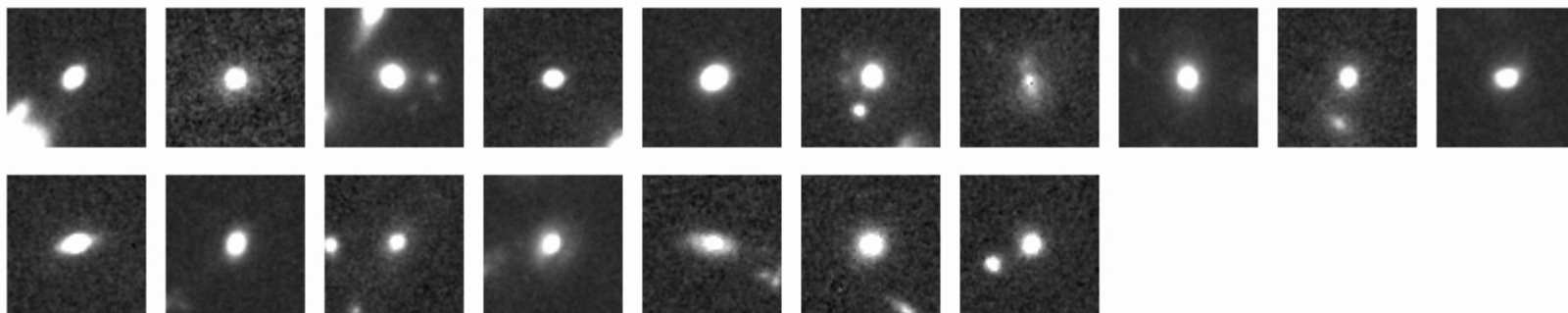
$1.0 < z < 1.5$

$\log(M_s) > 11$ $-9 < \log(\text{SSFR}) < -8.5$



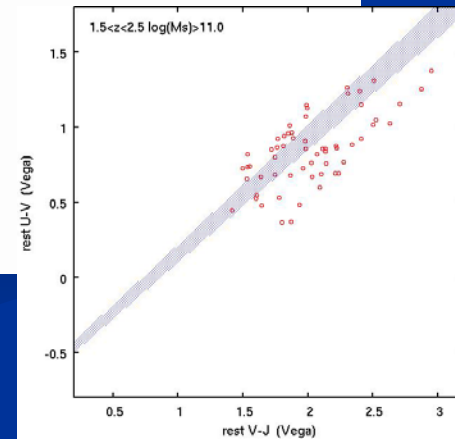
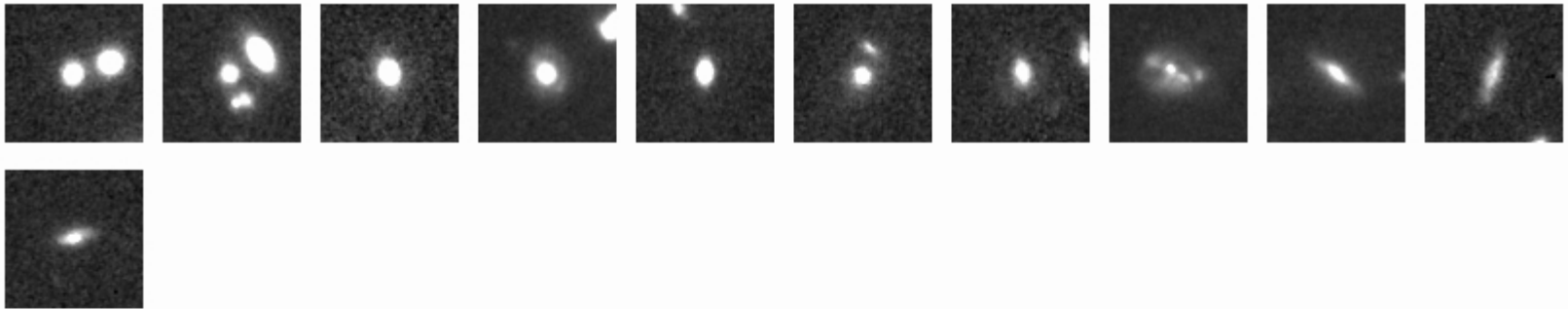
$1.5 < z < 2.5$

$\log(M_s) > 11$ $\log(\text{SSFR}) < -11$



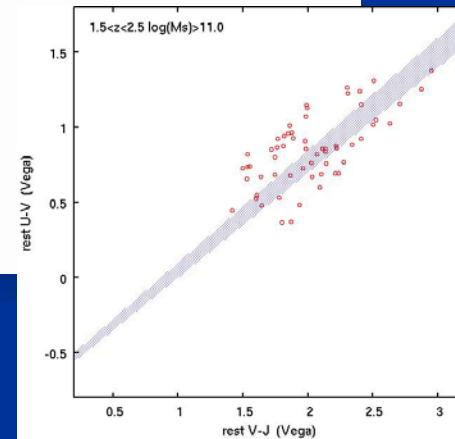
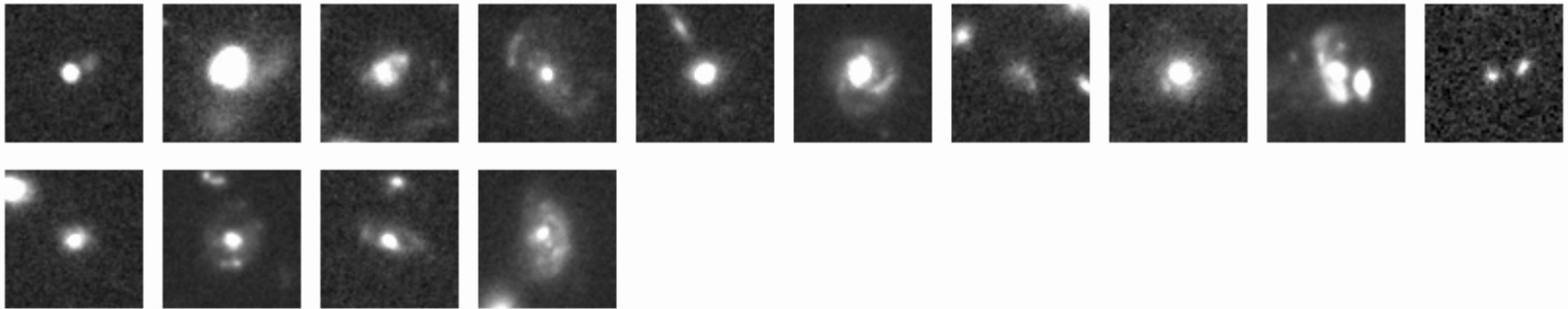
$1.5 < z < 2.5$

$\log(M_s) > 11$ $-11 < \log(\text{SSFR}) < -10$



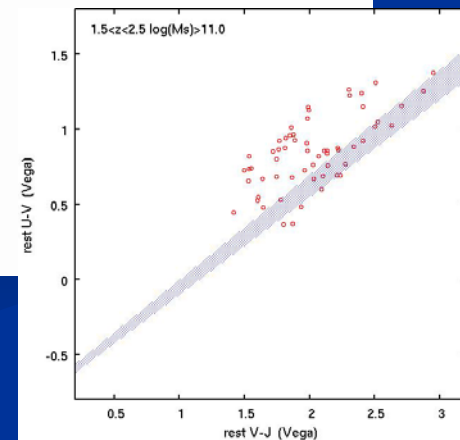
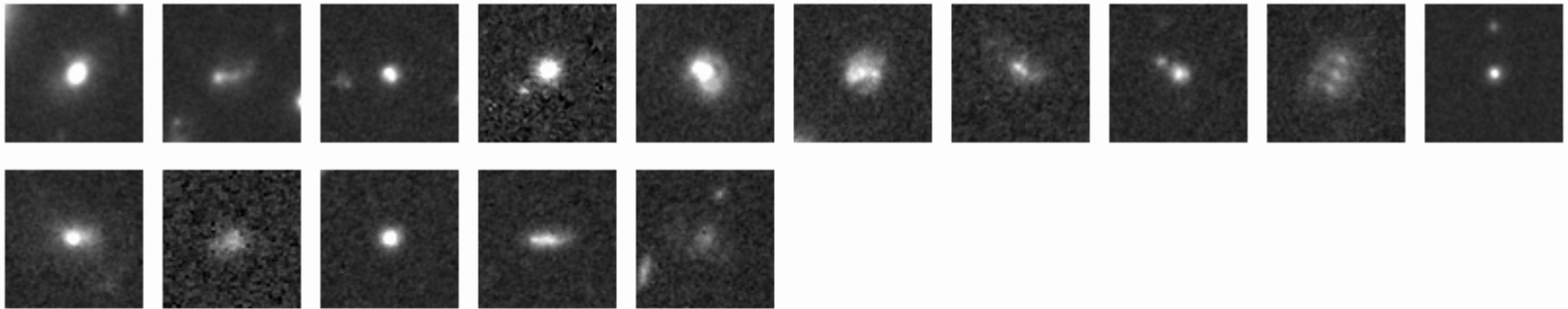
$1.5 < z < 2.5$

$\log(M_s) > 11$ $-10 < \log(\text{SSFR}) < -9.5$



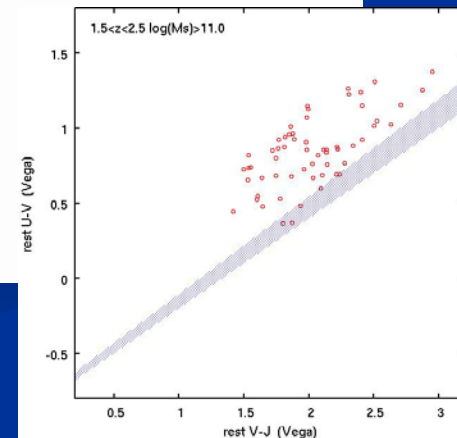
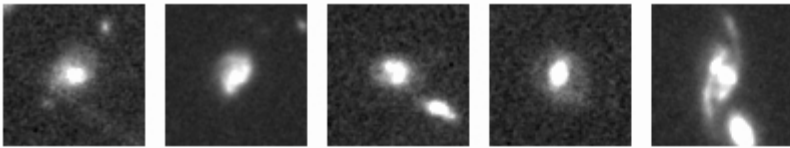
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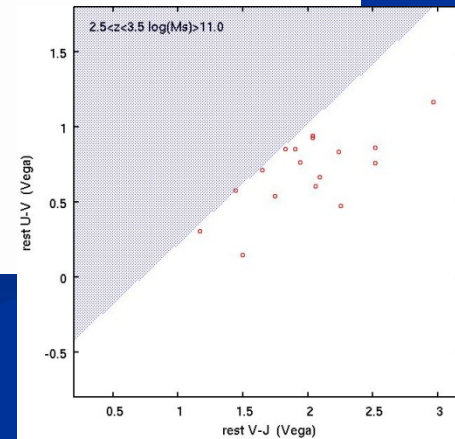
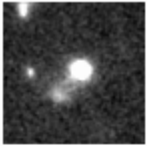
$1.5 < z < 2.5$

$\log(M_s) > 11$ $-9 < \log(\text{SSFR}) < -8.5$



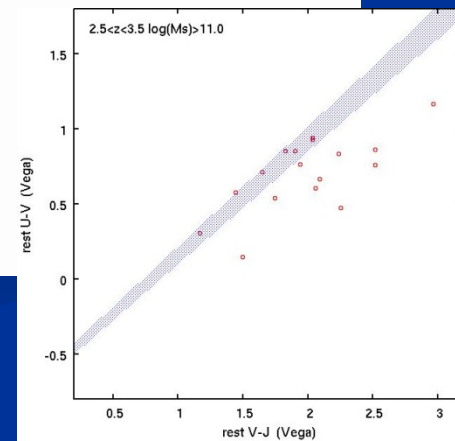
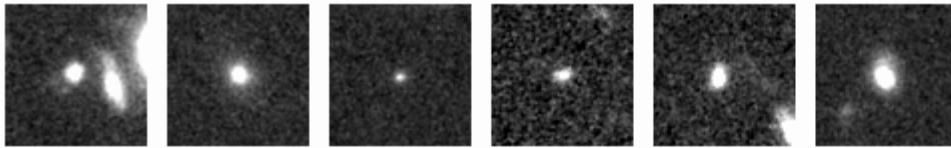
$$2.5 < z < 3.5$$

$$\log(M_s) > 11 \quad \log(\text{SSFR}) < -11$$



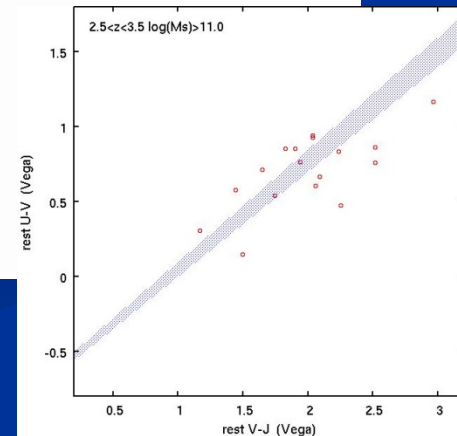
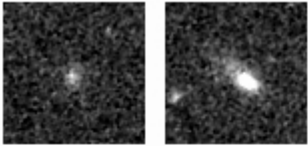
$2.5 < z < 3.5$

$\log(M_s) > 11$ $-11 < \log(SSFR) < -10$



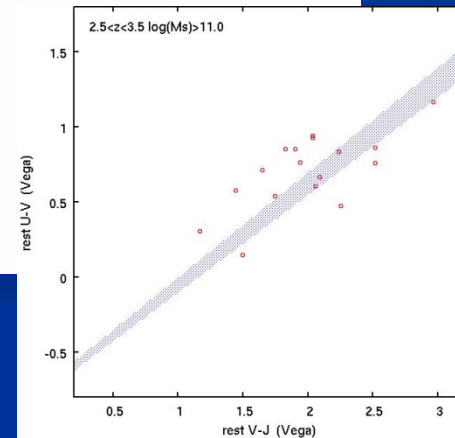
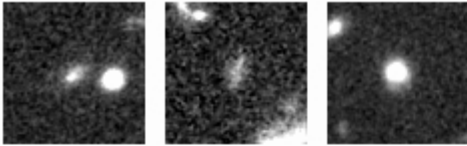
$$2.5 < z < 3.5$$

$$\log(M_s) > 11 \quad -10 < \log(\text{SSFR}) < -9.5$$



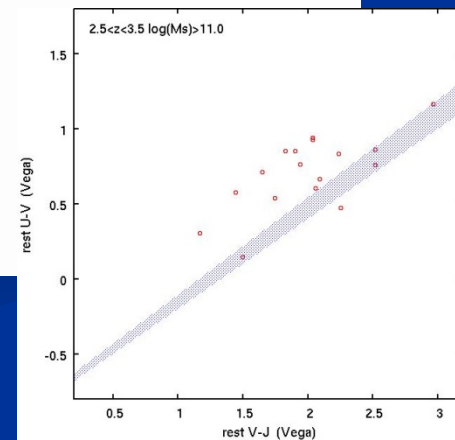
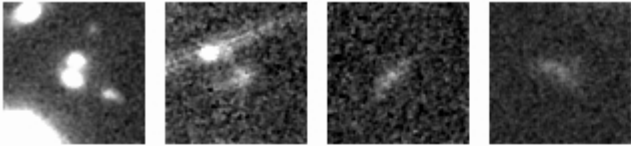
$2.5 < z < 3.5$

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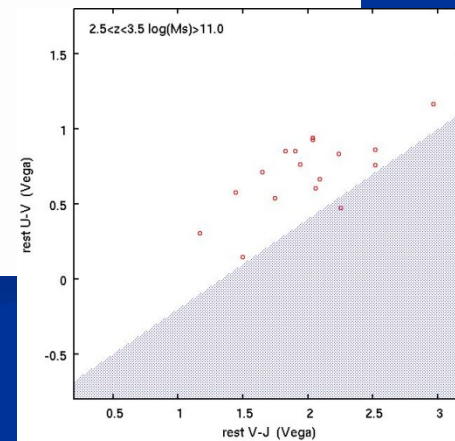
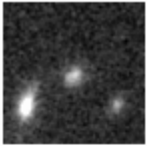
$$2.5 < z < 3.5$$

$$\log(M_s) > 11 \quad -9 < \log(\text{SSFR}) < -8.5$$



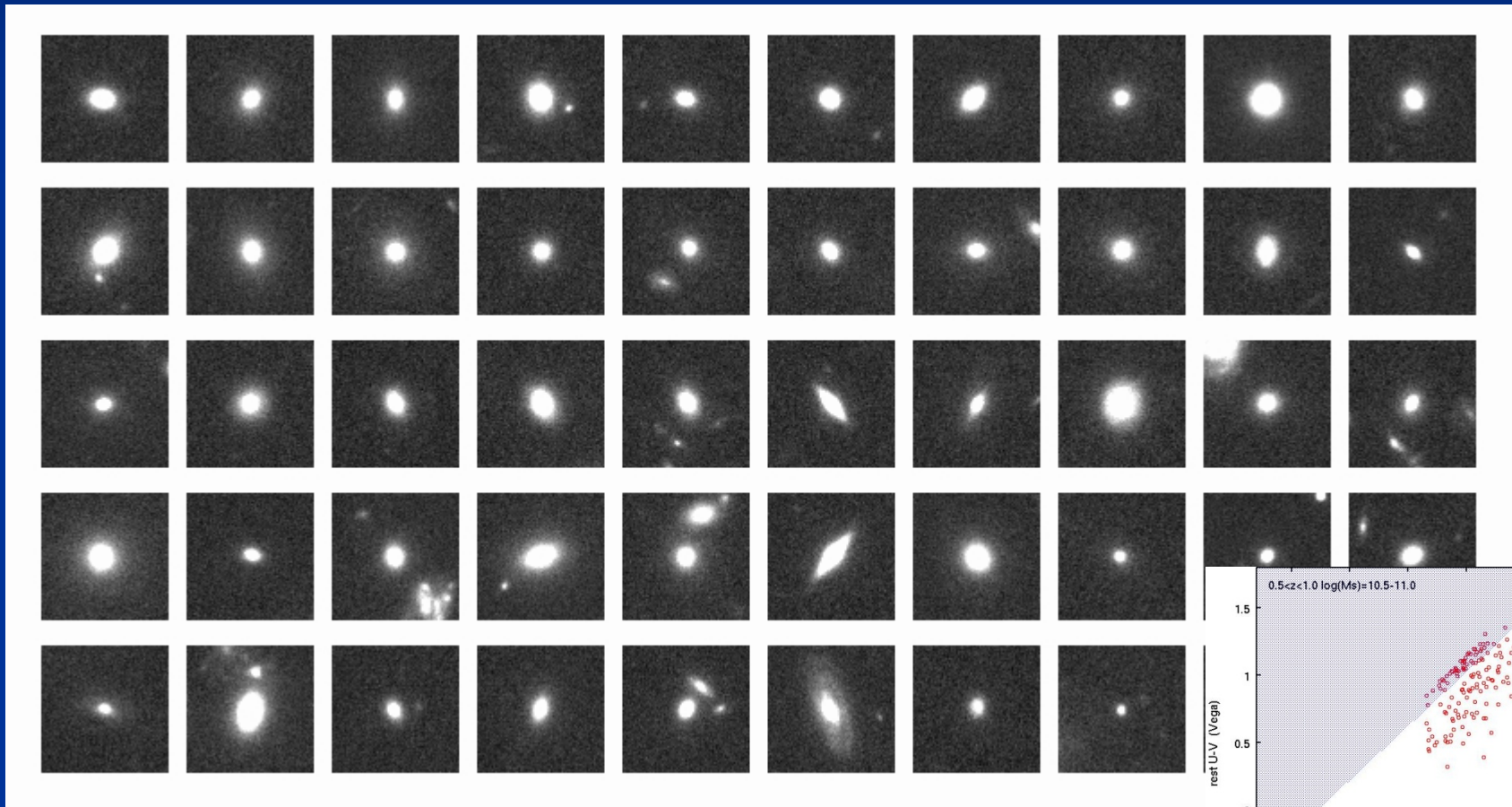
$$2.5 < z < 3.5$$

$$\log(M_s) > 11 \quad \log(\text{SSFR}) > -8.5$$



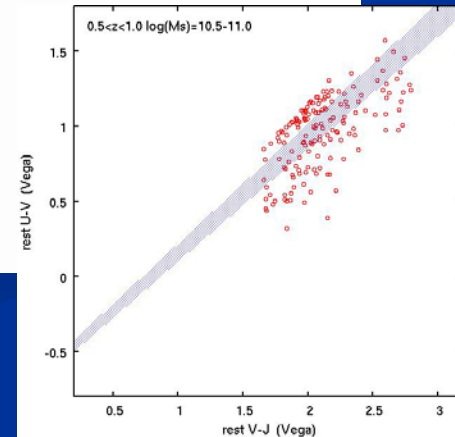
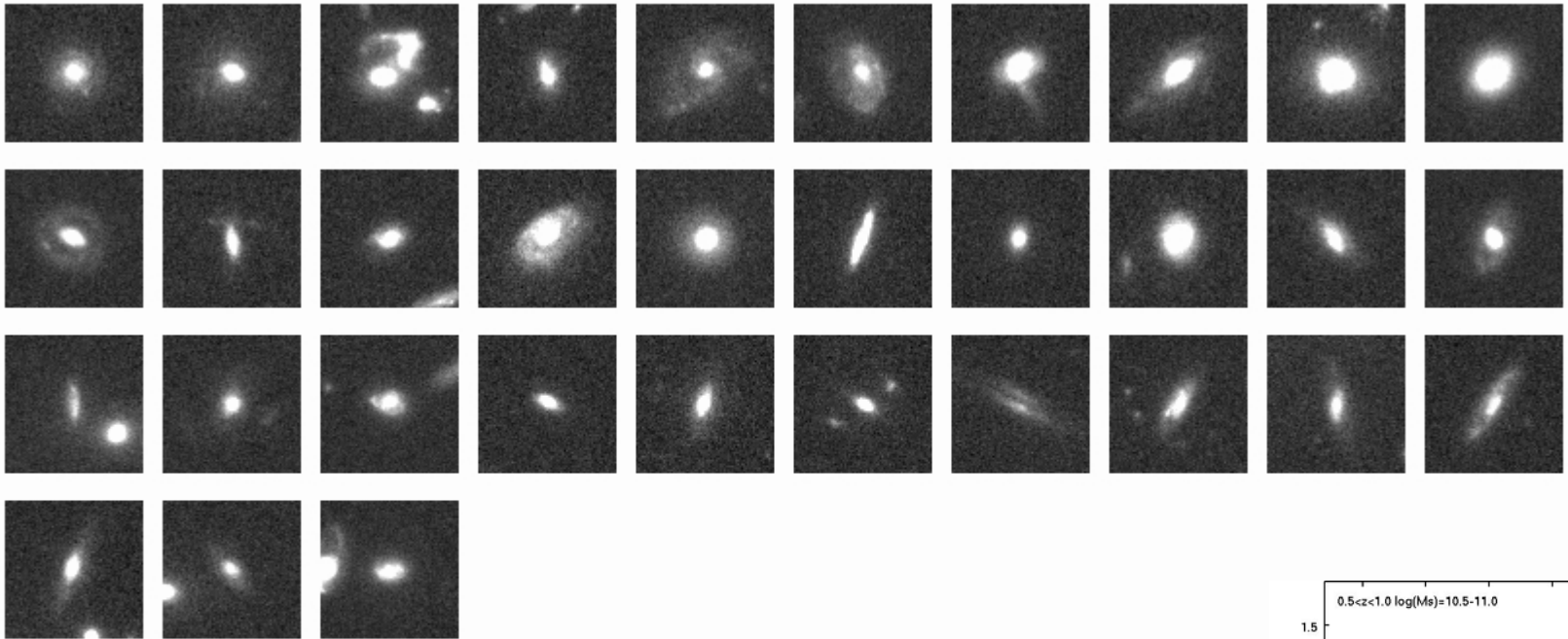
$0.5 < z < 1.0$

$\log(M_s) = 10.5 - 11$ $\log(SSFR) < -11$



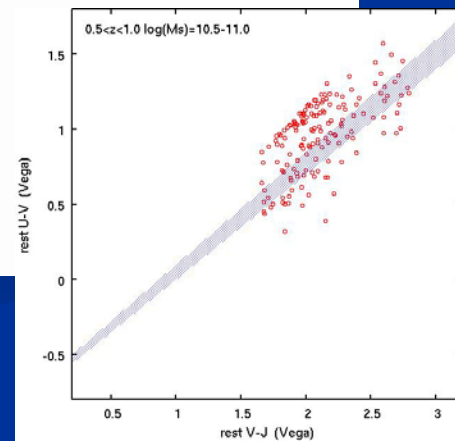
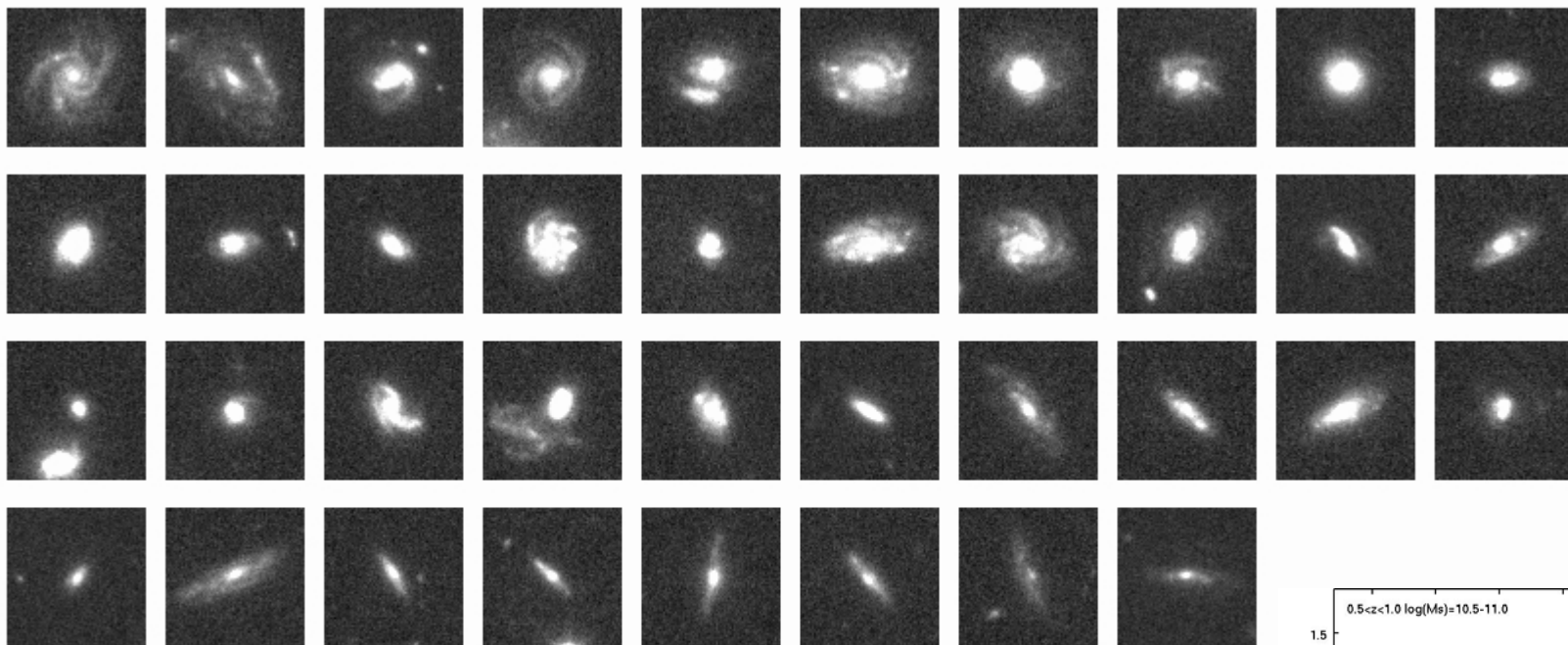
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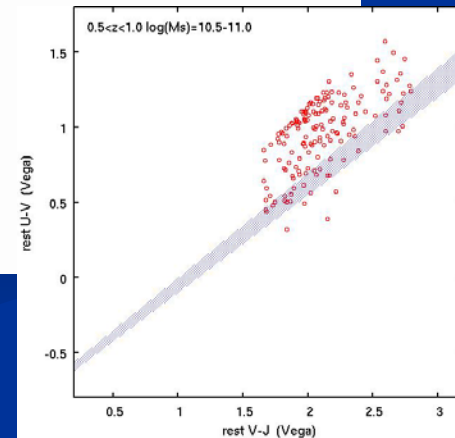
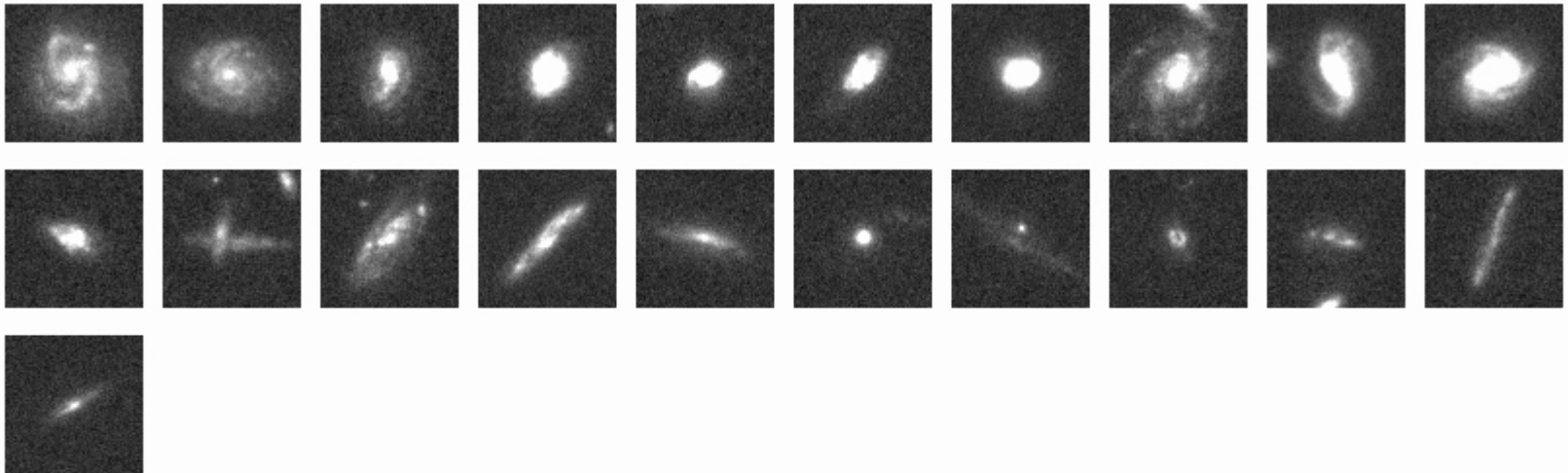
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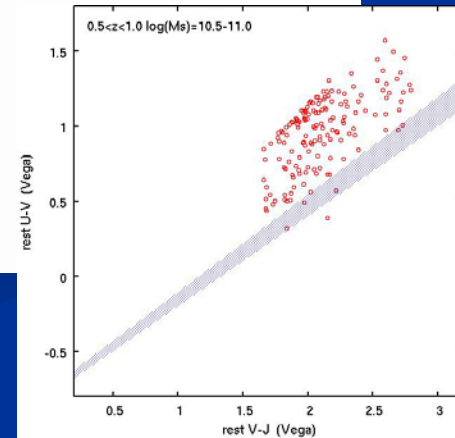
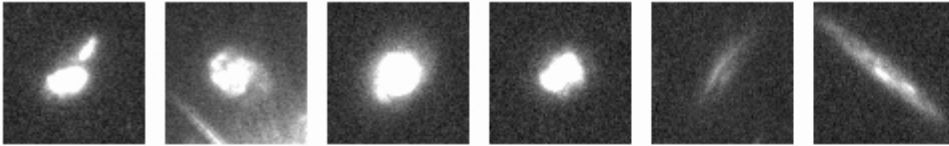
$0.5 < z < 1.0$

$\log(M_s) = 10.5 - 11$ $-9.5 < \log(\text{SSFR}) < -9$



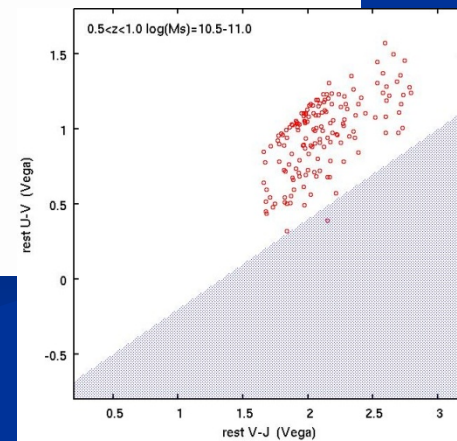
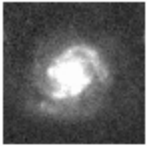
$$0.5 < z < 1.0$$

$$\log(M_s) = 10.5 - 11 \quad -9 < \log(\text{SSFR}) < -8.5$$



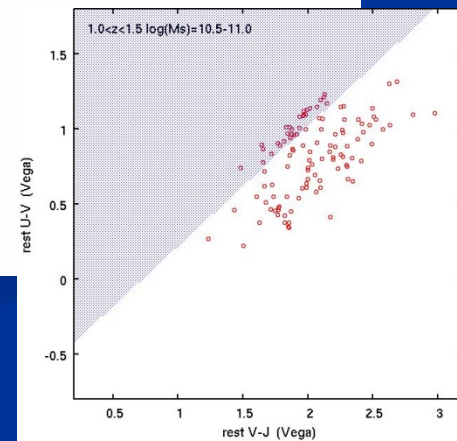
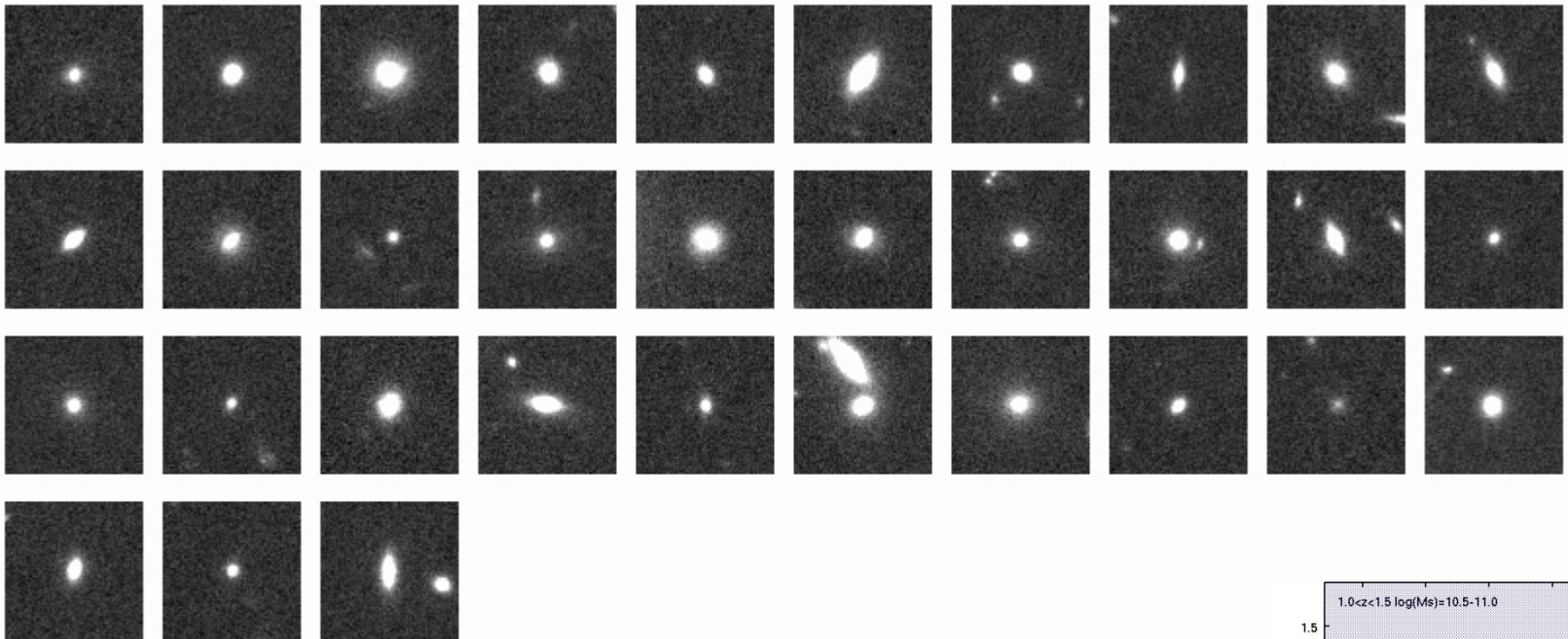
$$0.5 < z < 1.0$$

$$\log(M_s) = 10.5 - 11 \quad \log(\text{SSFR}) > -8.5$$



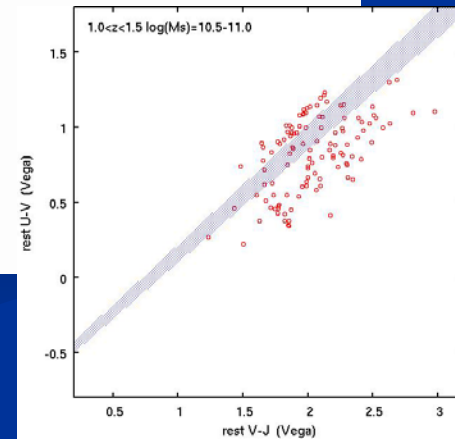
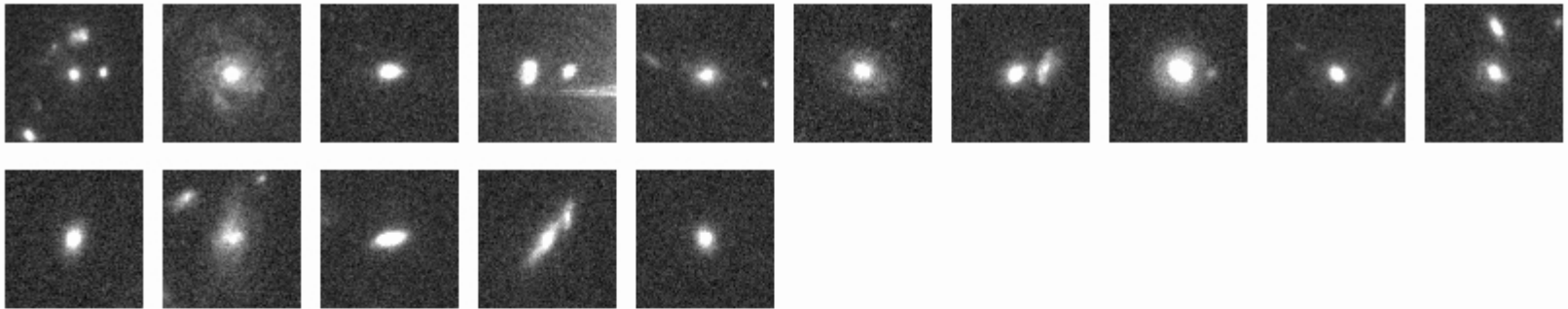
$1.0 < z < 1.5$

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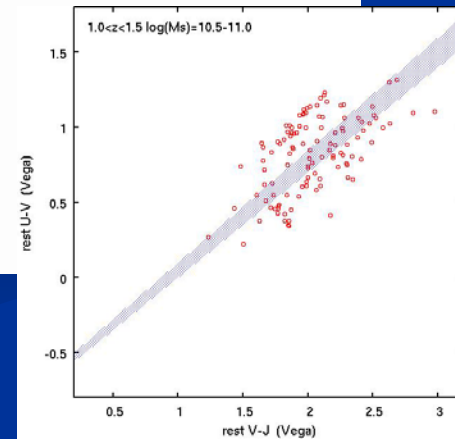
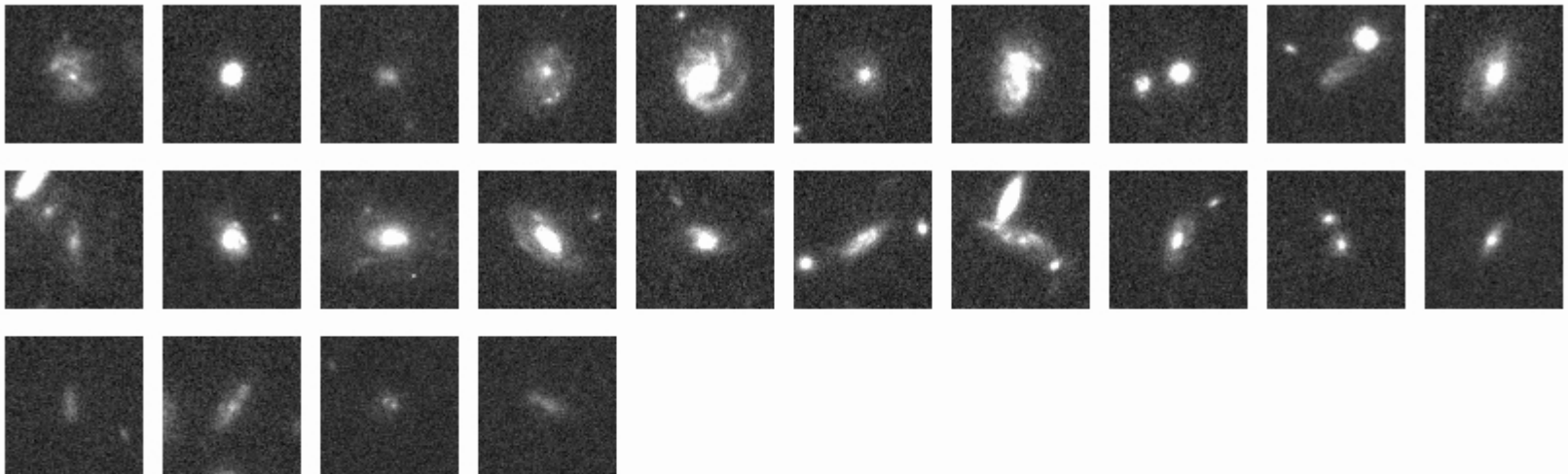
$1.0 < z < 1.5$

$\log(M_s) = 10.5 - 11$ $-11 < \log(\text{SSFR}) < -10$



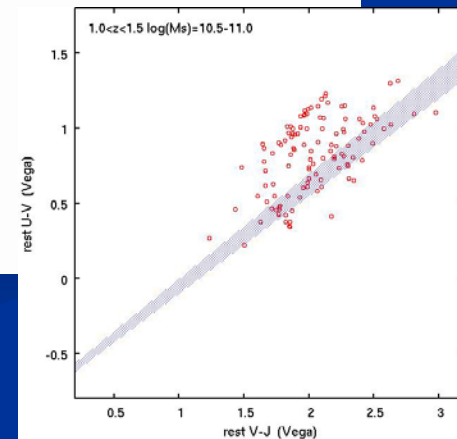
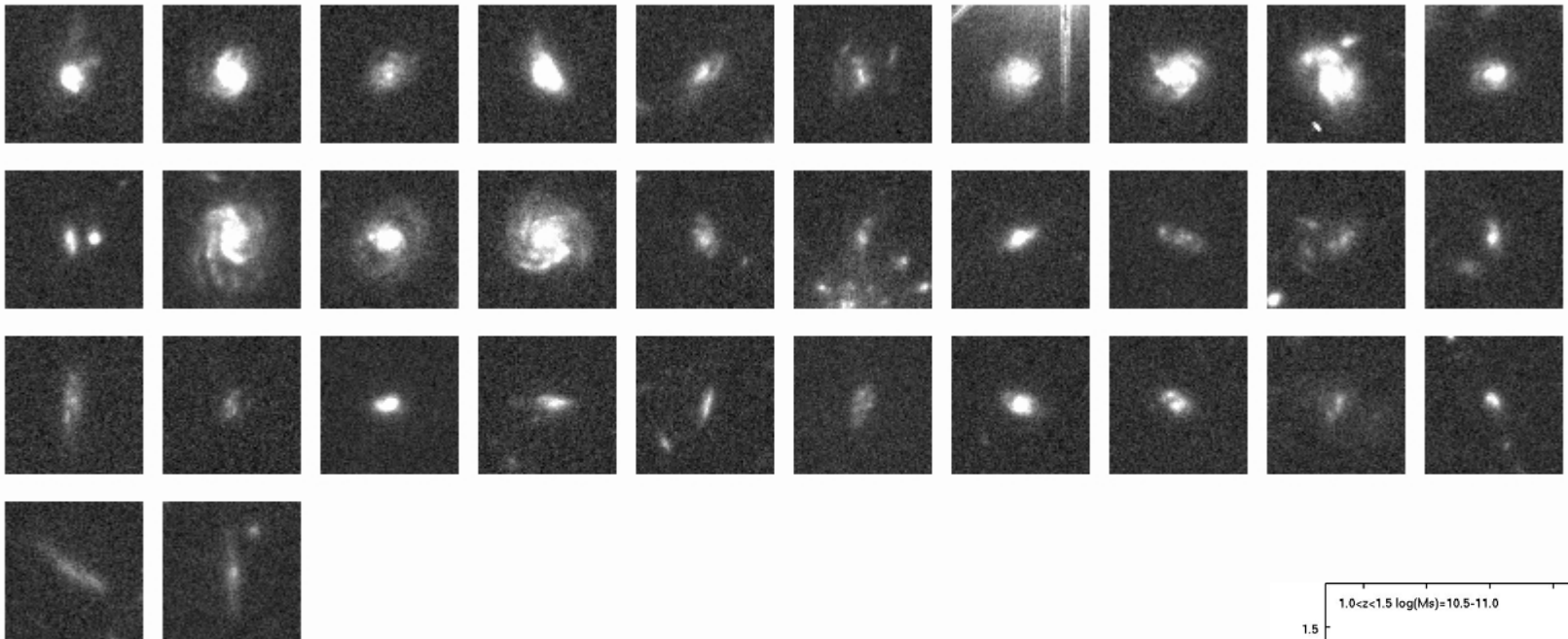
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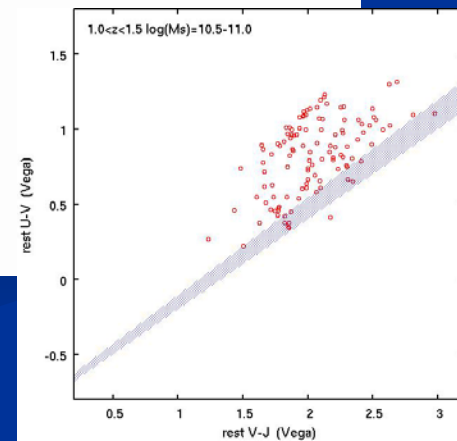
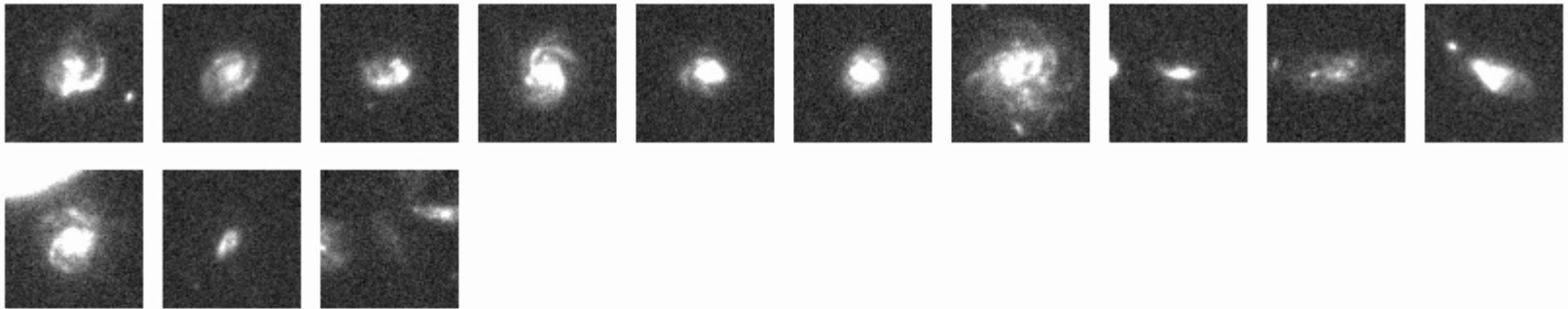
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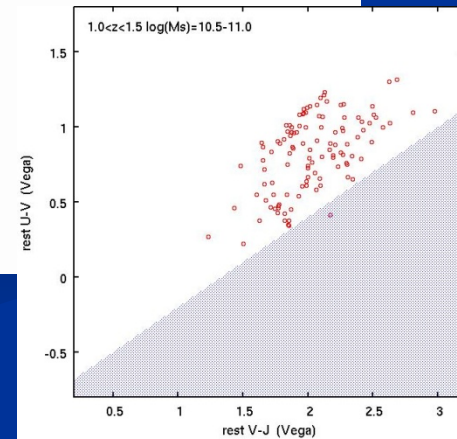
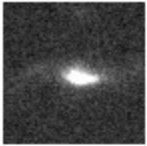
$$1.0 < z < 1.5$$

$$\log(M_s) = 10.5 - 11 \quad -9 < \log(\text{SSFR}) < -8.5$$



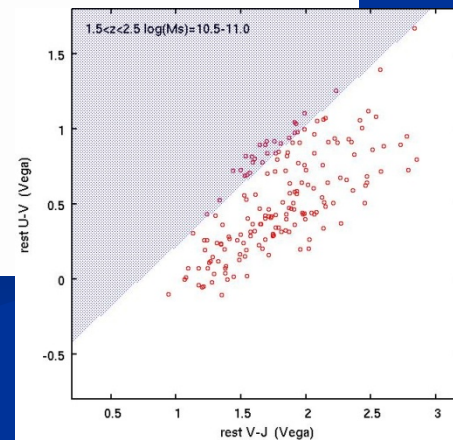
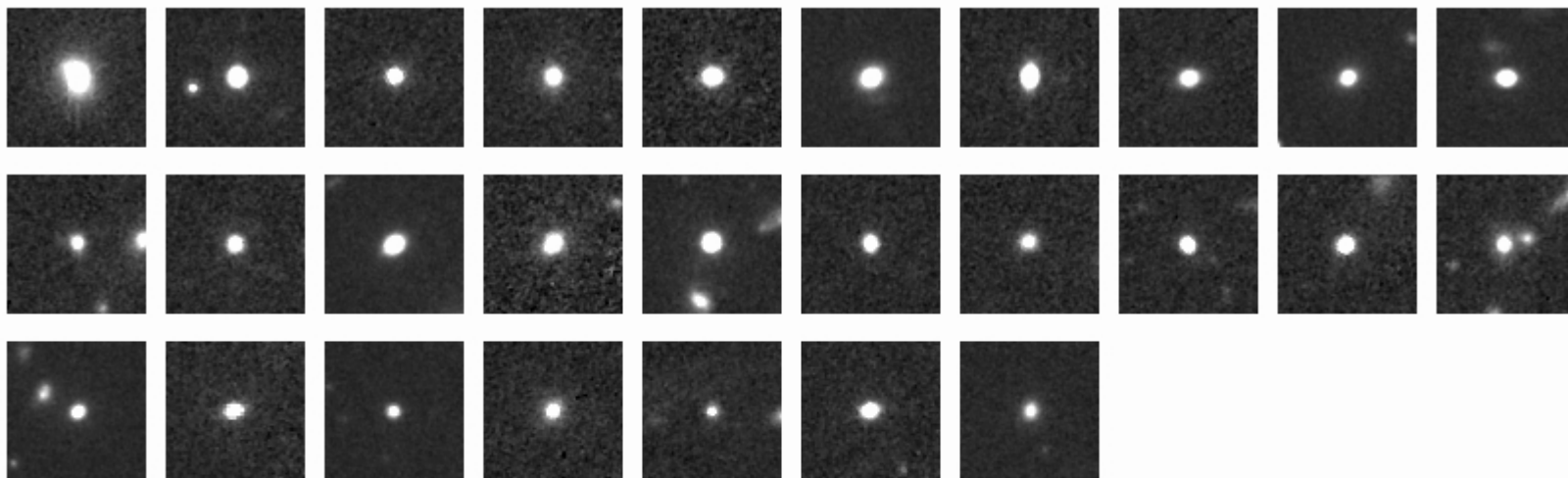
$$1.0 < z < 1.5$$

$$\log(M_s) = 10.5 - 11 \quad \log(\text{SSFR}) > -8.5$$



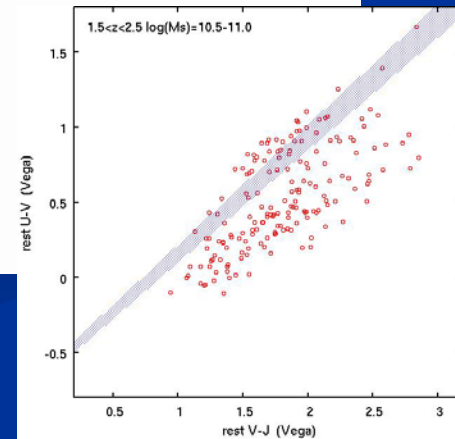
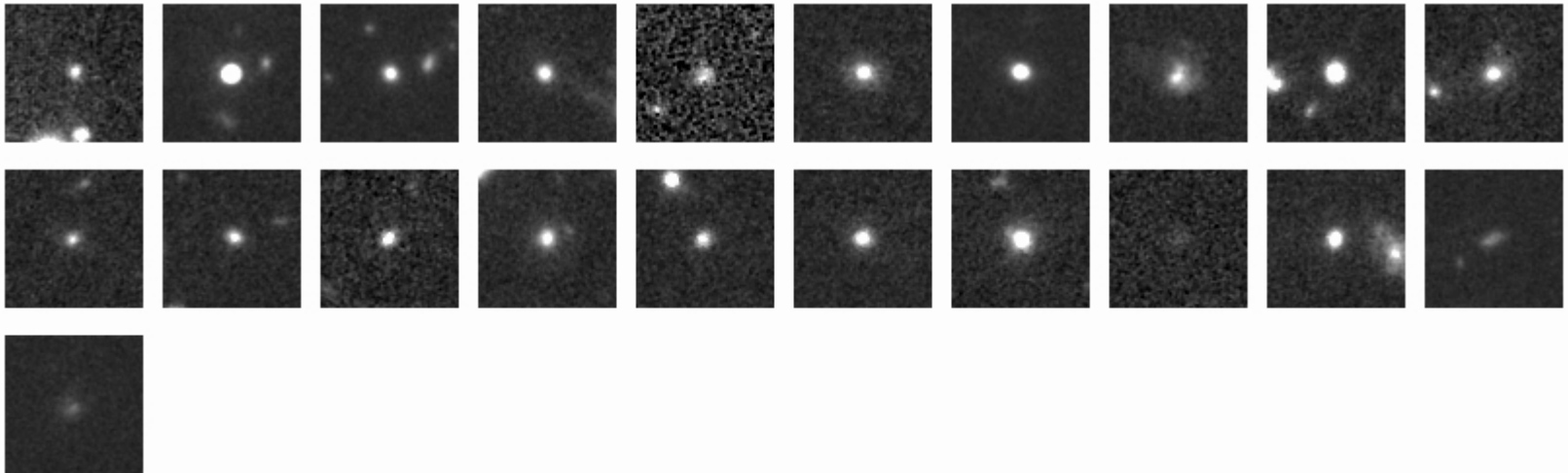
$1.5 < z < 2.5$

$\log(M_s) = 10.5 - 11$ $\log(\text{SSFR}) < -11$



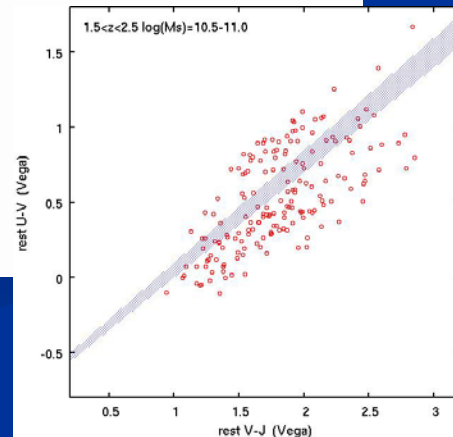
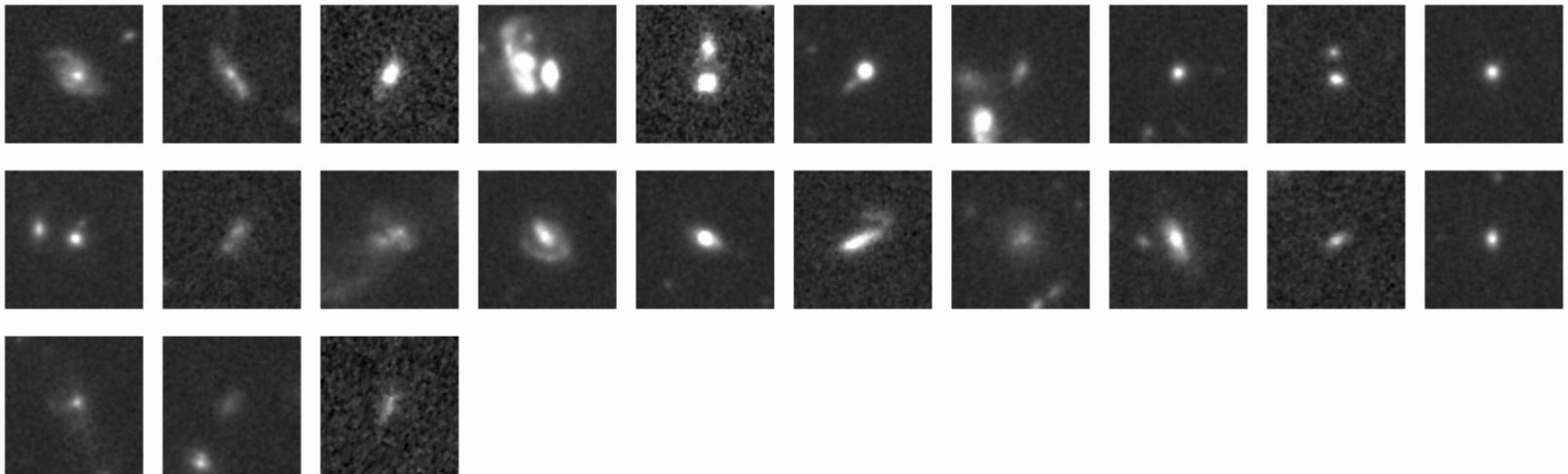
$1.5 < z < 2.5$

$\log(M_s) = 10.5 - 11$ $-11 < \log(\text{SSFR}) < -10$



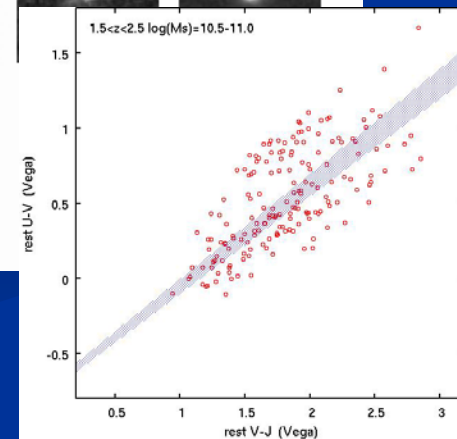
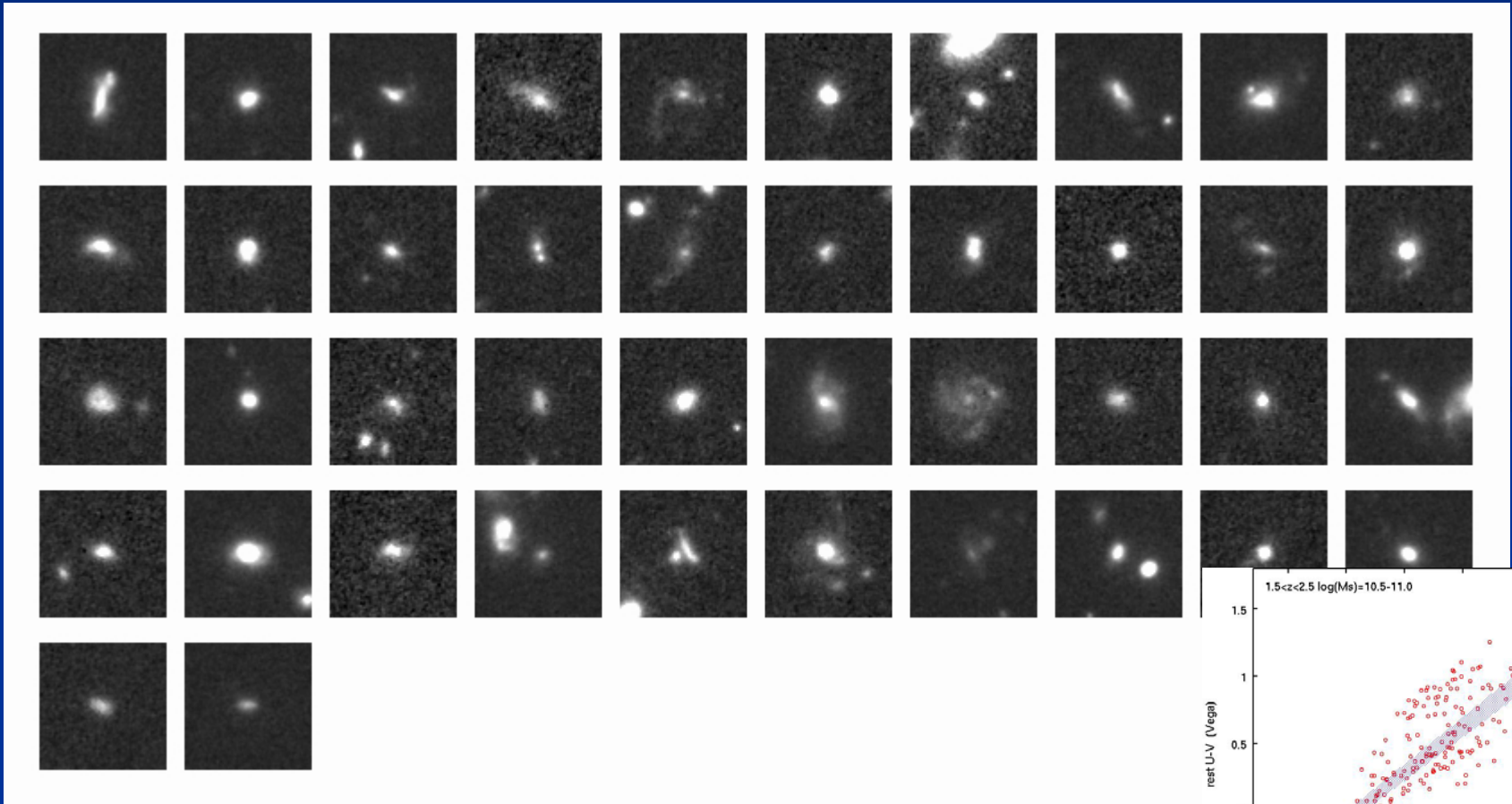
$1.5 < z < 2.5$

$\log(M_s) = 10.5 - 11$ $-10 < \log(\text{SSFR}) < -9.5$



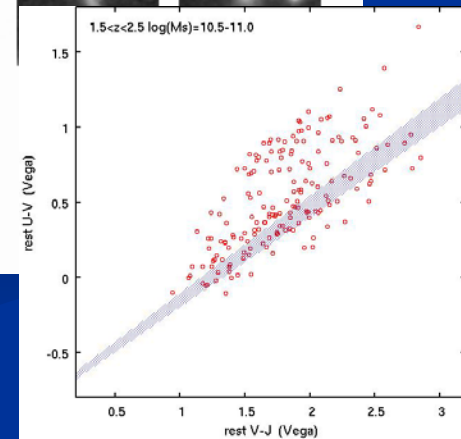
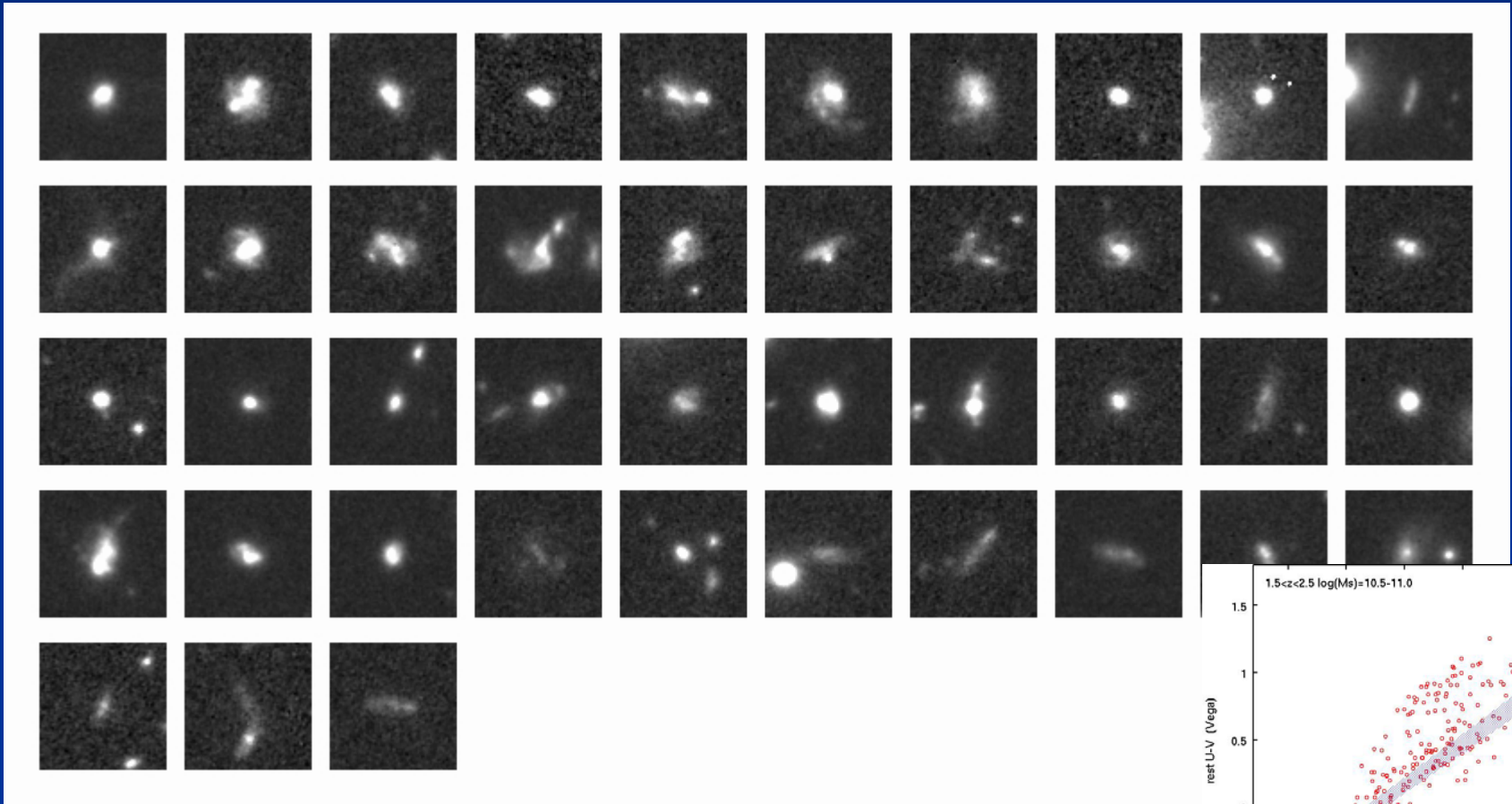
$1.5 < z < 2.5$

$\log(M_s) = 10.5 - 11$ $-9.5 < \log(\text{SSFR}) < -9$



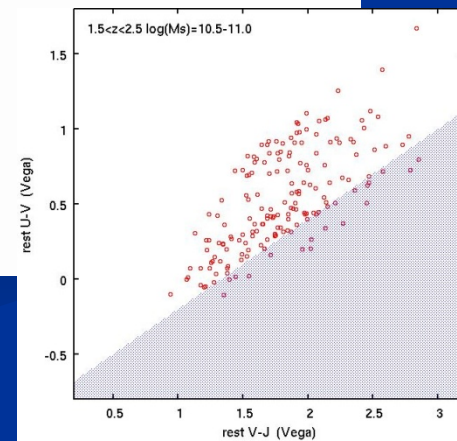
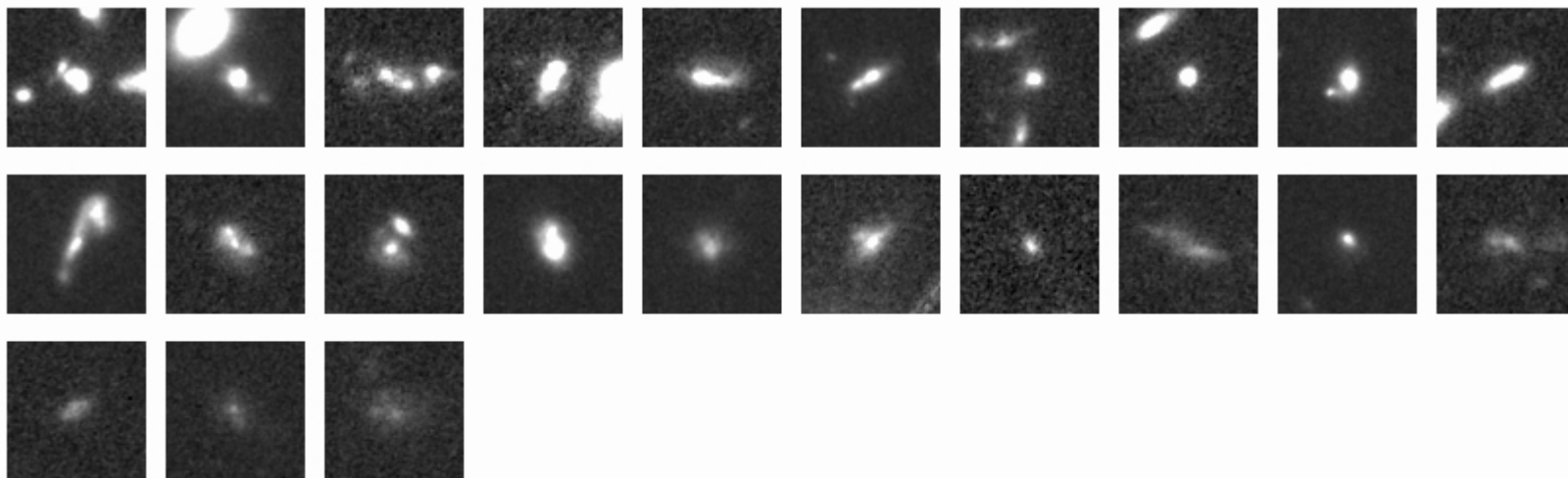
$1.5 < z < 2.5$

$\log(M_s) = 10.5 - 11$ $-9 < \log(\text{SSFR}) < -8.5$



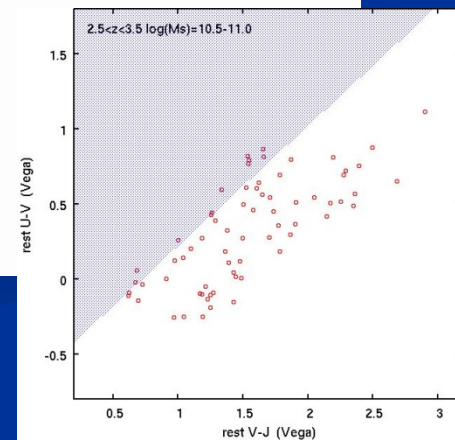
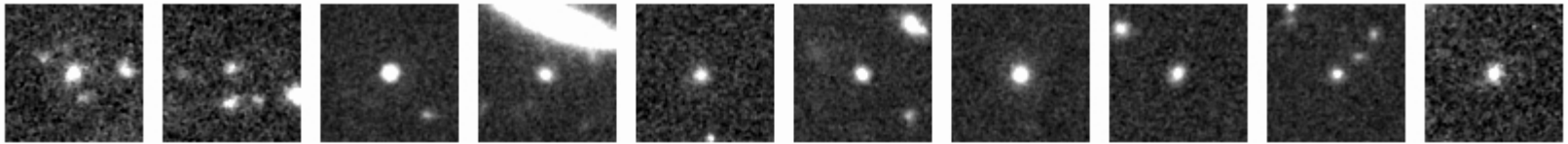
$1.5 < z < 2.5$

$\log(M_s) = 10.5 - 11$ $\log(\text{SSFR}) > -8.5$



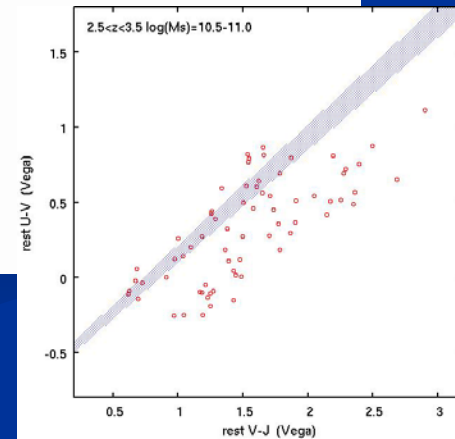
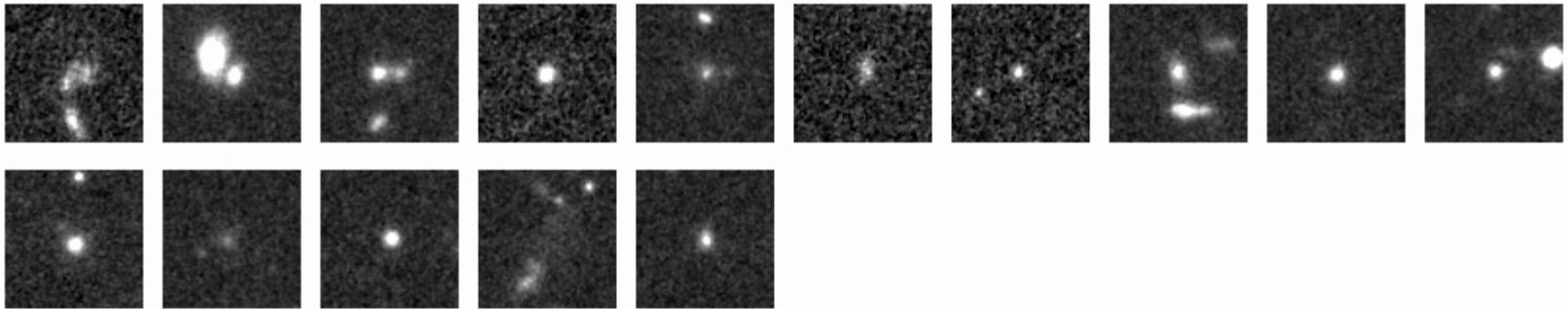
$$2.5 < z < 3.5$$

$$\log(M_s) = 10.5 - 11 \quad \log(\text{SSFR}) < -11$$



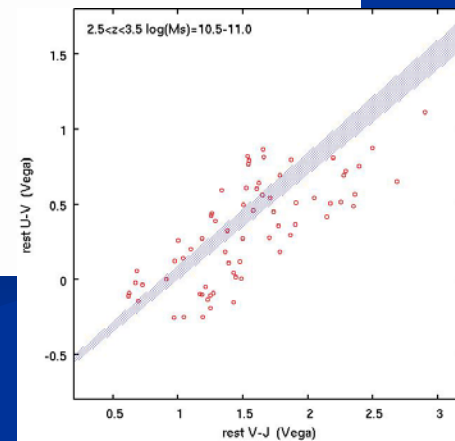
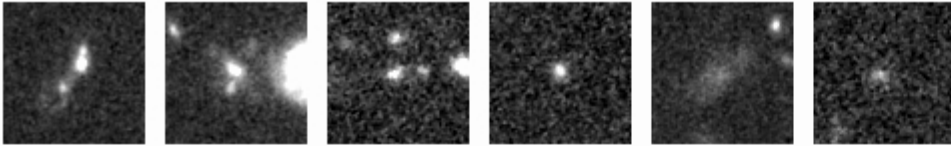
$2.5 < z < 3.5$

$\log(M_s) = 10.5 - 11$ $-11 < \log(SSFR) < -10$



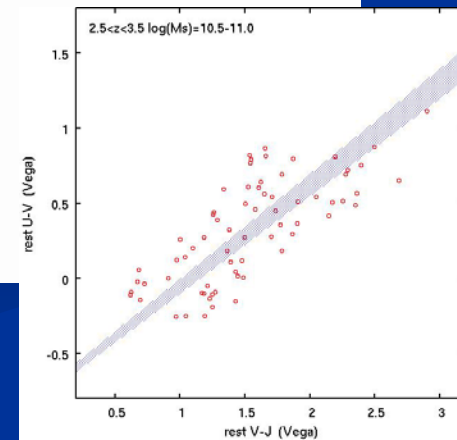
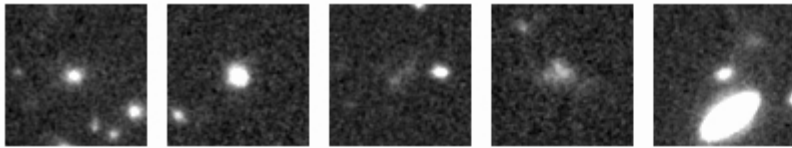
$$2.5 < z < 3.5$$

$$\log(M_s) = 10.5 - 11 \quad -10 < \log(\text{SSFR}) < -9.5$$



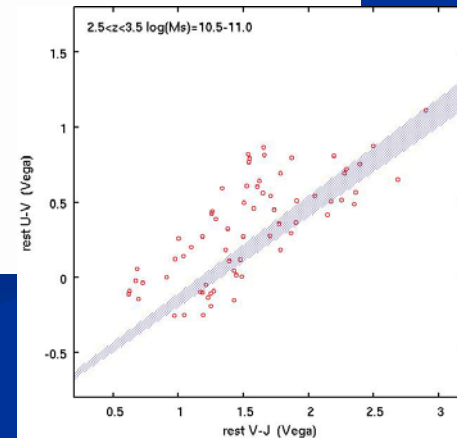
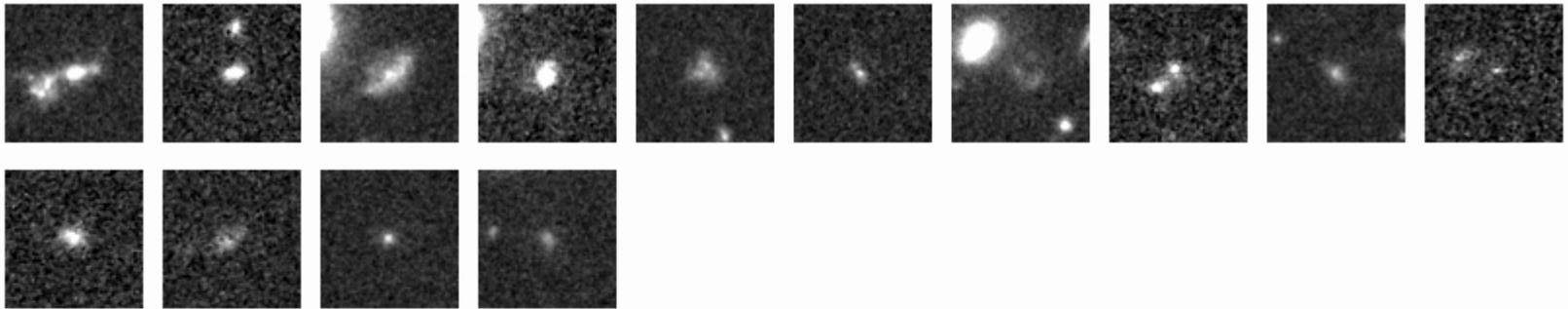
$$2.5 < z < 3.5$$

$$\log(M_s) = 10.5 - 11 \quad -9.5 < \log(\text{SSFR}) < -9$$



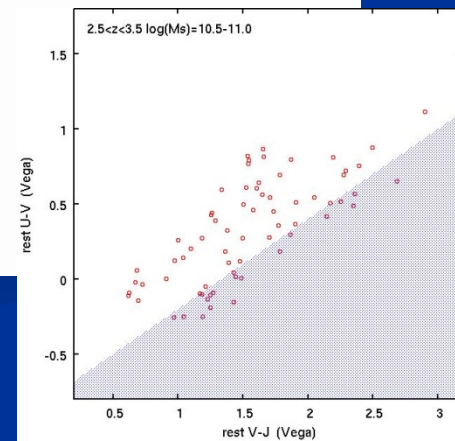
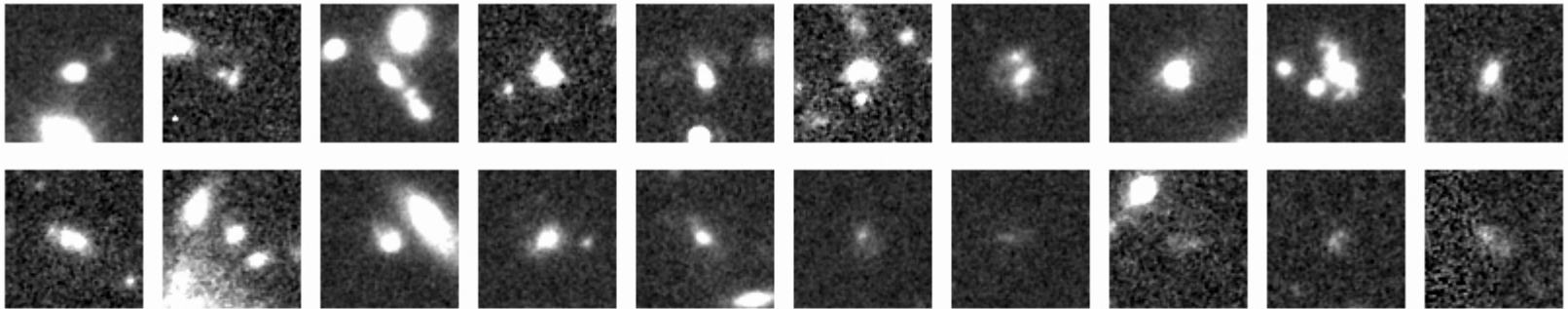
$2.5 < z < 3.5$

$\log(M_s) = 10.5 - 11$ $-9 < \log(\text{SSFR}) < -8.5$



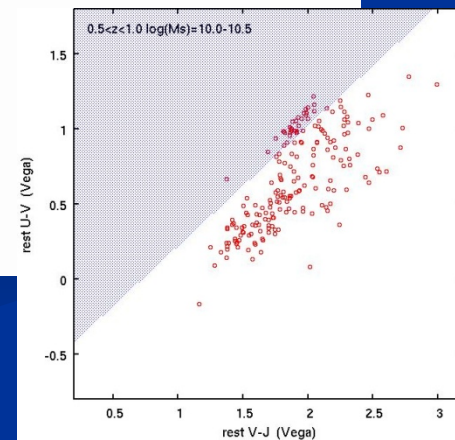
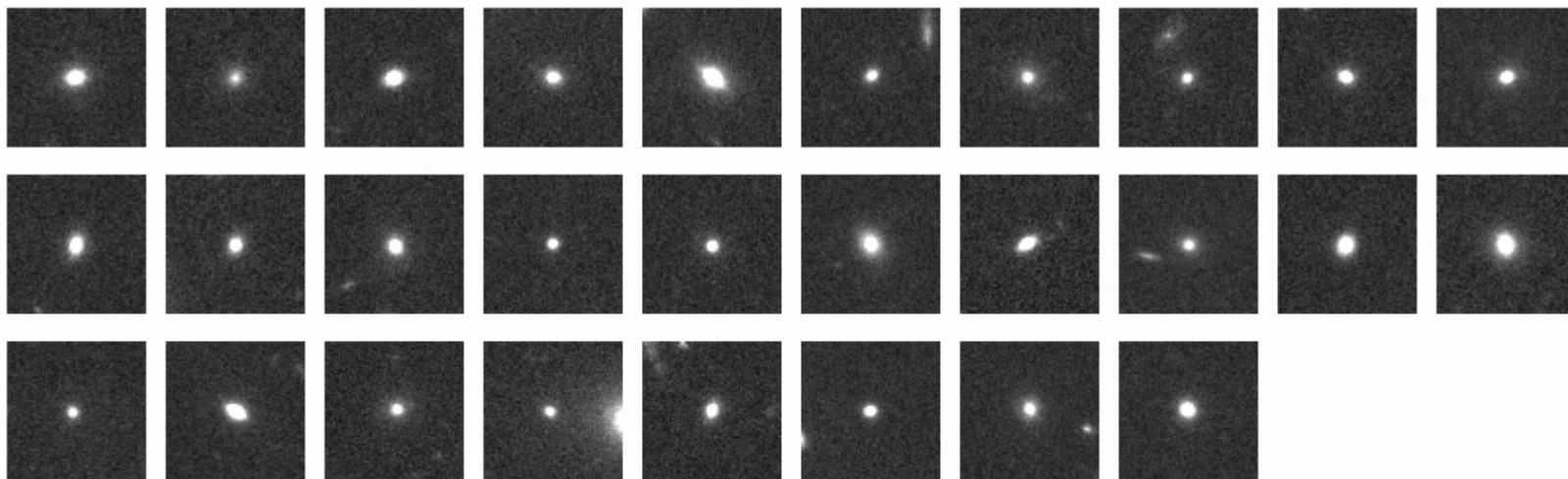
$2.5 < z < 3.5$

$\log(M_s) = 10.5 - 11$ $\log(\text{SSFR}) > -8.5$



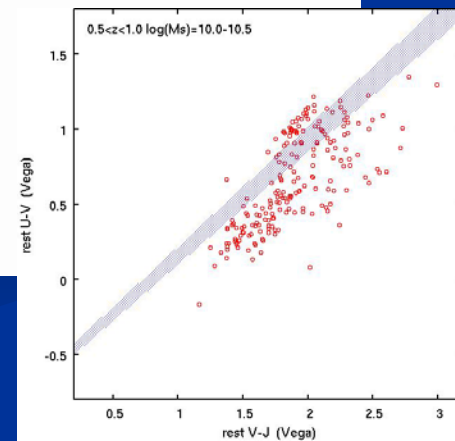
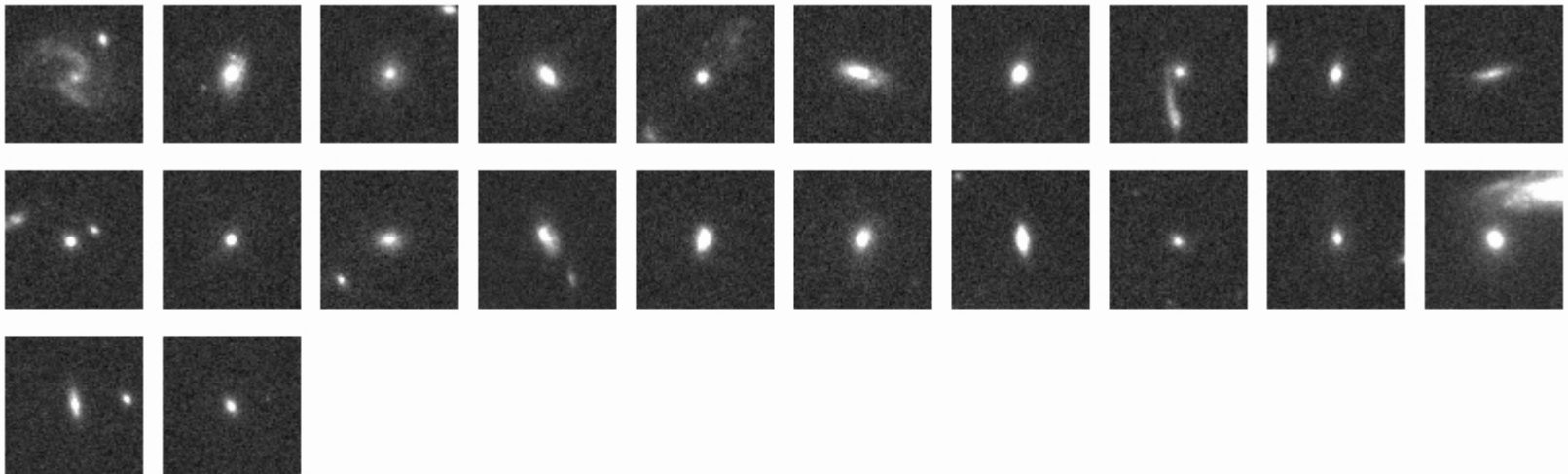
$0.5 < z < 1.0$

$\log(M_s) = 10 - 10.5$ $\log(\text{SSFR}) < -11$



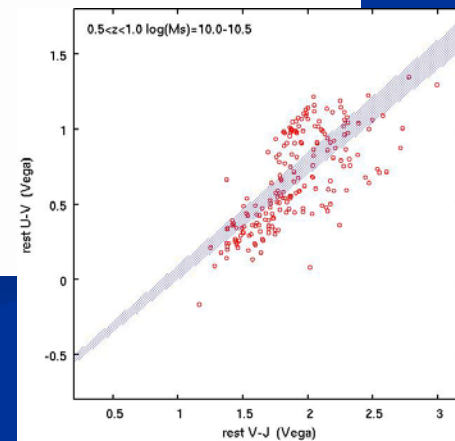
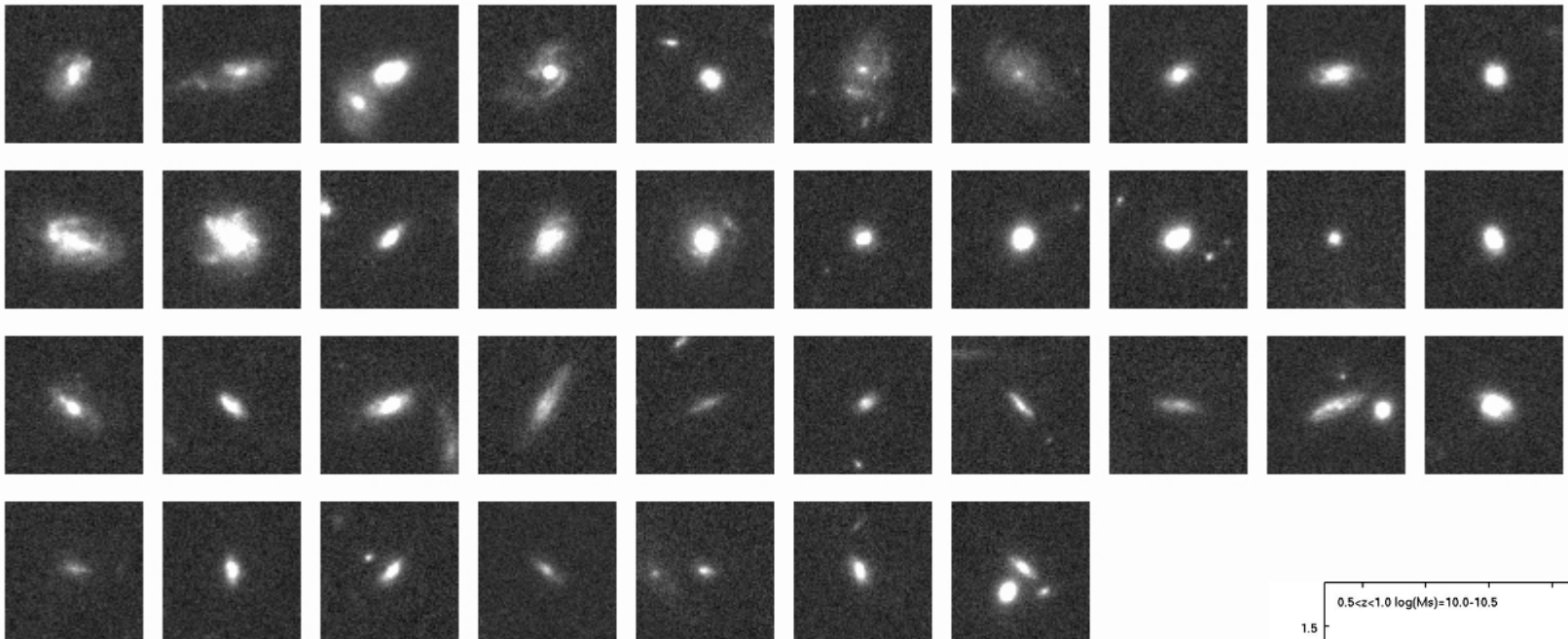
$0.5 < z < 1.0$

$\log(M_s) = 10 - 10.5$ $-11 < \log(\text{SSFR}) < -10$



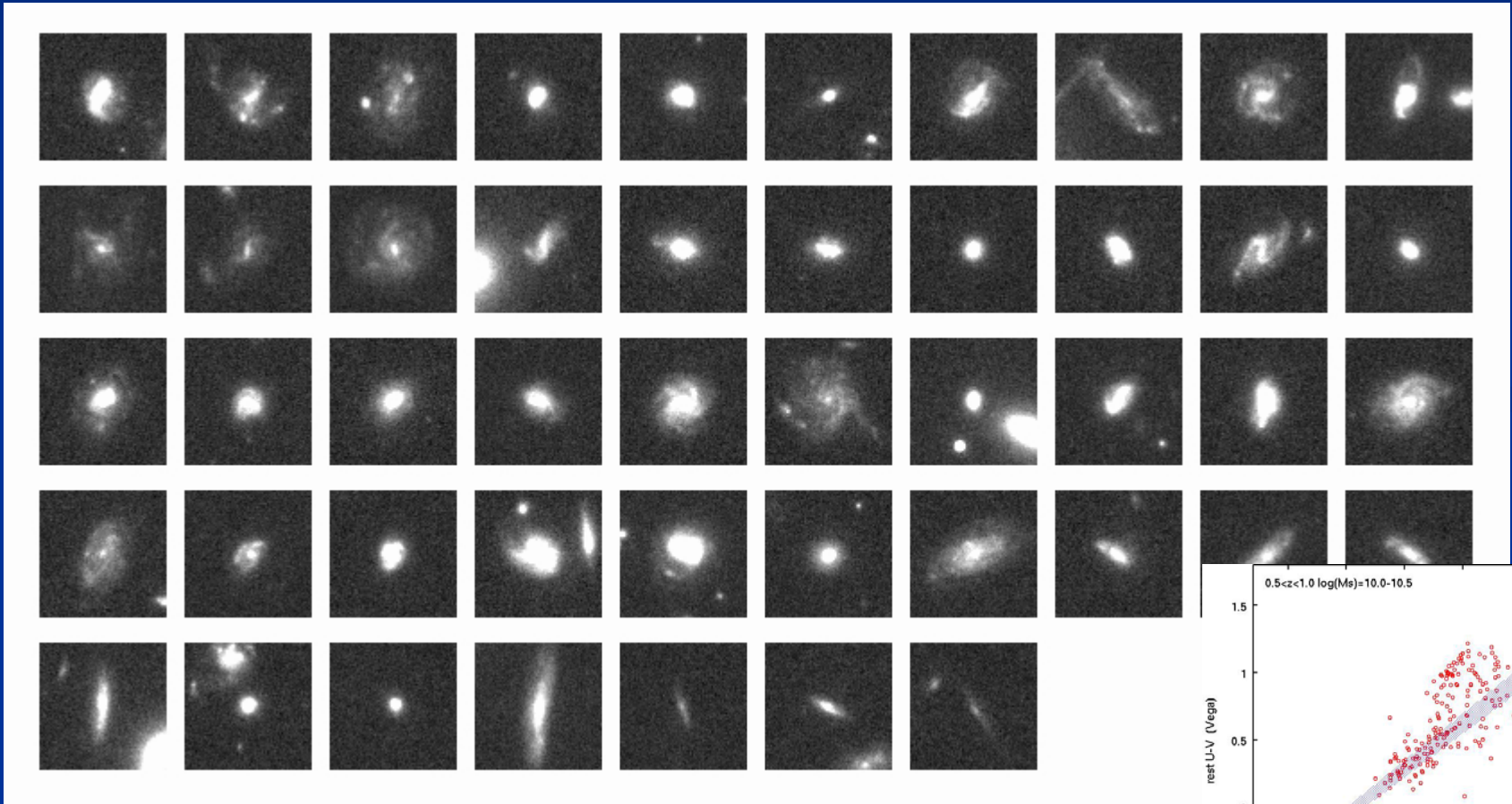
$0.5 < z < 1.0$

$\log(M_s) = 10 - 10.5$ $-10 < \log(\text{SSFR}) < -9.5$



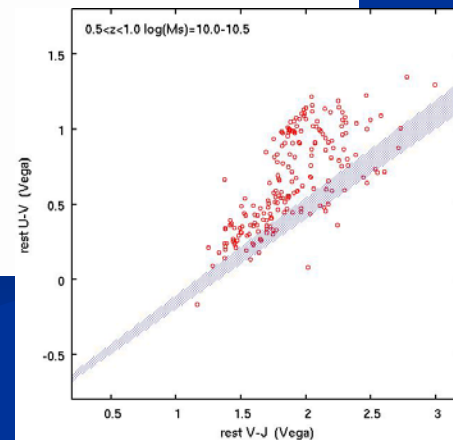
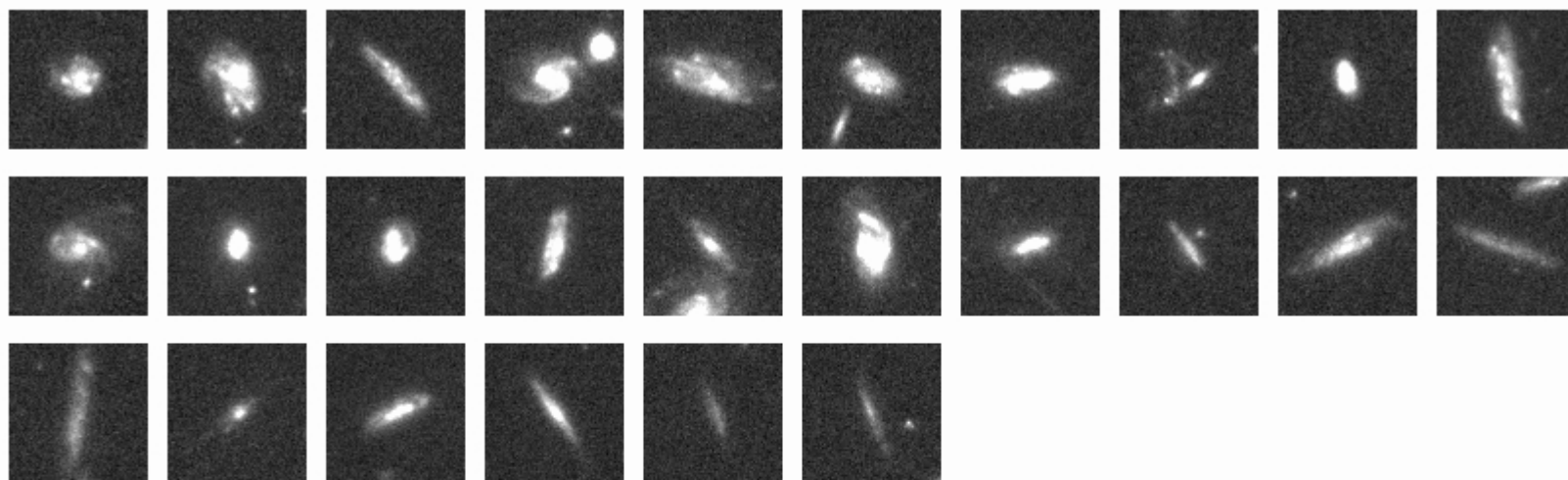
$0.5 < z < 1.0$

$\log(M_s) = 10 - 10.5$ $-9.5 < \log(\text{SSFR}) < -9$



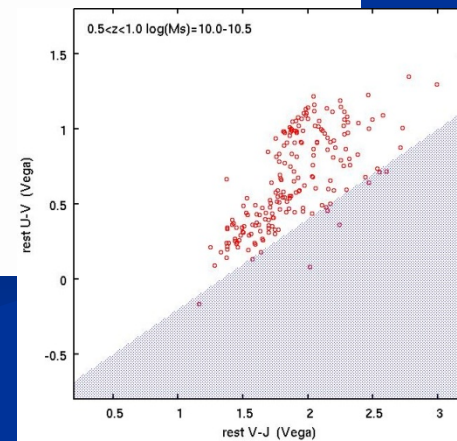
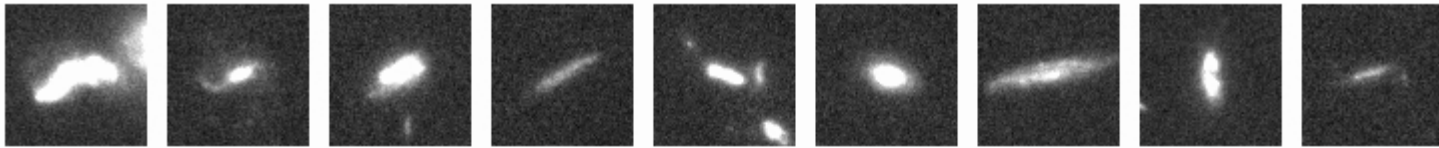
$0.5 < z < 1.0$

$\log(M_s) = 10 - 10.5$ $-9 < \log(\text{SSFR}) < -8.5$



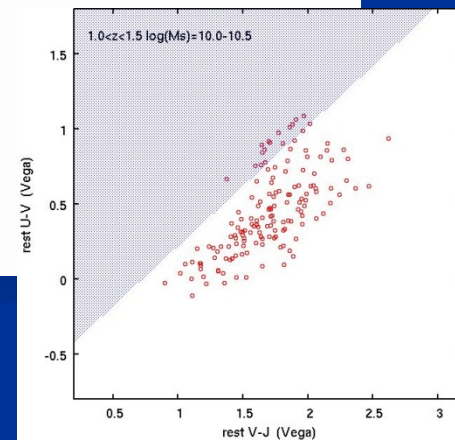
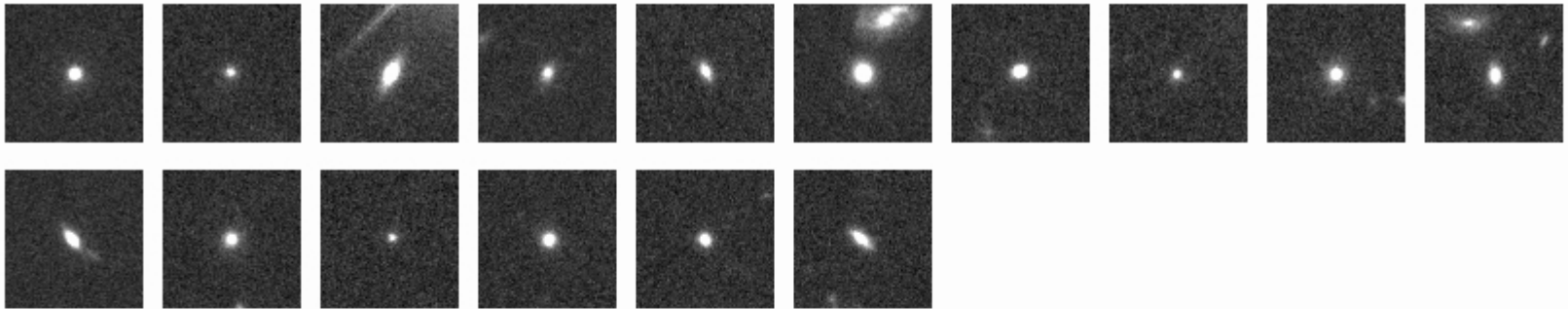
$$0.5 < z < 1.0$$

$$\log(M_s) = 10 - 10.5 \quad \log(\text{SSFR}) > -8.5$$



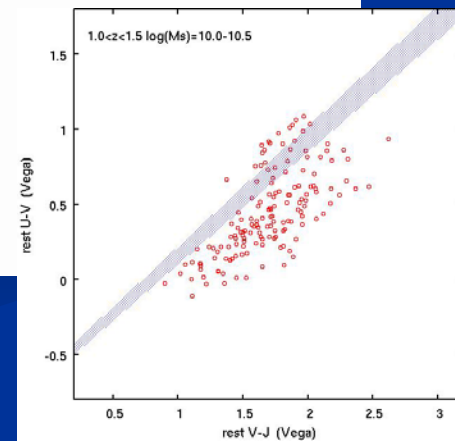
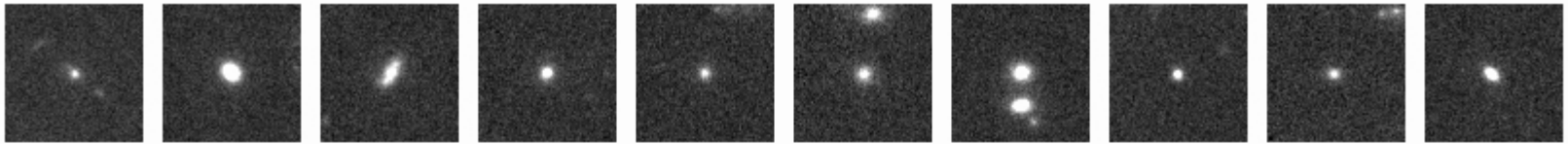
$1.0 < z < 1.5$

$\log(M_s) = 10 - 10.5$ $\log(\text{SSFR}) < -11$



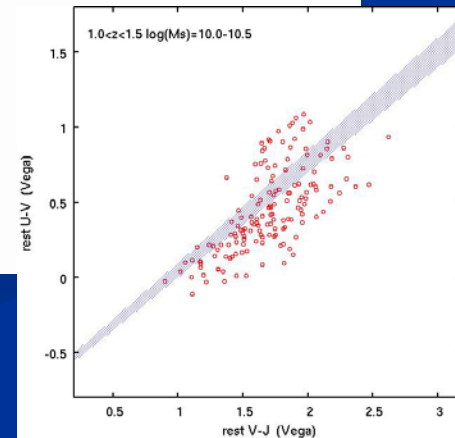
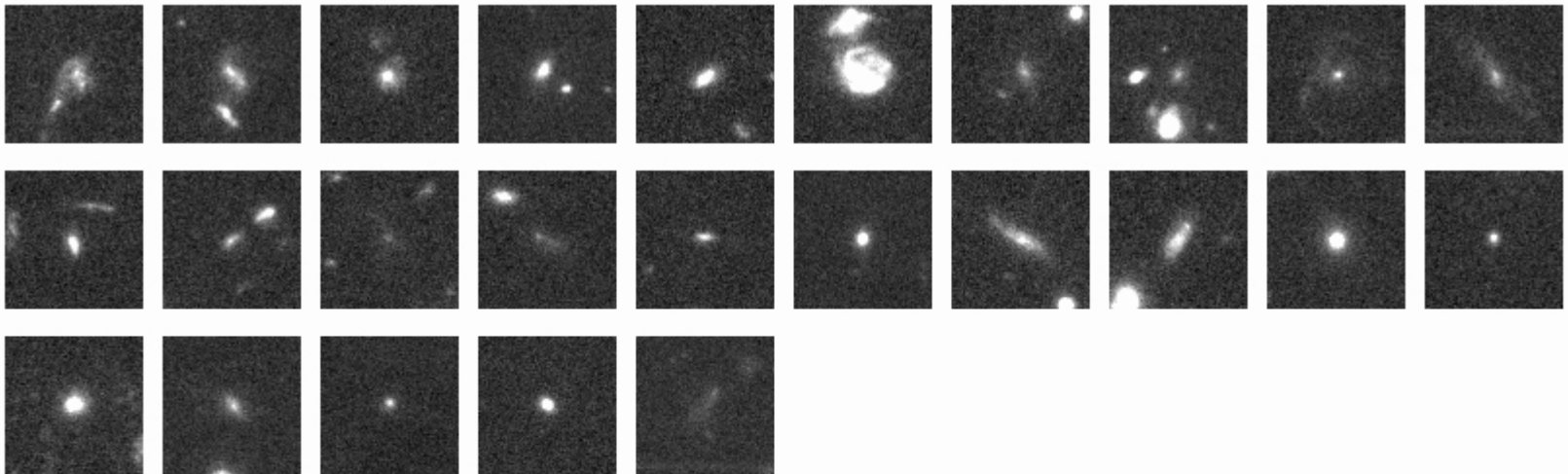
$1.0 < z < 1.5$

$\log(M_s) = 10 - 10.5$ $-11 < \log(\text{SSFR}) < -10$



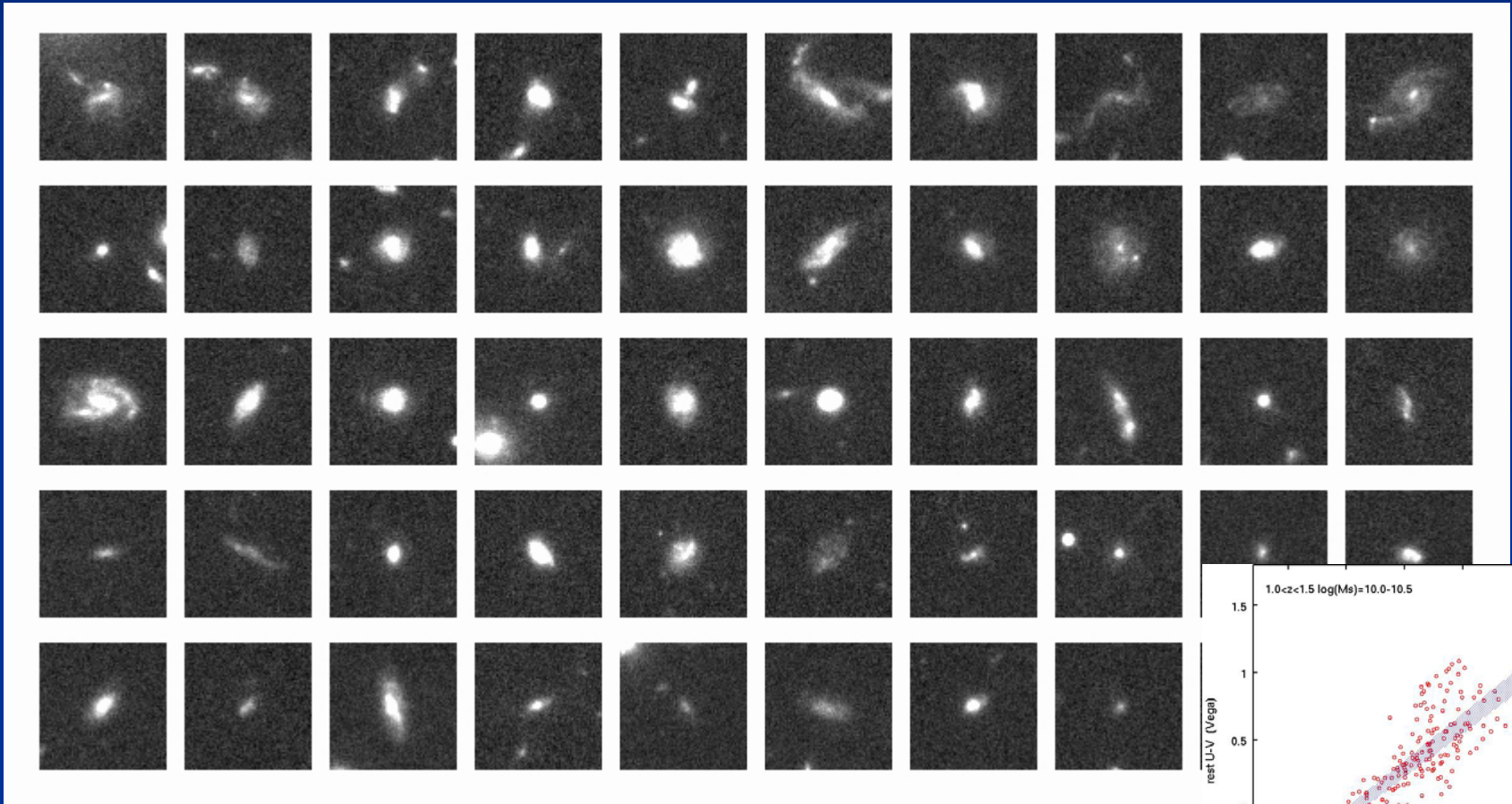
$1.0 < z < 1.5$

$\log(M_s) = 10 - 10.5$ $-10 < \log(\text{SSFR}) < -9.5$



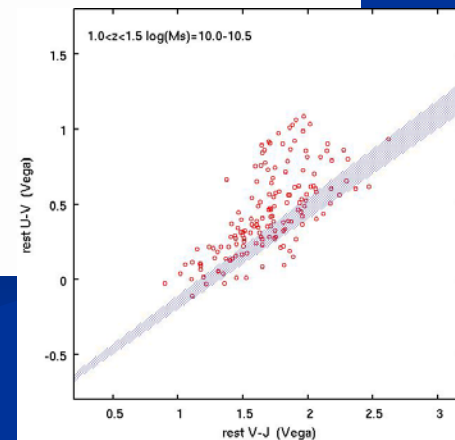
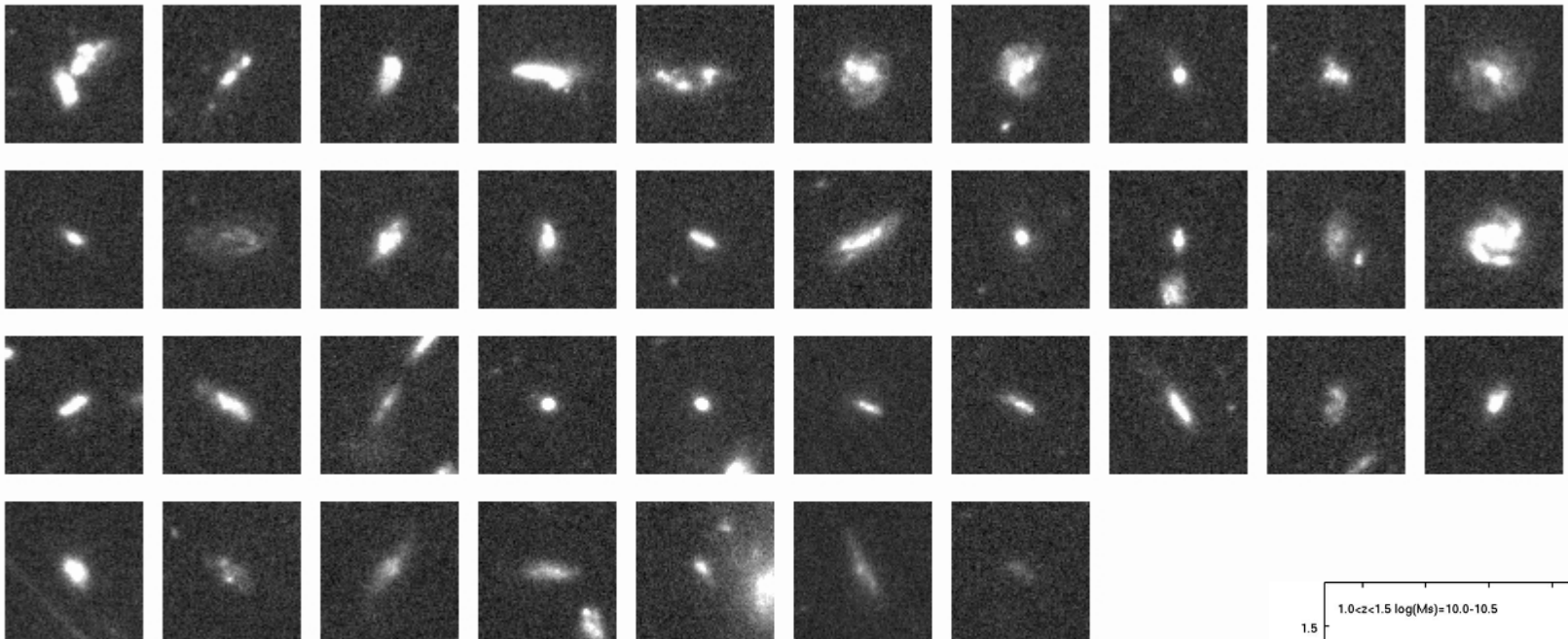
$1.0 < z < 1.5$

$\log(M_s) = 10 - 10.5$ $-9.5 < \log(\text{SSFR}) < -9$



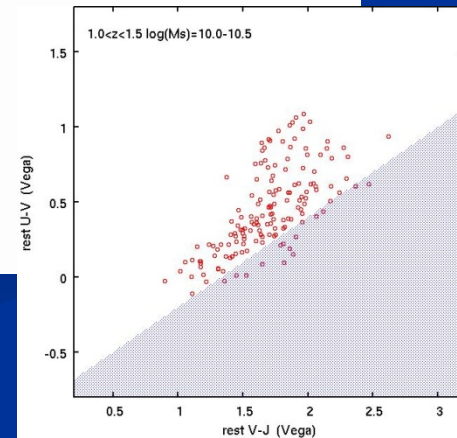
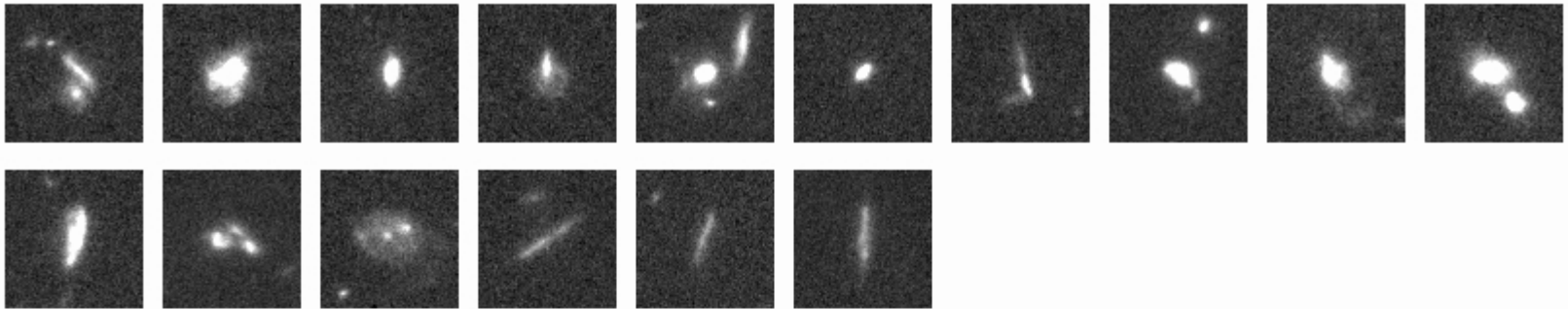
$1.0 < z < 1.5$

$\log(M_s) = 10 - 10.5$ $-9 < \log(\text{SSFR}) < -8.5$



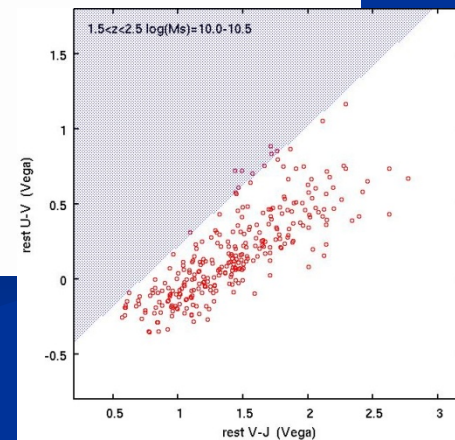
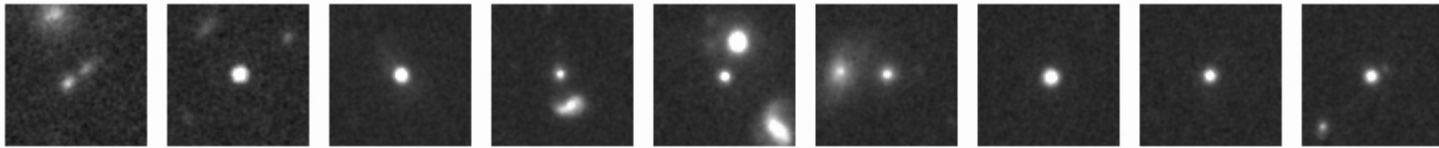
$1.0 < z < 1.5$

$\log(M_s) = 10 - 10.5$ $\log(\text{SSFR}) > -8.5$



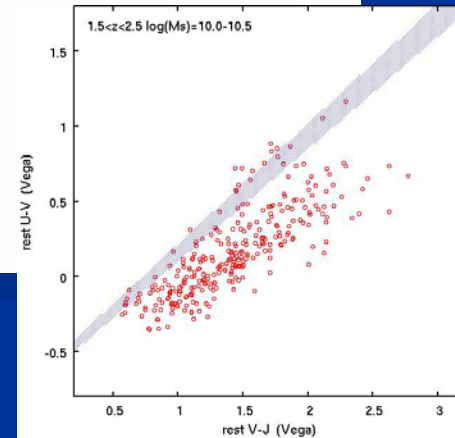
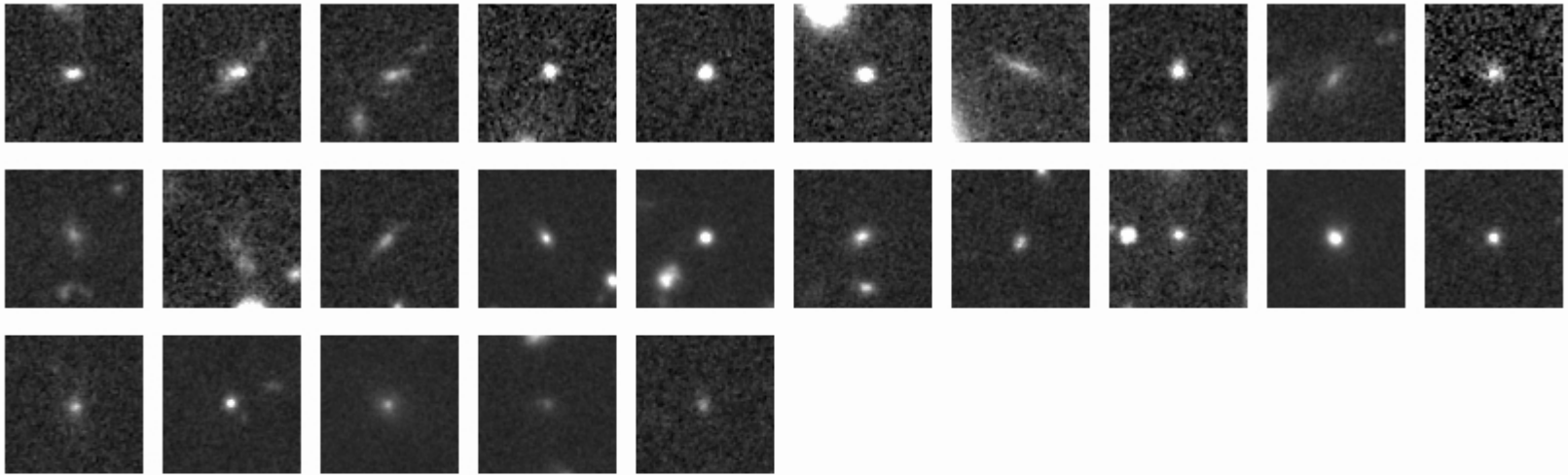
$1.5 < z < 2.5$

$\log(M_s) = 10 - 10.5$ $\log(\text{SSFR}) < -11$



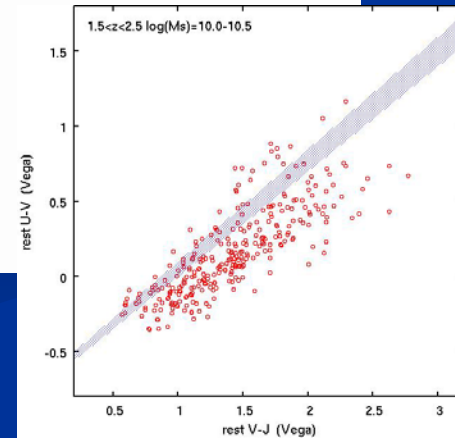
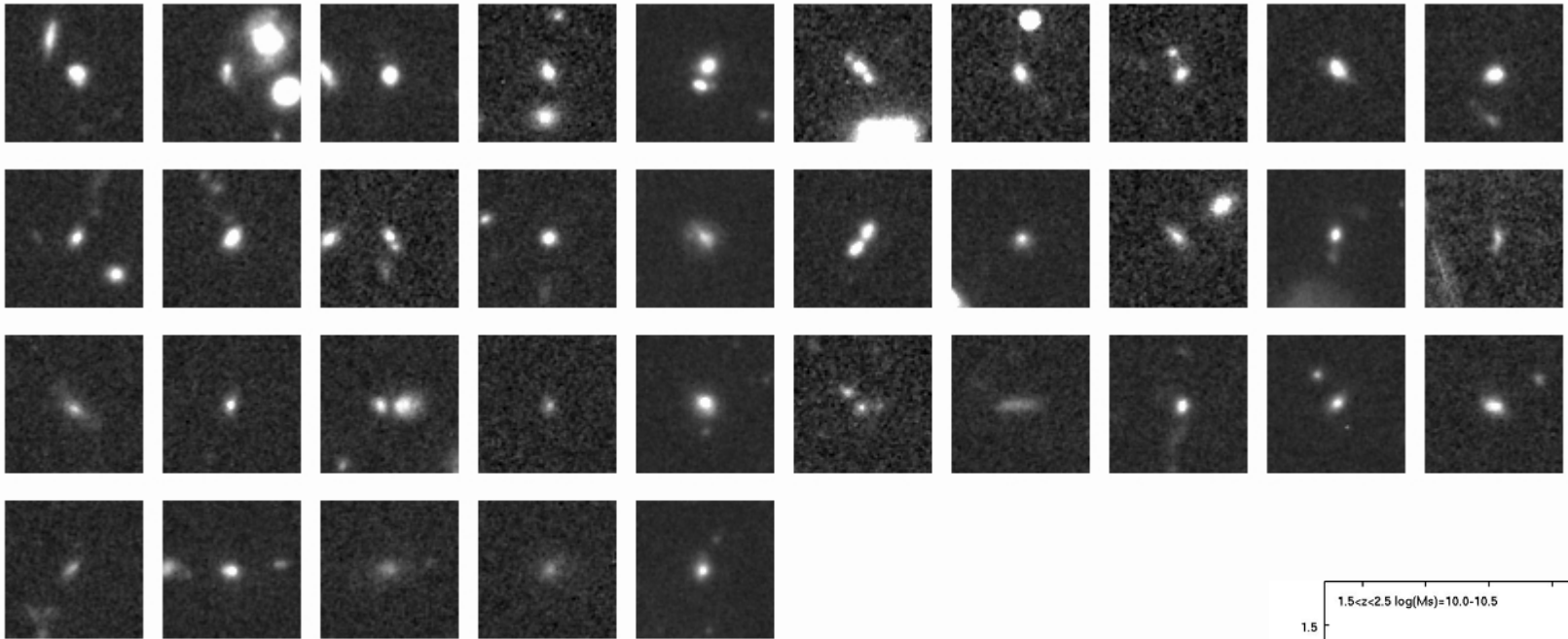
$1.5 < z < 2.5$

$\log(M_s) = 10 - 10.5$ $-11 < \log(\text{SSFR}) < -10$



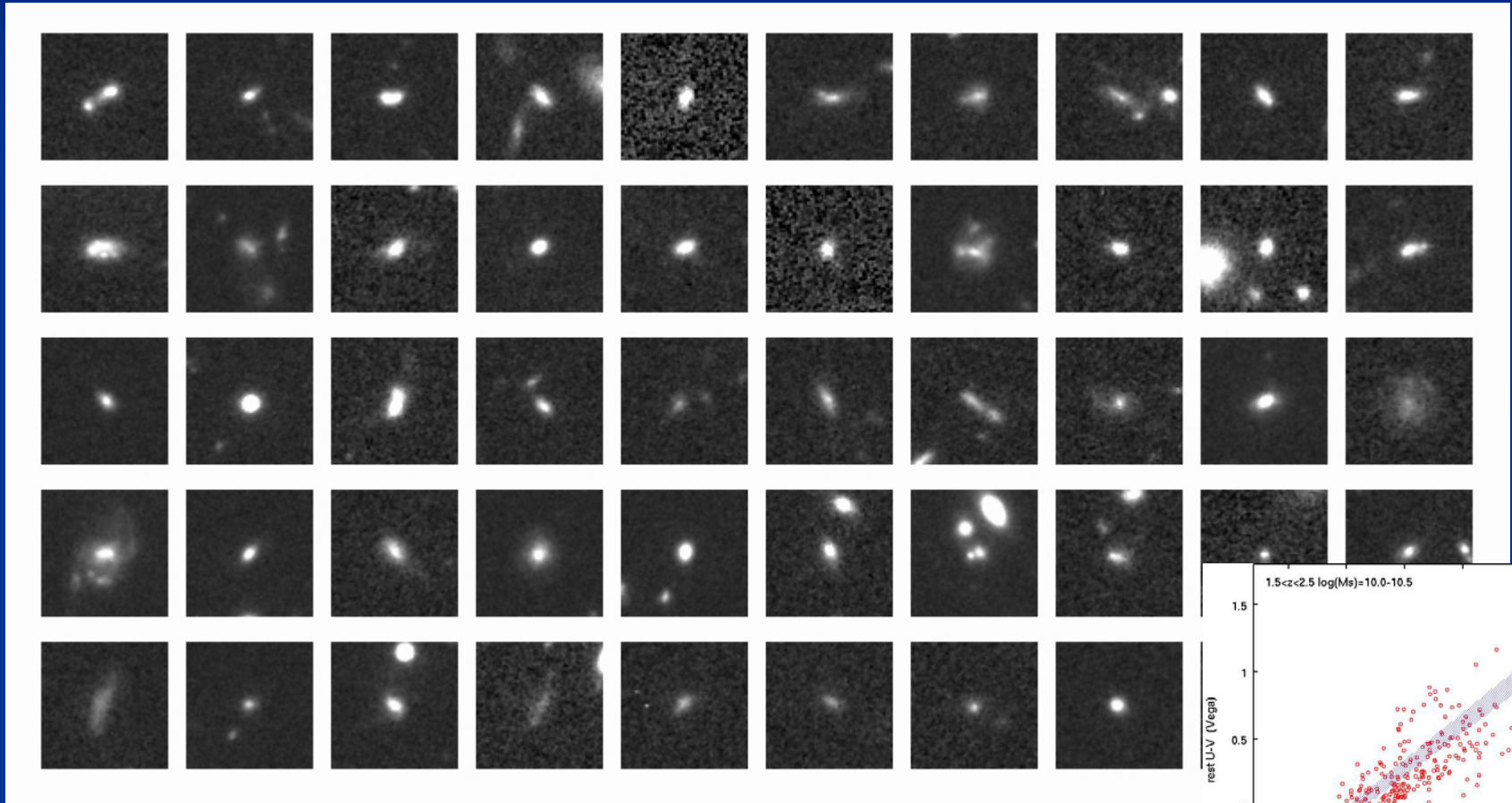
$1.5 < z < 2.5$

$\log(M_s) = 10 - 10.5$ $-10 < \log(\text{SSFR}) < -9.5$



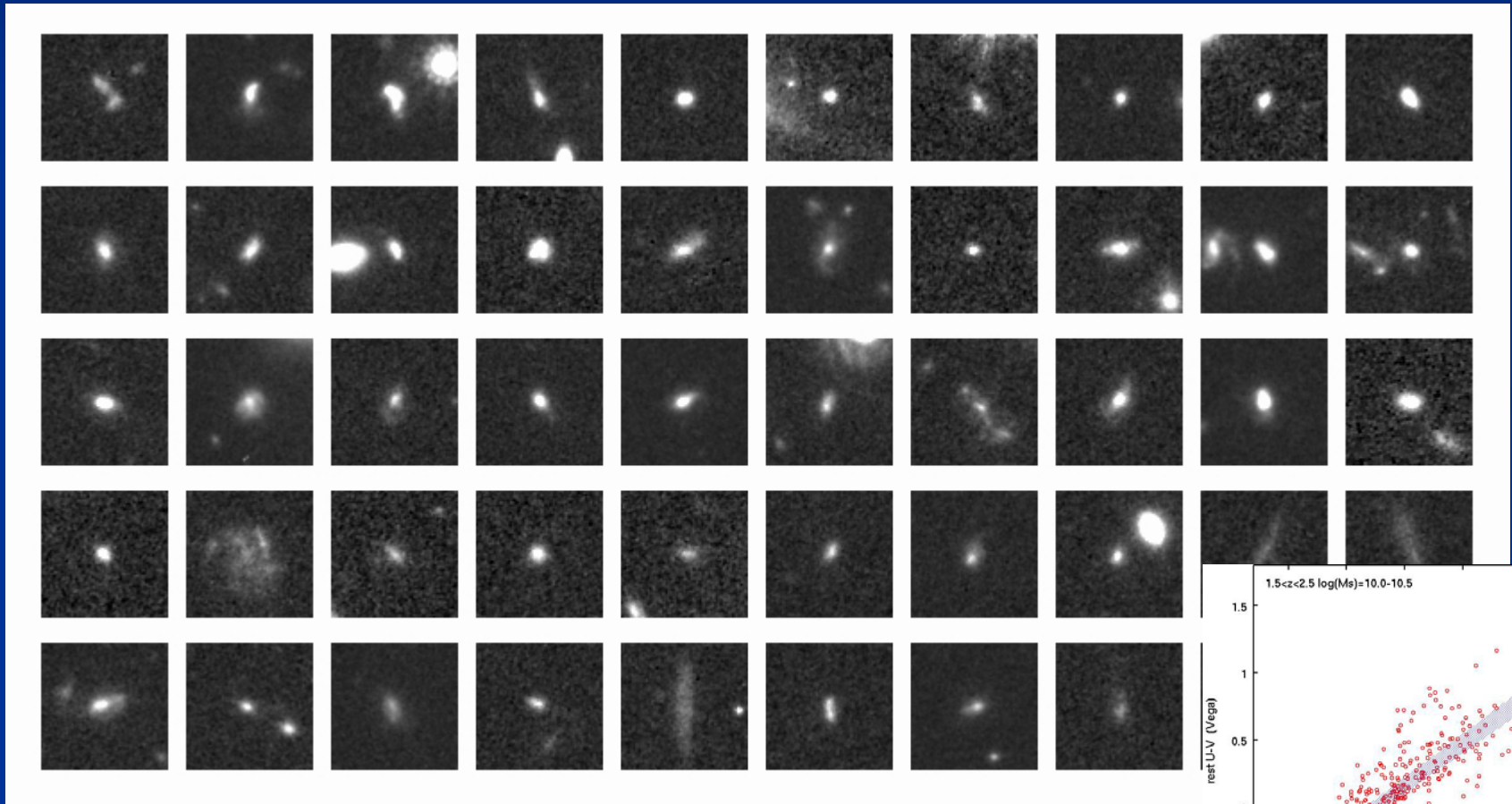
$1.5 < z < 2.5$

$\log(M_s) = 10 - 10.5$ $-9.5 < \log(\text{SSFR}) < -9$



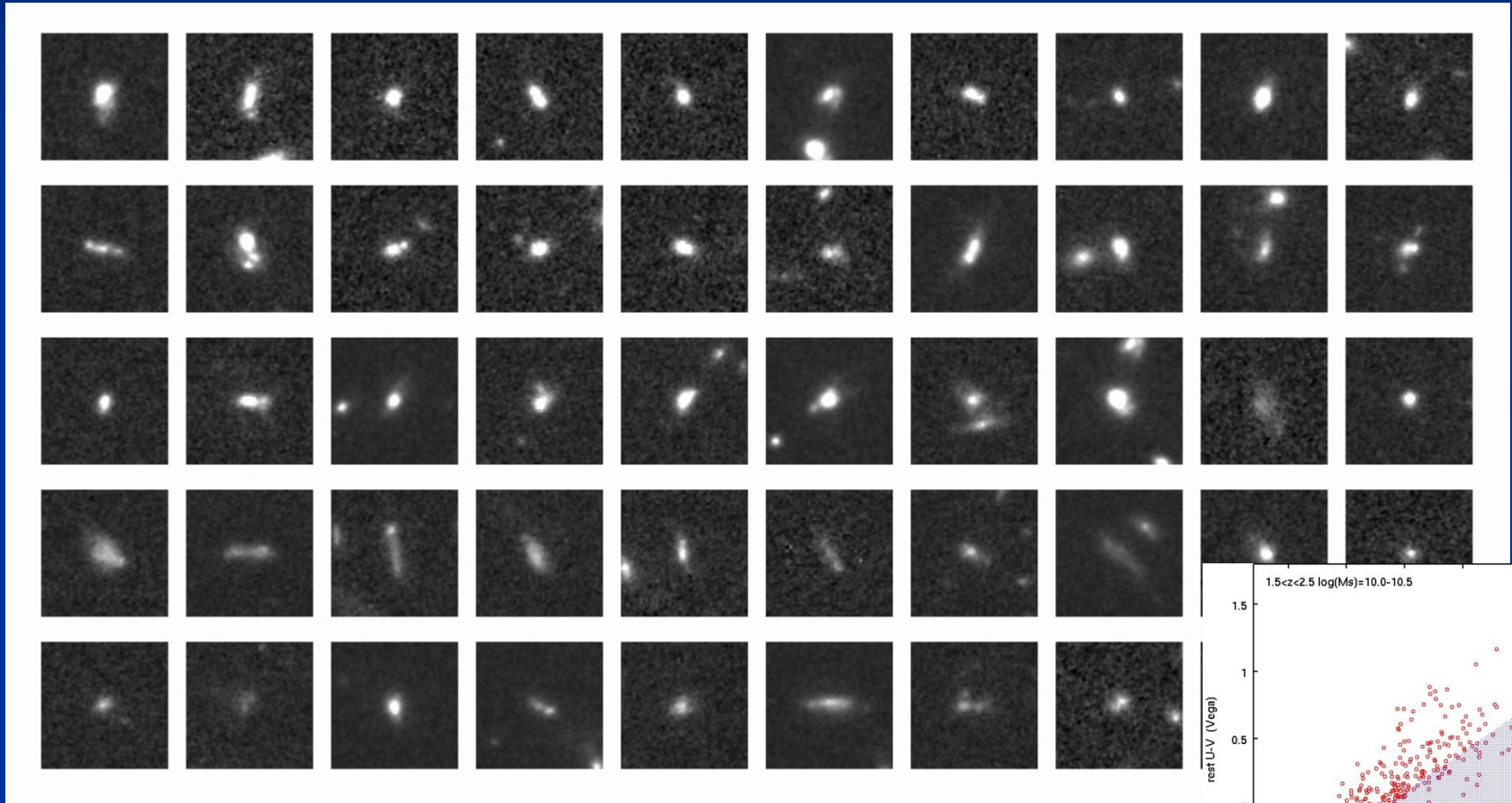
$1.5 < z < 2.5$

$\log(M_s) = 10 - 10.5$ $-9 < \log(\text{SSFR}) < -8.5$



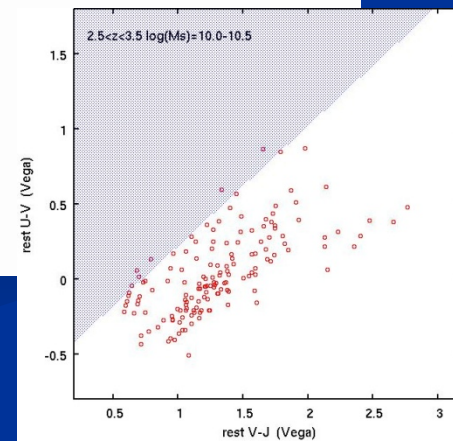
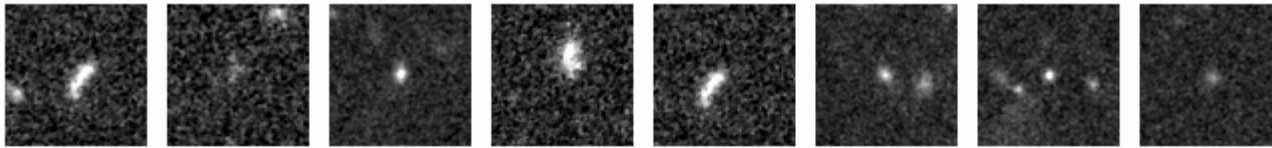
$1.5 < z < 2.5$

$\log(M_s) = 10 - 10.5$ $\log(\text{SSFR}) > -8.5$



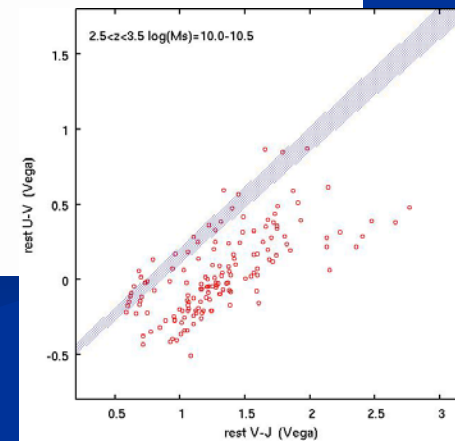
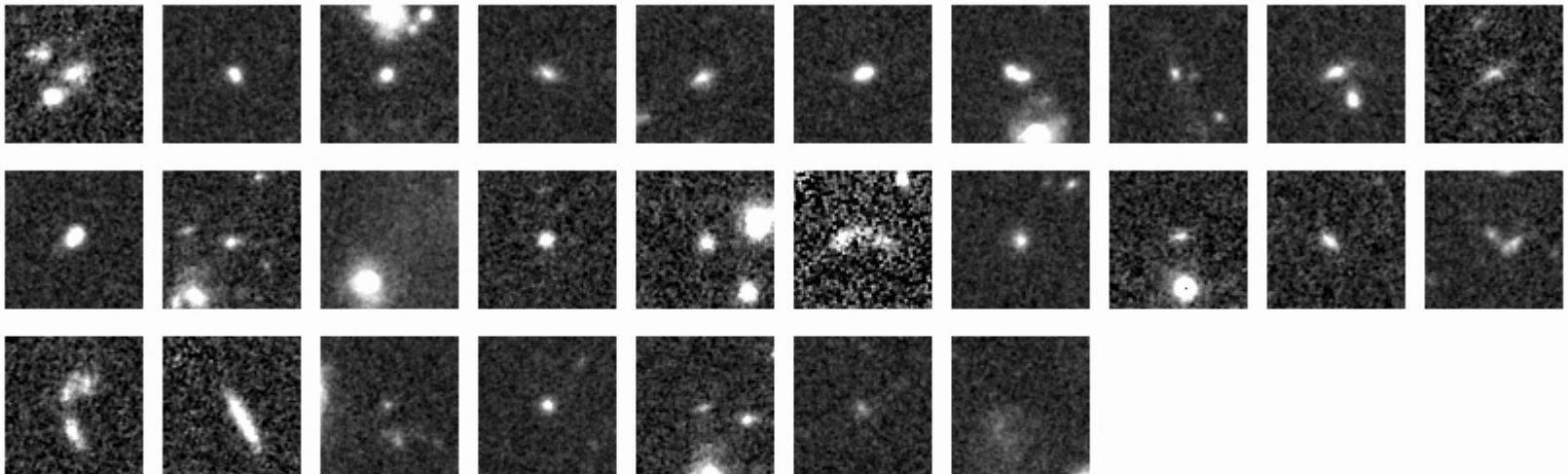
$2.5 < z < 3.5$

$\log(M_s) = 10 - 10.5$ $\log(\text{SSFR}) < -11$



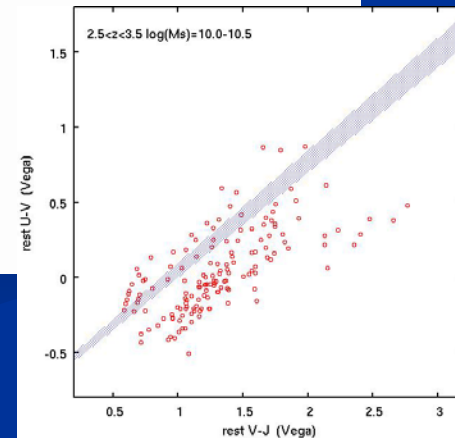
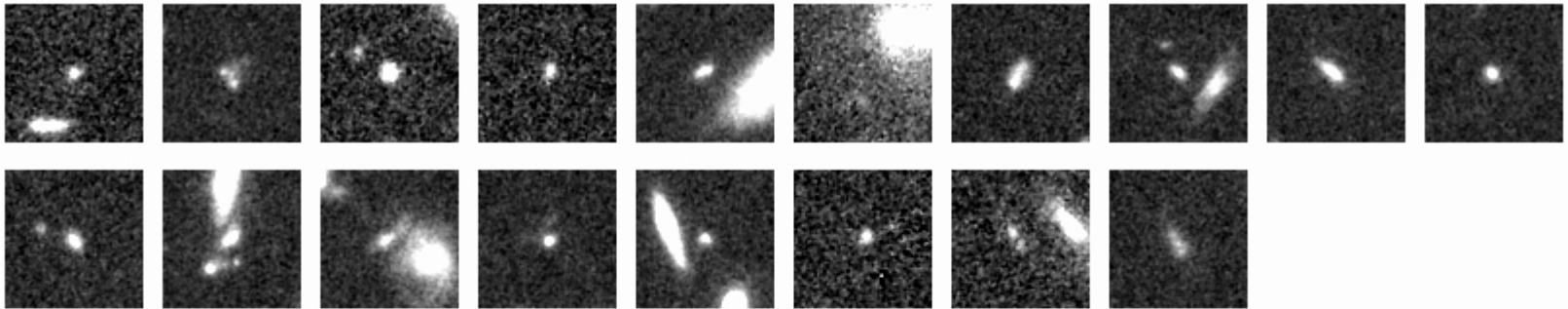
$2.5 < z < 3.5$

$\log(M_s) = 10 - 10.5$ $-11 < \log(\text{SSFR}) < -10$



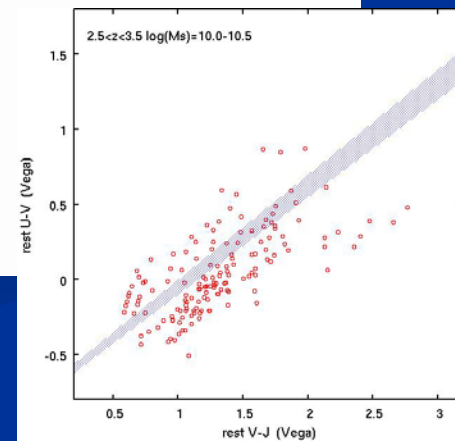
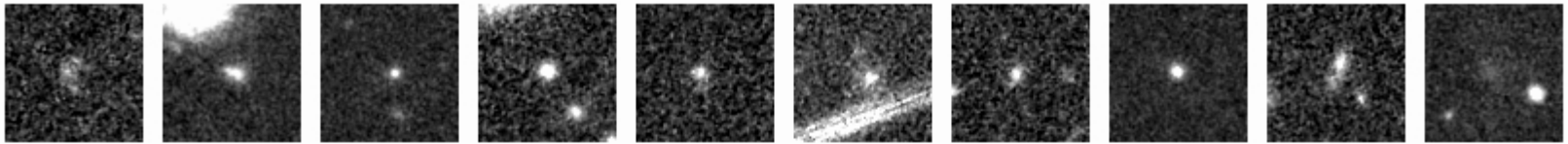
$2.5 < z < 3.5$

$\log(M_s) = 10 - 10.5$ $-10 < \log(\text{SSFR}) < -9.5$



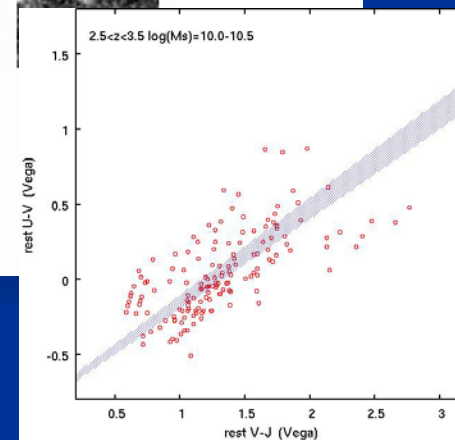
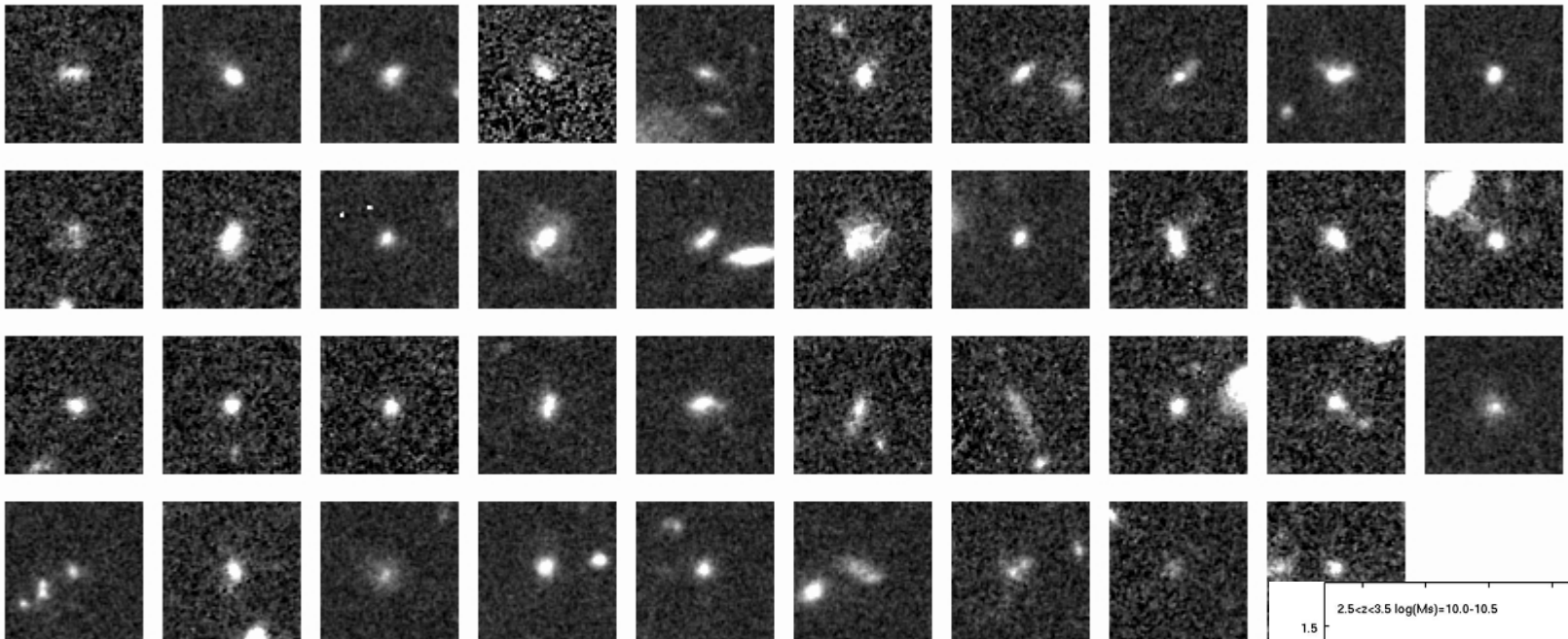
$$2.5 < z < 3.5$$

$$\log(M_s) = 10 - 10.5 \quad -9.5 < \log(\text{SSFR}) < -9$$



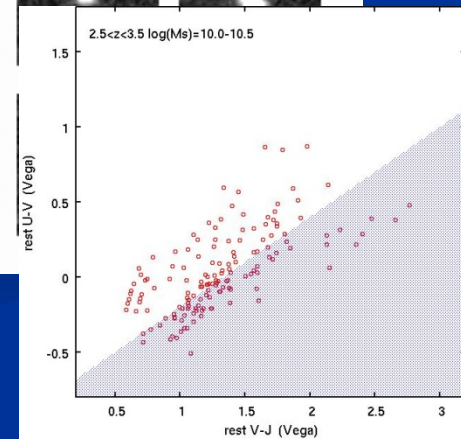
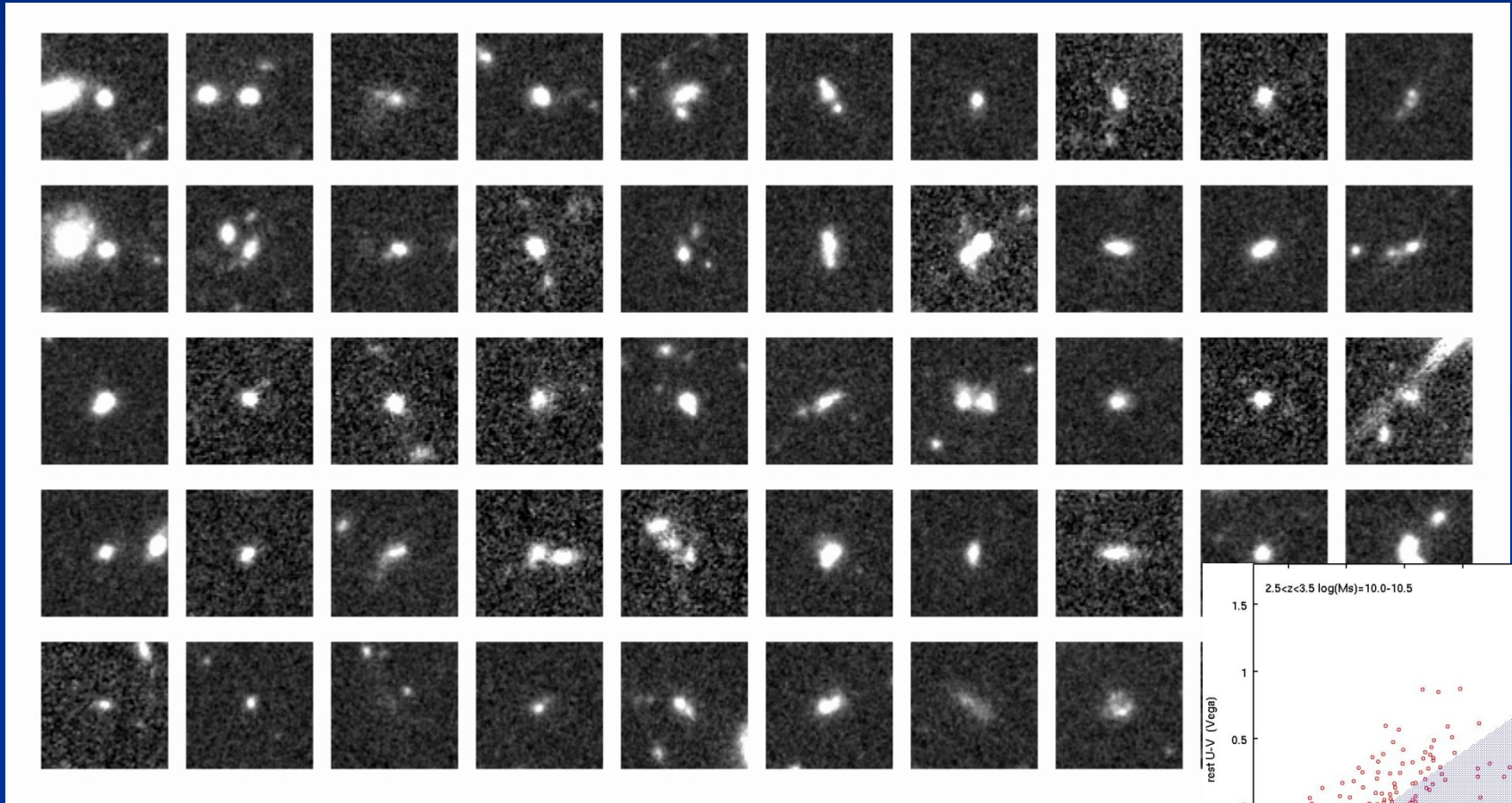
$2.5 < z < 3.5$

$\log(M_s) = 10 - 10.5$ $-9 < \log(\text{SSFR}) < -8.5$



$2.5 < z < 3.5$

$\log(M_s) = 10 - 10.5$ $\log(\text{SSFR}) > -8.5$



静止系Bバンド形態

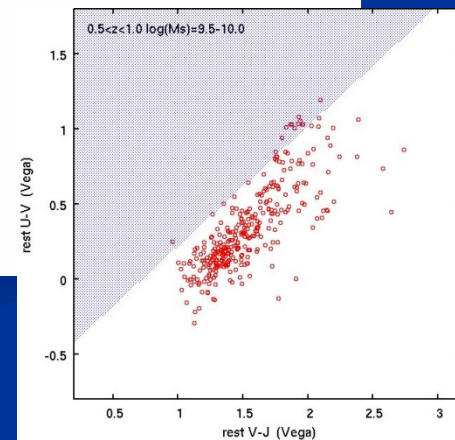
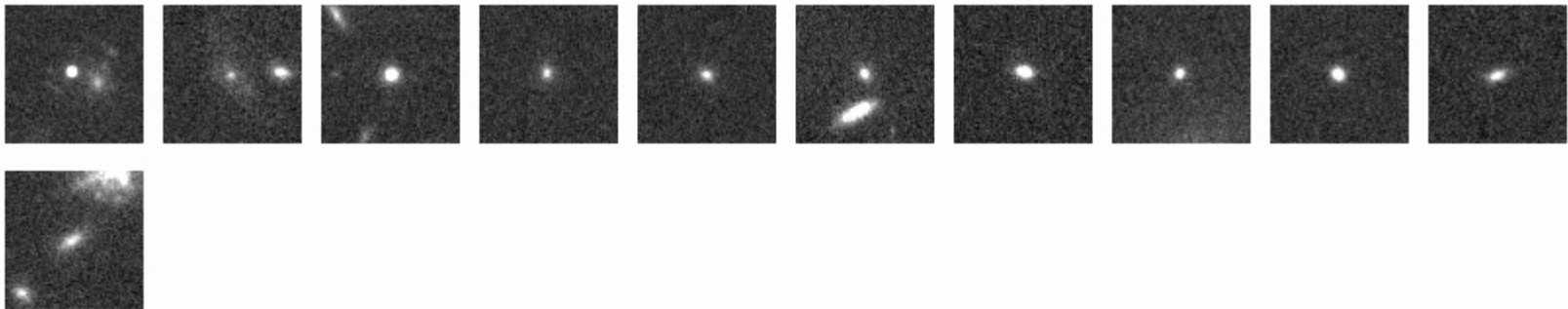
- SSFRと形態の間には相関がありそう
- SSFRが低い銀河は早期型形態
- SSFRが低めの星形成銀河は現在の円盤銀河と同じような形態
- SSFRが高くなるにつれて、非対称な形だったり、clumpyな形態が増えてくる
- $z \sim 2-3$ ではSSFRが低めの星形成銀河でも現在の円盤銀河とは違う??

これから

- 現在の円盤銀河とは違っていそうな形態をどのように分類するとよいか？
- 少なくとも kpc スケールの clump を複数持つ銀河を客観的に(自動で)分類して統計的に議論できないか
- Surface brightness dimming 効果のチェック
- cold accretion 起源で clumpy disk ができたとするシナリオは、 $z \sim 1$ で clumpy な円盤銀河と normal 円盤銀河の gas fraction 分布や gas の空間分布・運動を調べて検証できそうな気がする

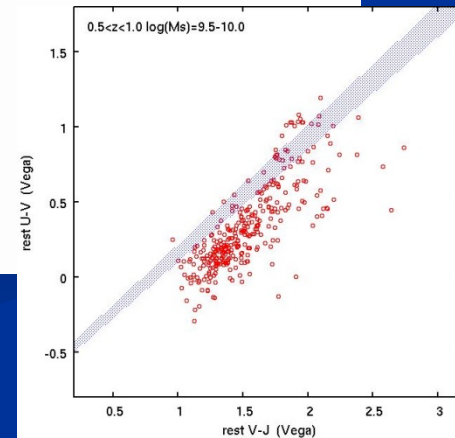
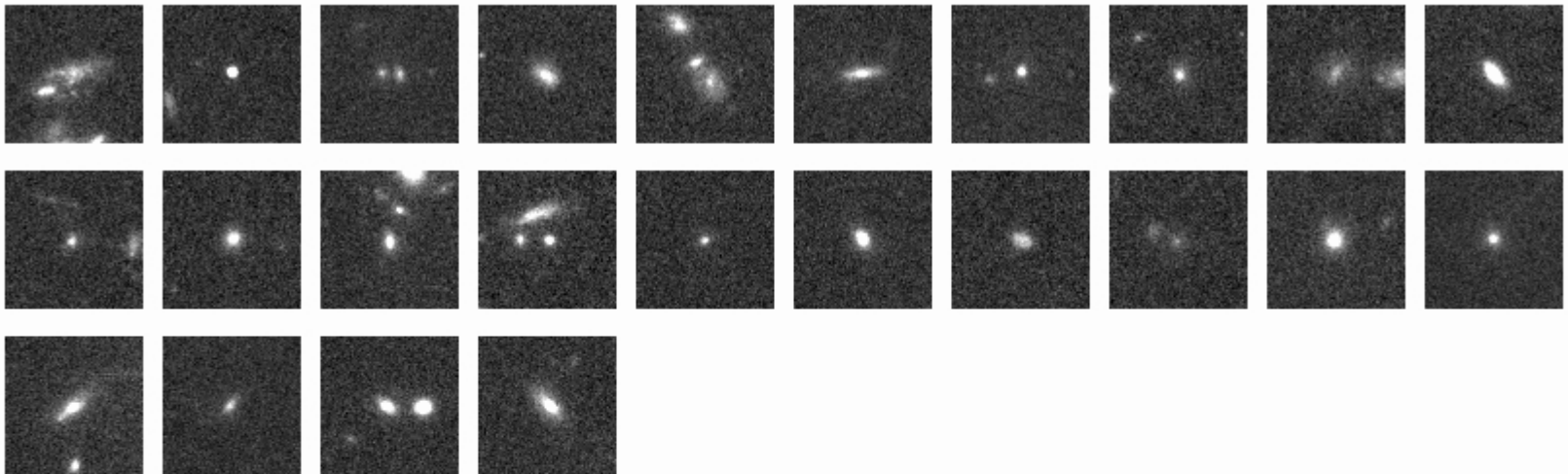
$0.5 < z < 1.0$

$\log(M_s) = 9.5 - 10$ $\log(\text{SSFR}) < -11$



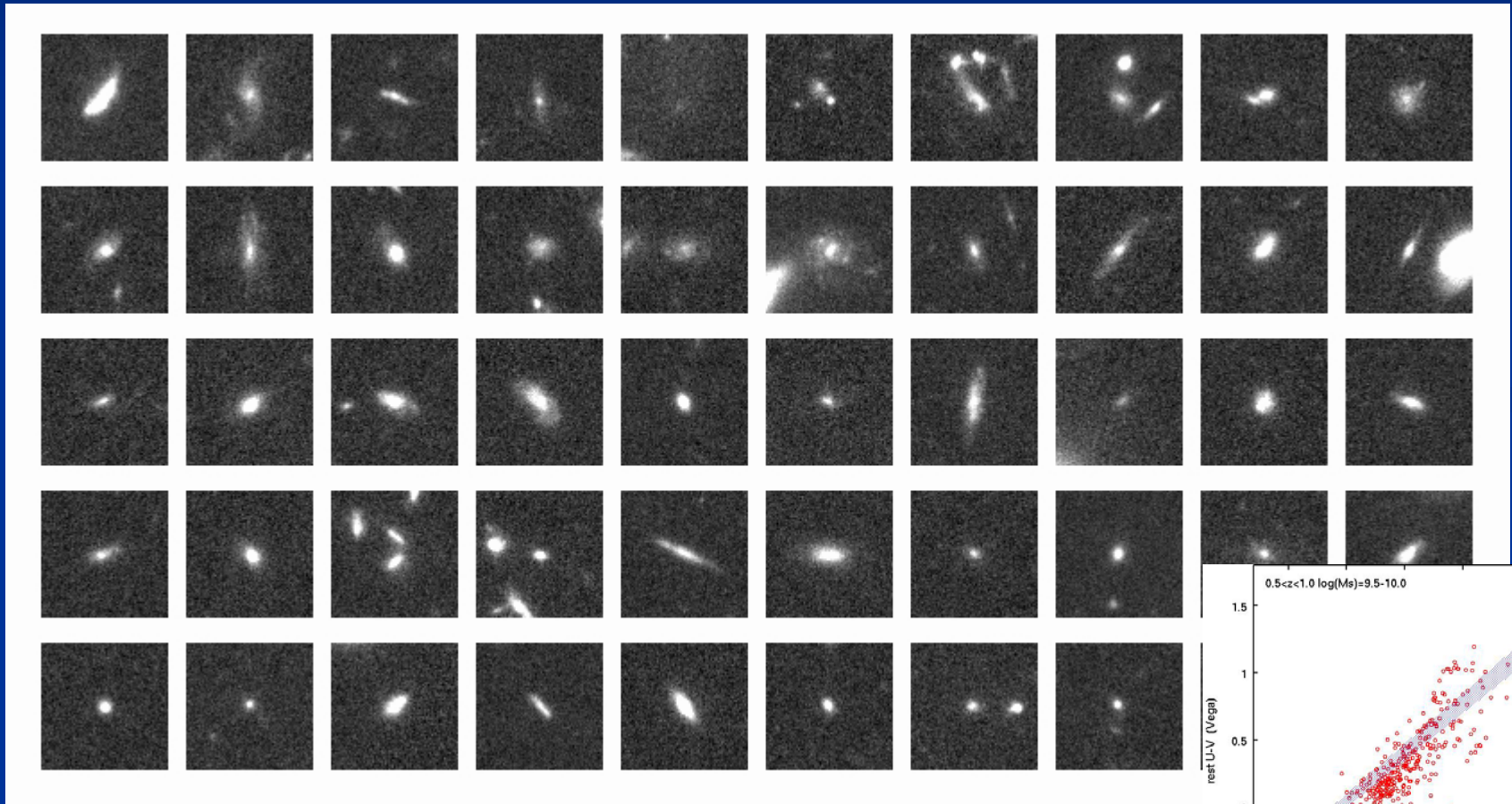
$0.5 < z < 1.0$

$\log(M_s) = 9.5 - 10$ $-11 < \log(\text{SSFR}) < -10$



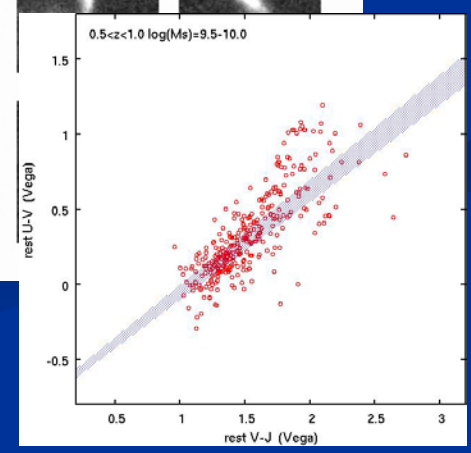
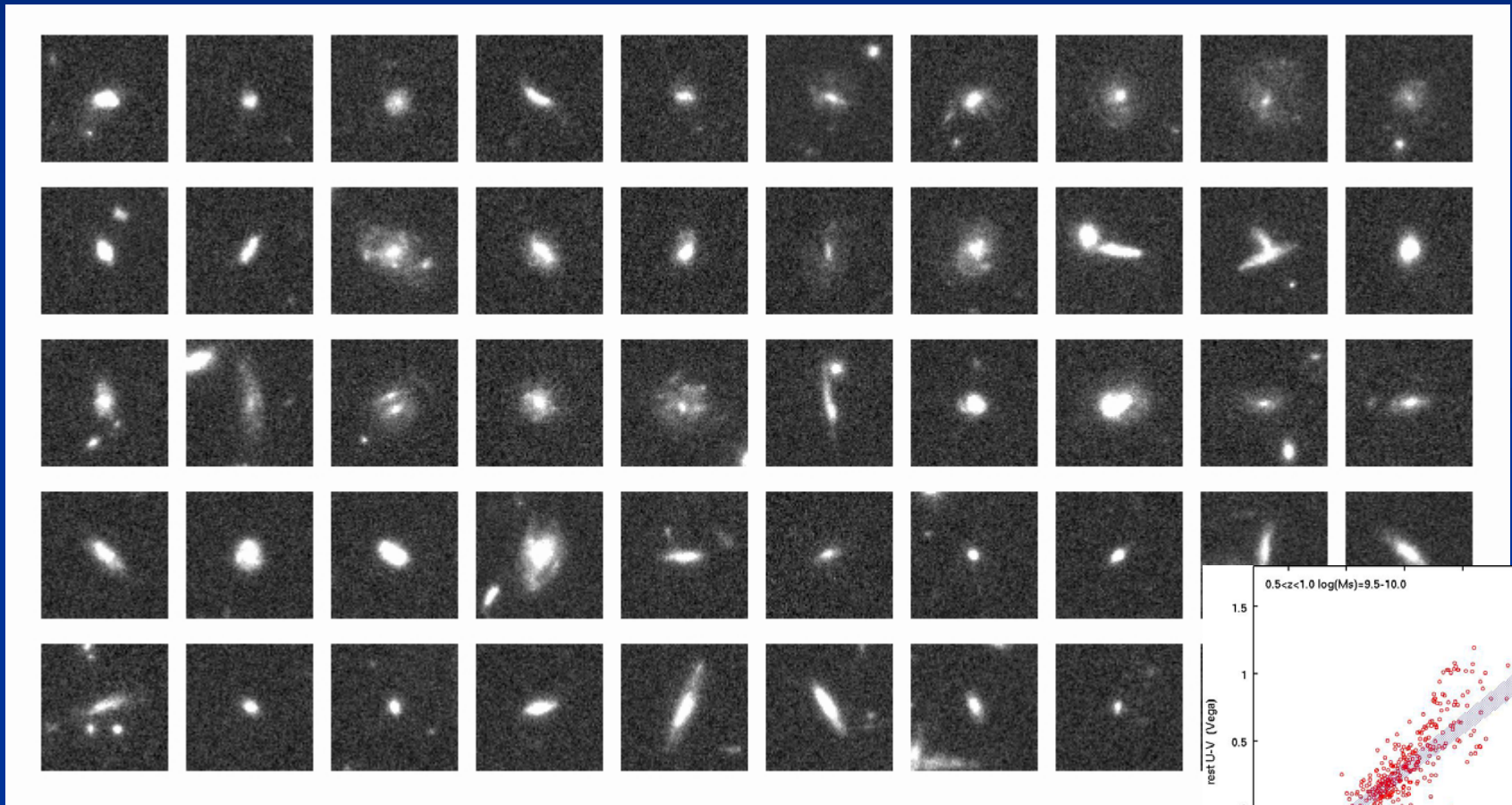
$0.5 < z < 1.0$

$\log(M_s) = 9.5 - 10$ $-10 < \log(\text{SSFR}) < -9.5$



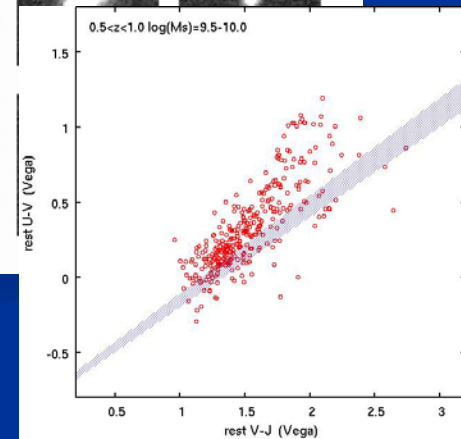
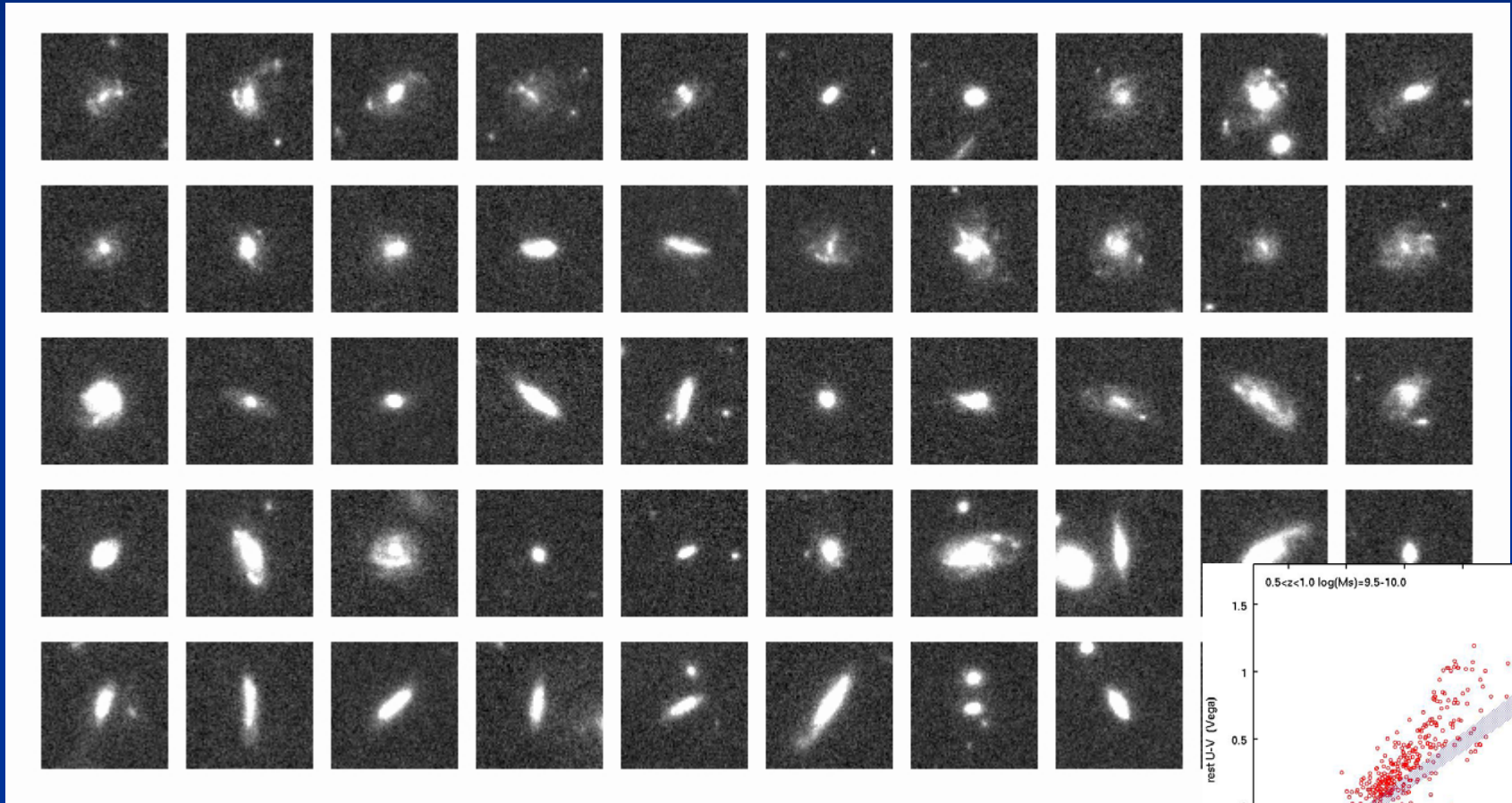
$0.5 < z < 1.0$

$\log(M_s) = 9.5 - 10$ $-9.5 < \log(\text{SSFR}) < -9$



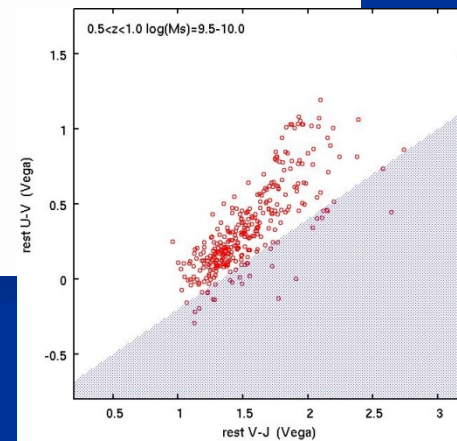
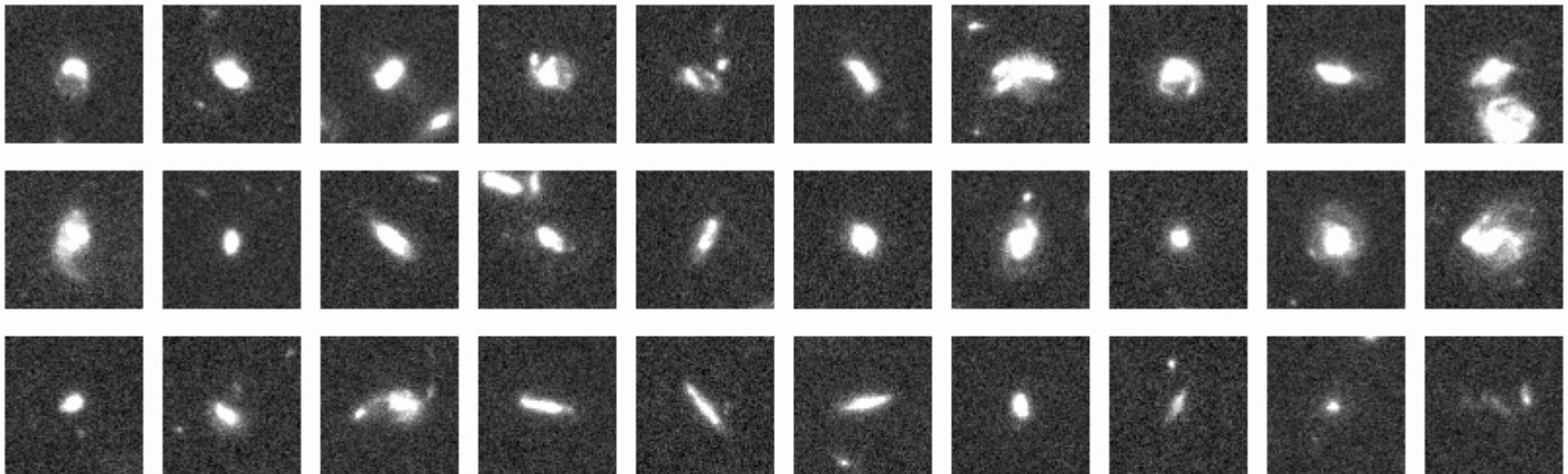
$0.5 < z < 1.0$

$\log(M_s) = 9.5 - 10$ $-9 < \log(\text{SSFR}) < -8.5$



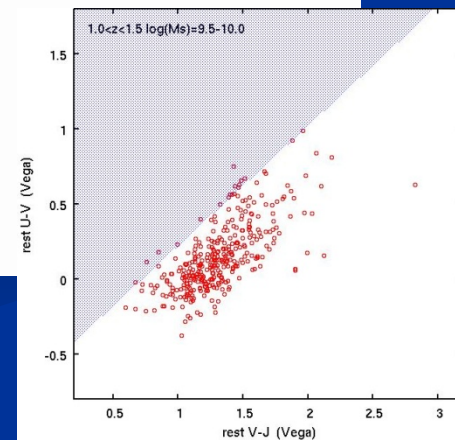
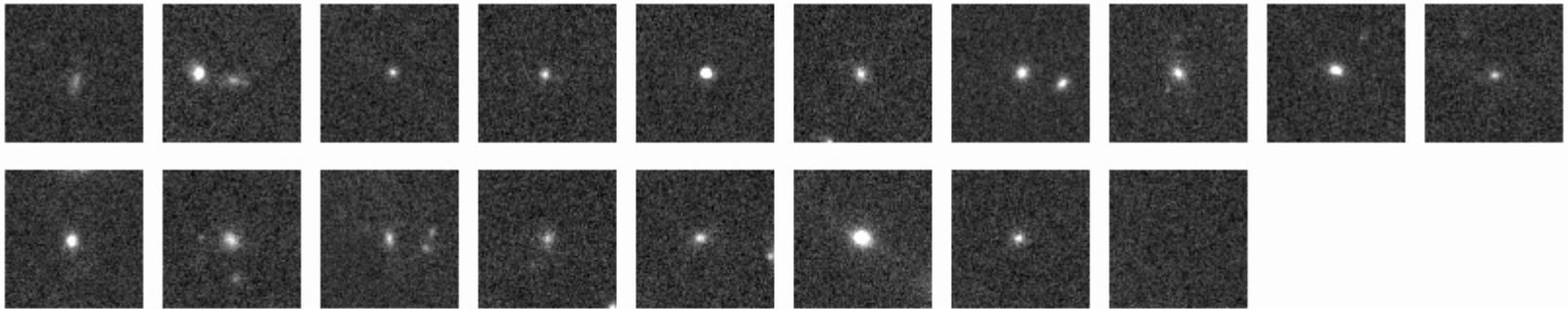
$0.5 < z < 1.0$

$\log(M_s) = 9.5 - 10$ $\log(SSFR) > -8.5$



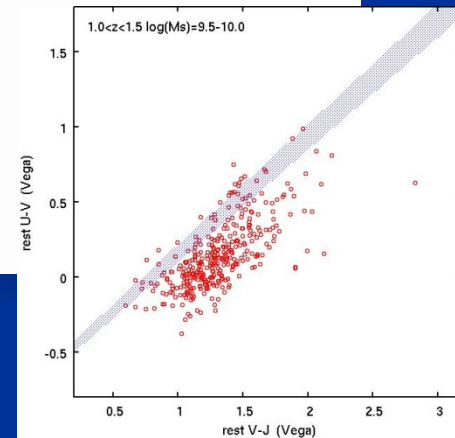
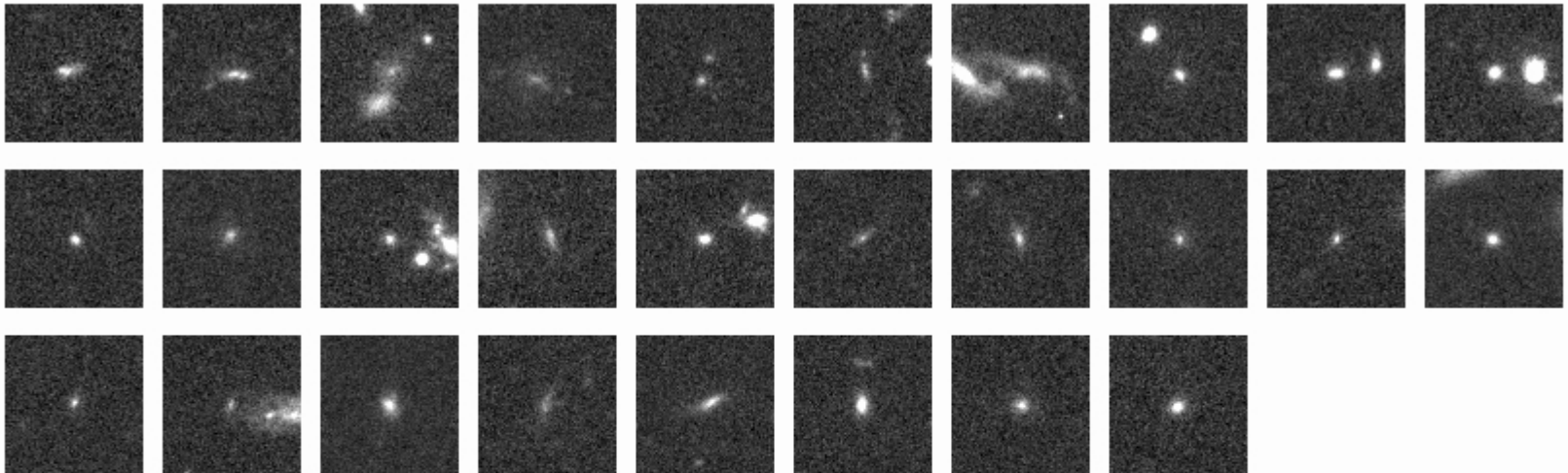
$1.0 < z < 1.5$

$\log(M_s) = 9.5 - 10$ $\log(\text{SSFR}) < -11$



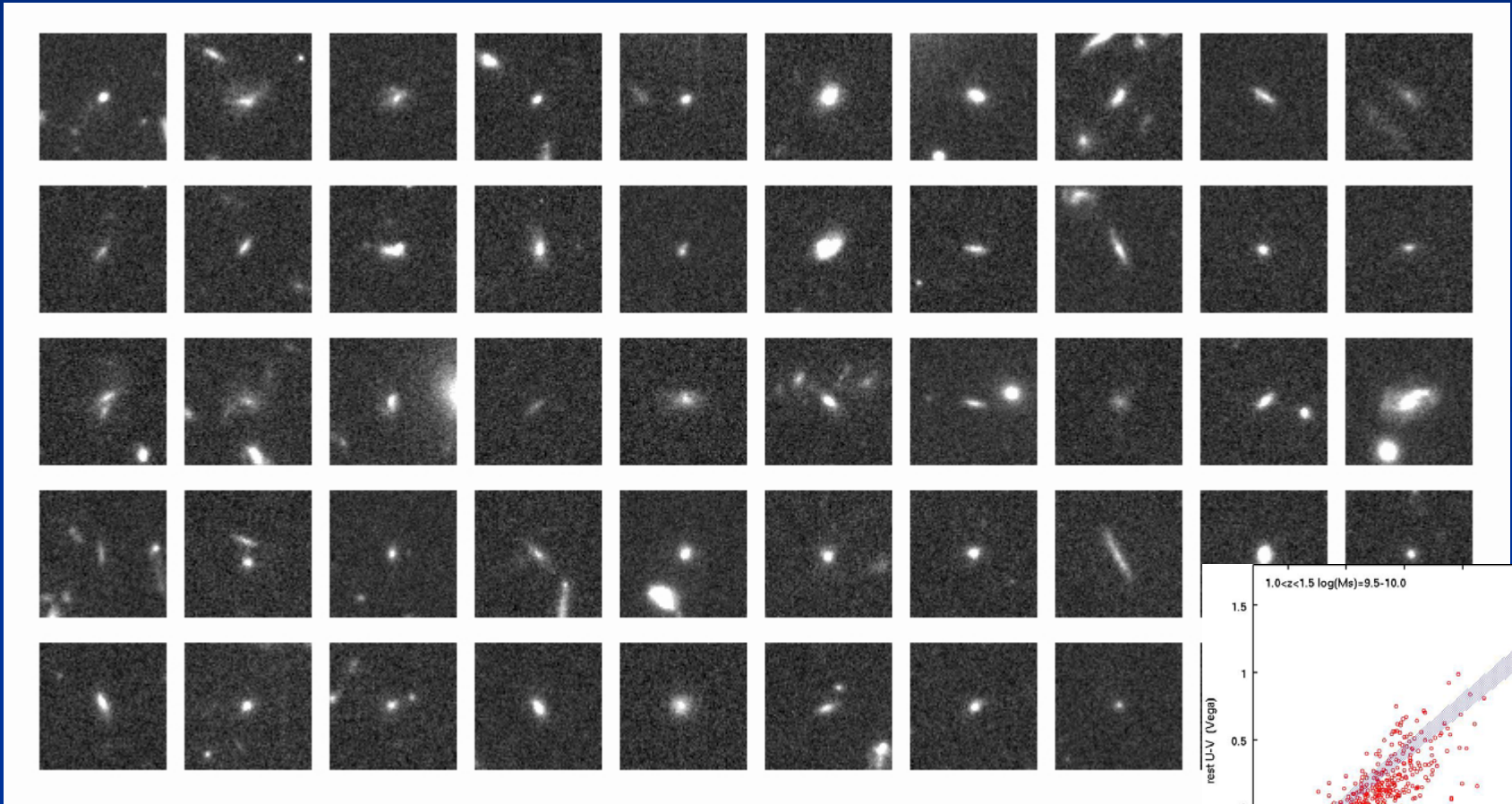
$1.0 < z < 1.5$

$\log(M_s) = 9.5 - 10$ $-11 < \log(\text{SSFR}) < -10$



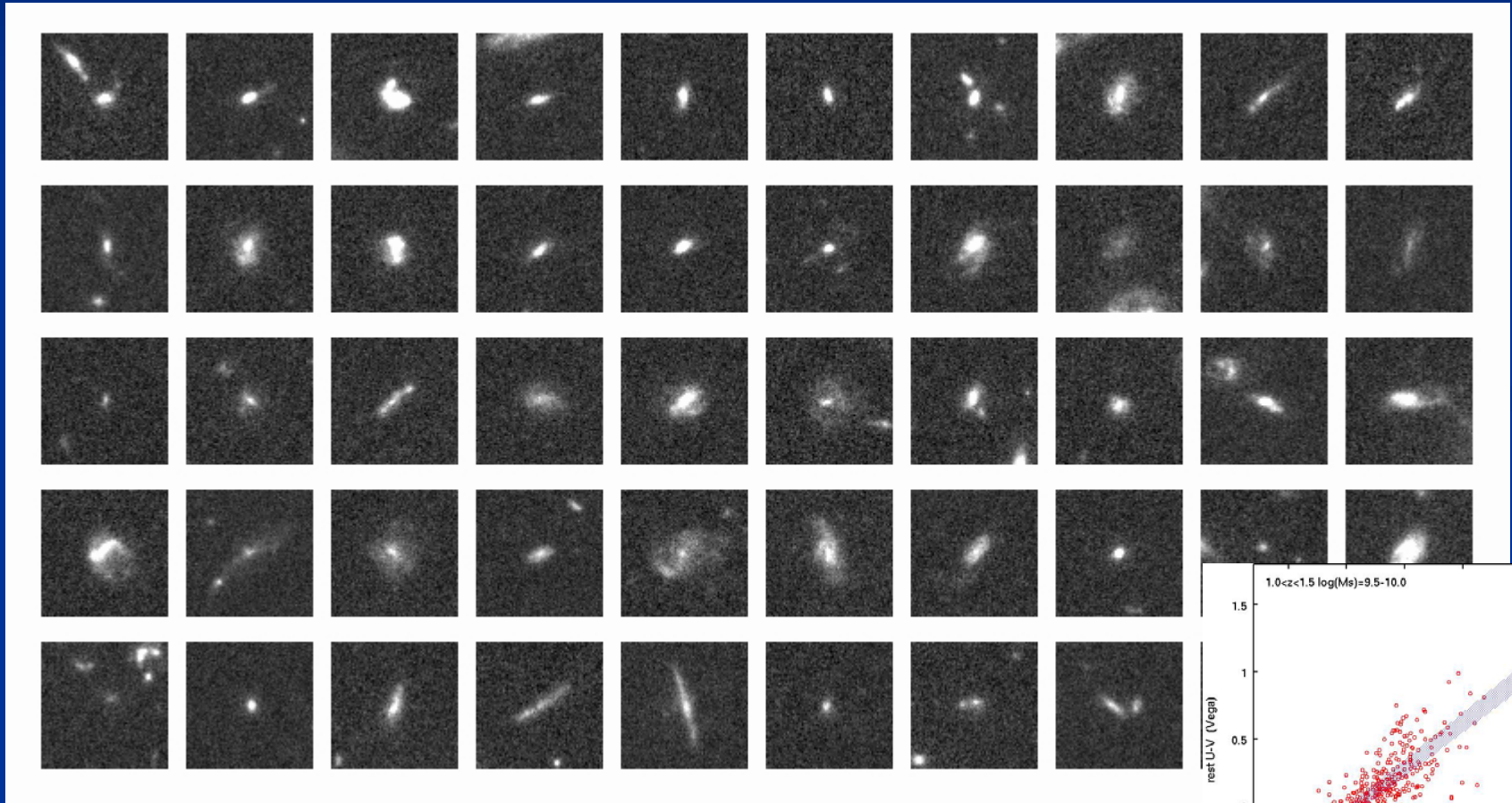
$1.0 < z < 1.5$

$\log(M_s) = 9.5 - 10$ $-10 < \log(SSFR) < -9.5$



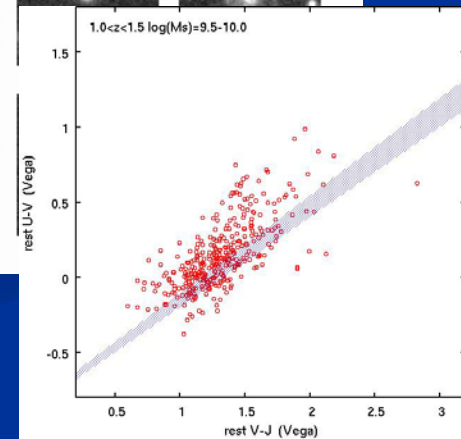
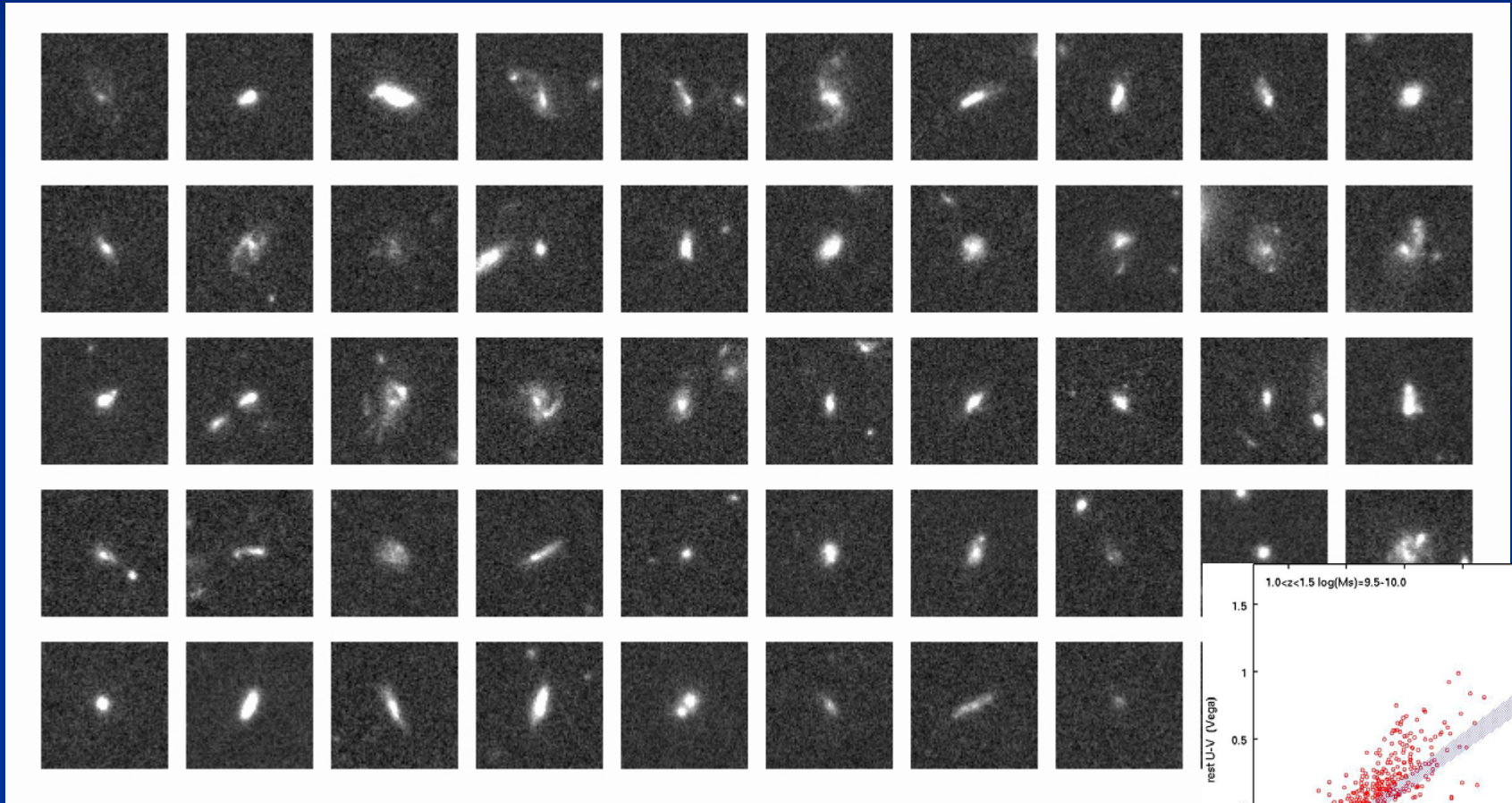
$1.0 < z < 1.5$

$\log(M_s) = 9.5 - 10$ $-9.5 < \log(\text{SSFR}) < -9$



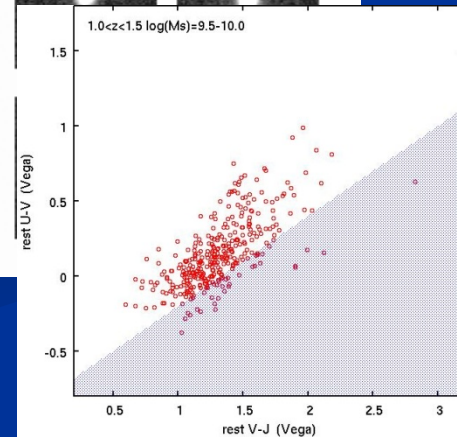
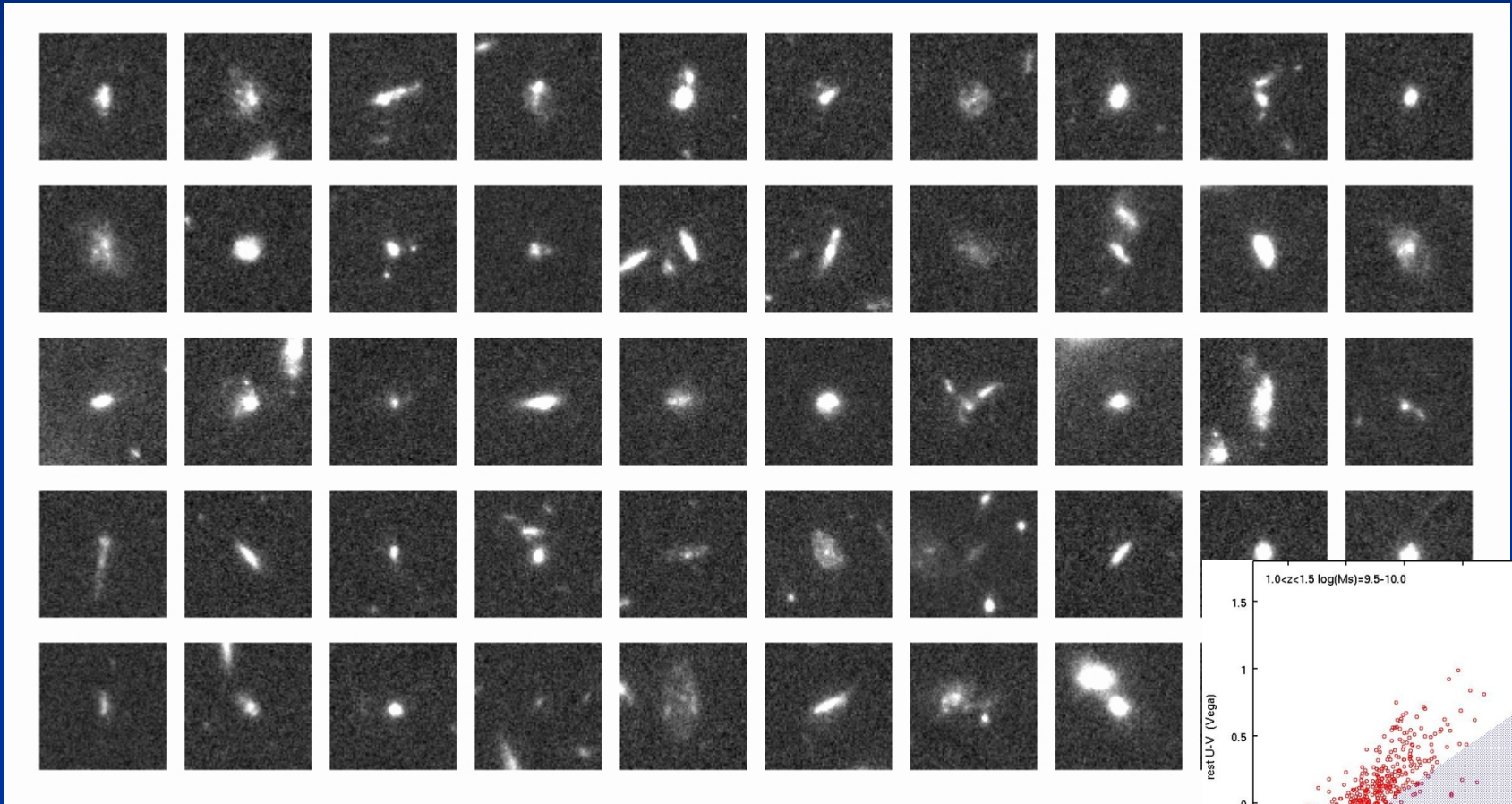
$1.0 < z < 1.5$

$\log(M_s) = 9.5 - 10$ $-9 < \log(\text{SSFR}) < -8.5$



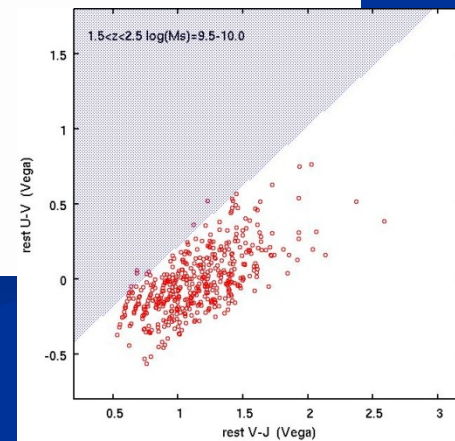
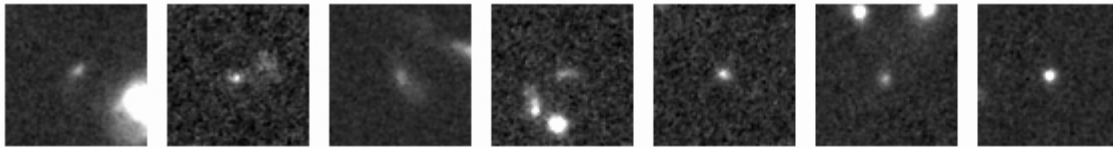
$1.0 < z < 1.5$

$\log(M_s) = 9.5 - 10$ $\log(SSFR) > -8.5$



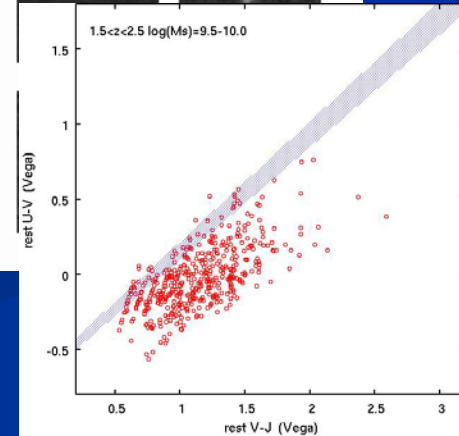
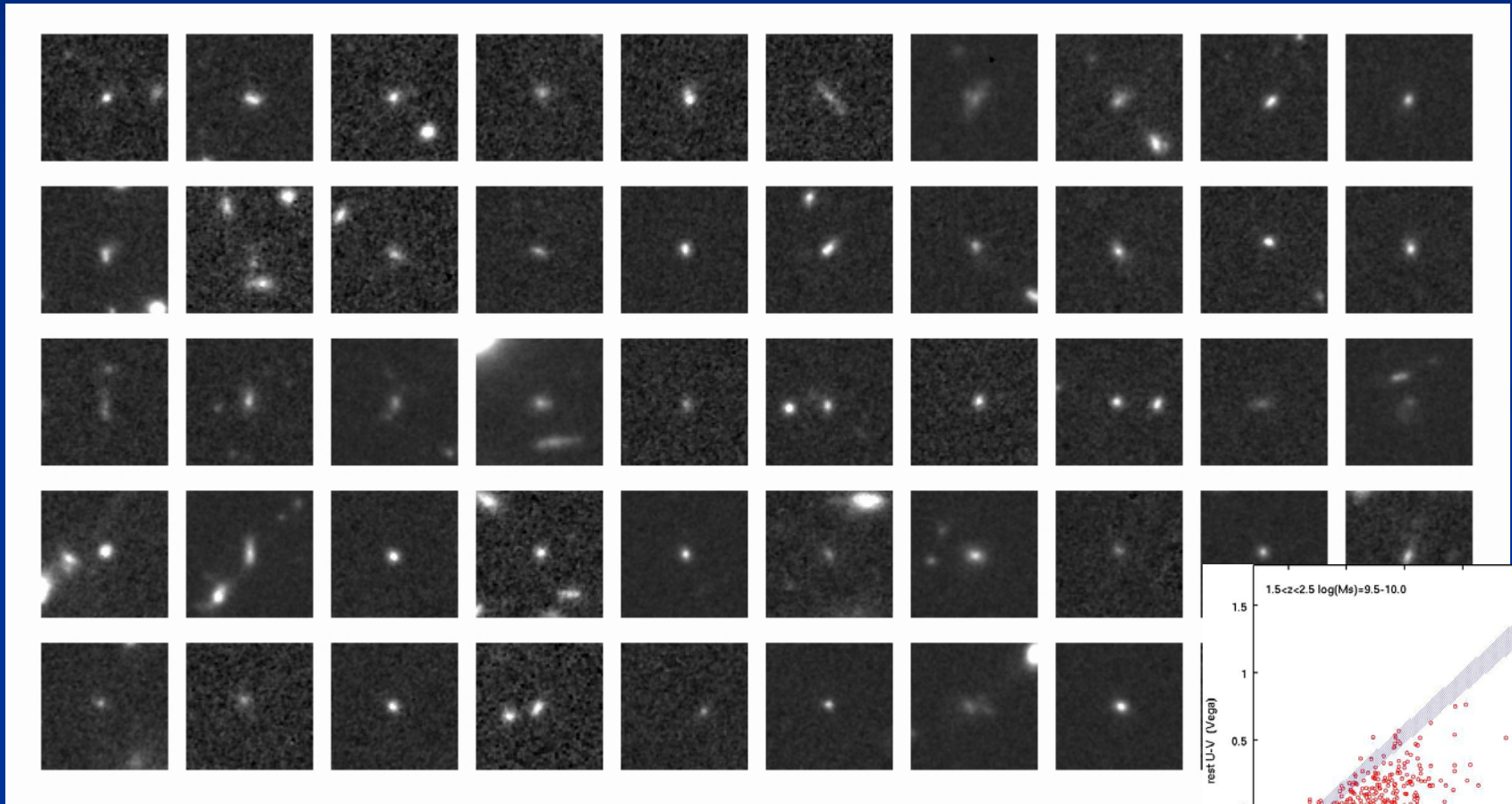
$1.5 < z < 2.5$

$\log(M_s) = 9.5 - 10$ $\log(\text{SSFR}) < -11$



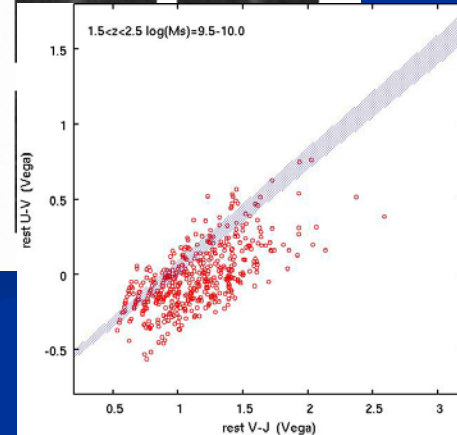
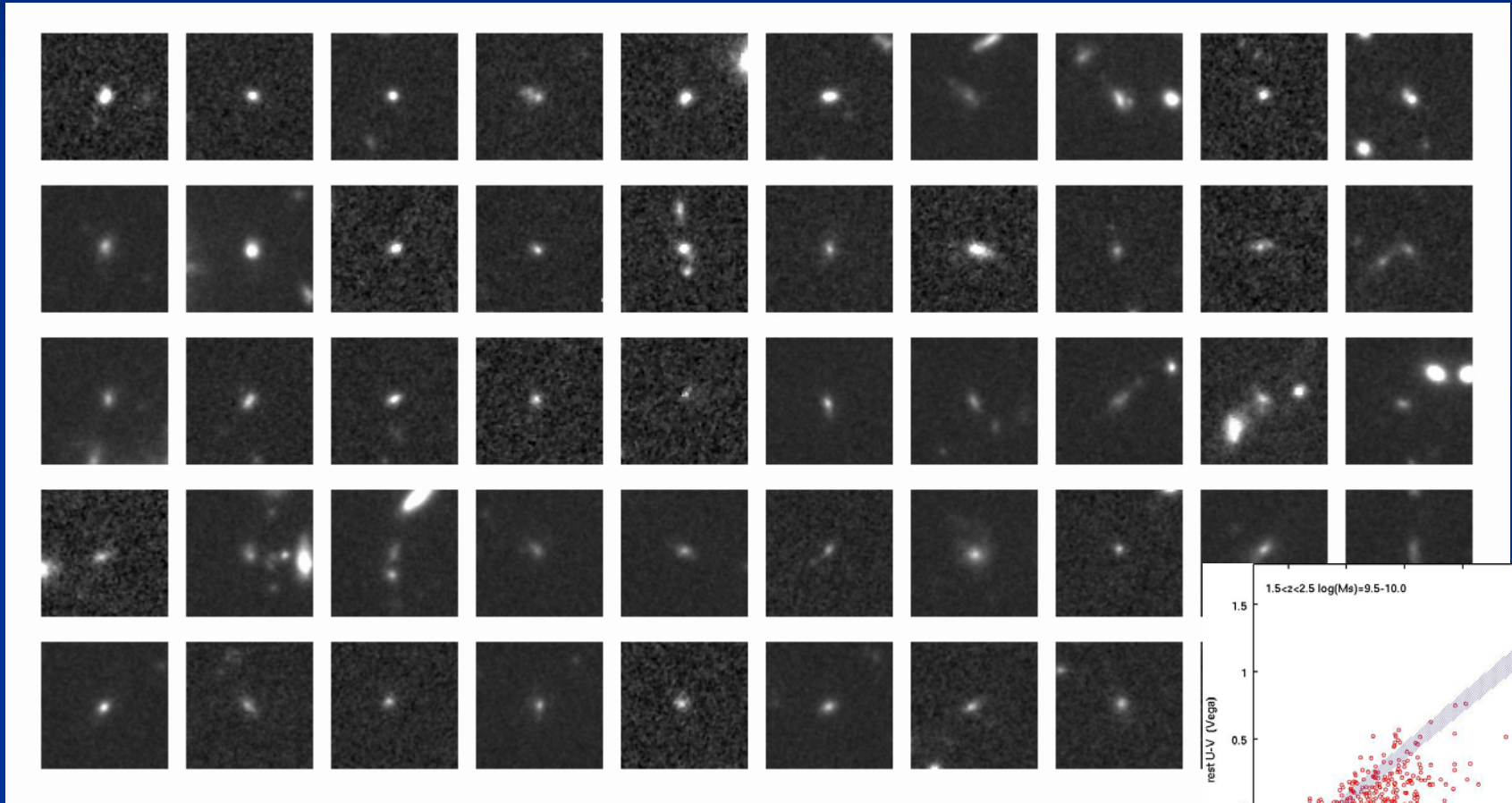
$1.5 < z < 2.5$

$\log(M_s) = 9.5 - 10$ $-11 < \log(\text{SSFR}) < -10$



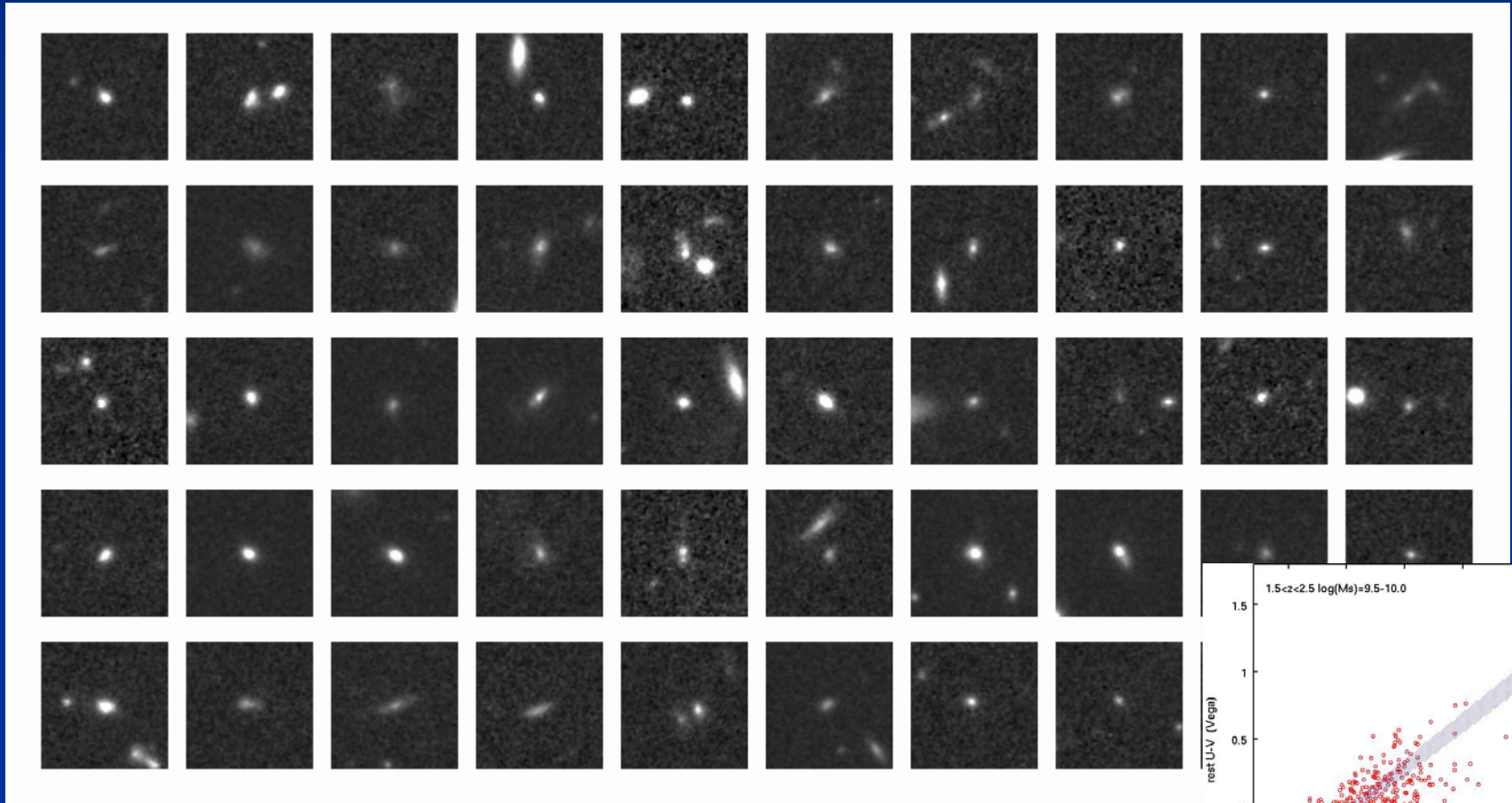
$1.5 < z < 2.5$

$\log(M_s) = 9.5 - 10$ $-10 < \log(\text{SSFR}) < -9.5$



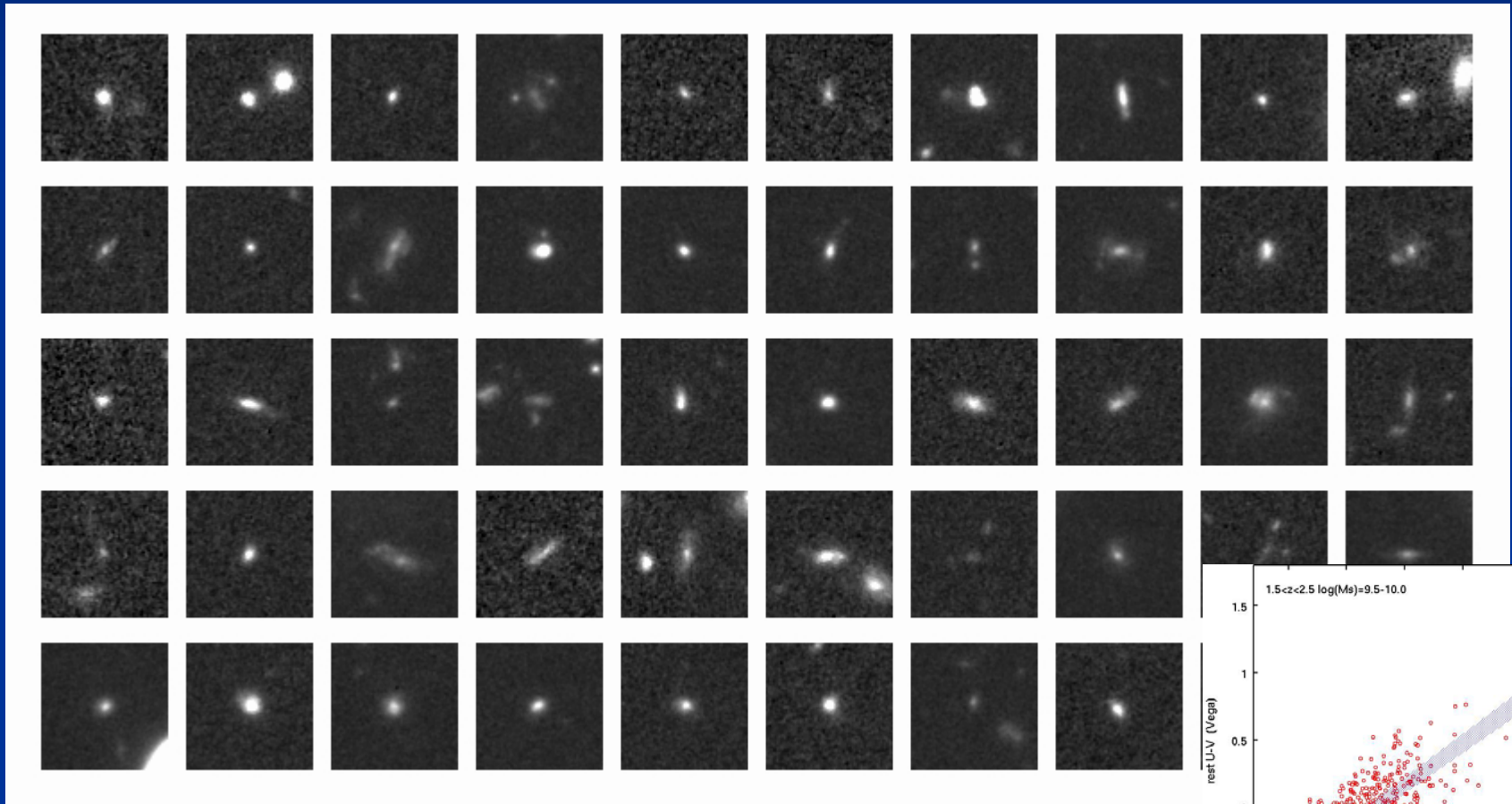
$1.5 < z < 2.5$

$\log(M_s) = 9.5 - 10$ $-9.5 < \log(\text{SSFR}) < -9$



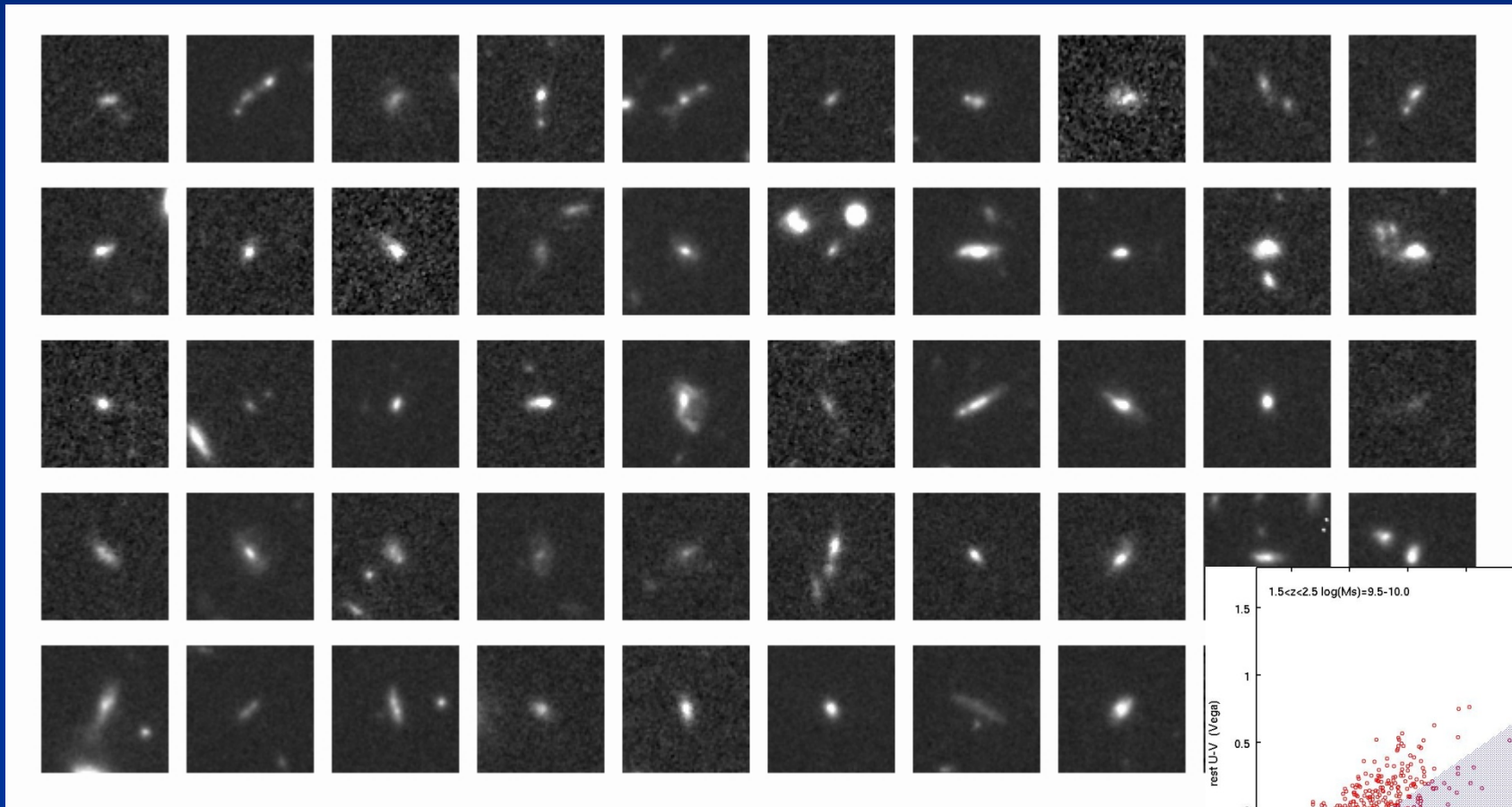
$1.5 < z < 2.5$

$\log(M_s) = 9.5 - 10$ $-9 < \log(\text{SSFR}) < -8.5$



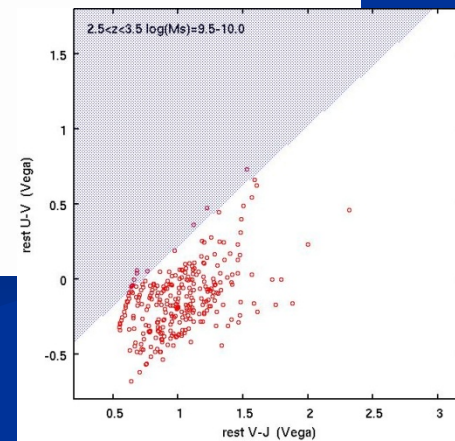
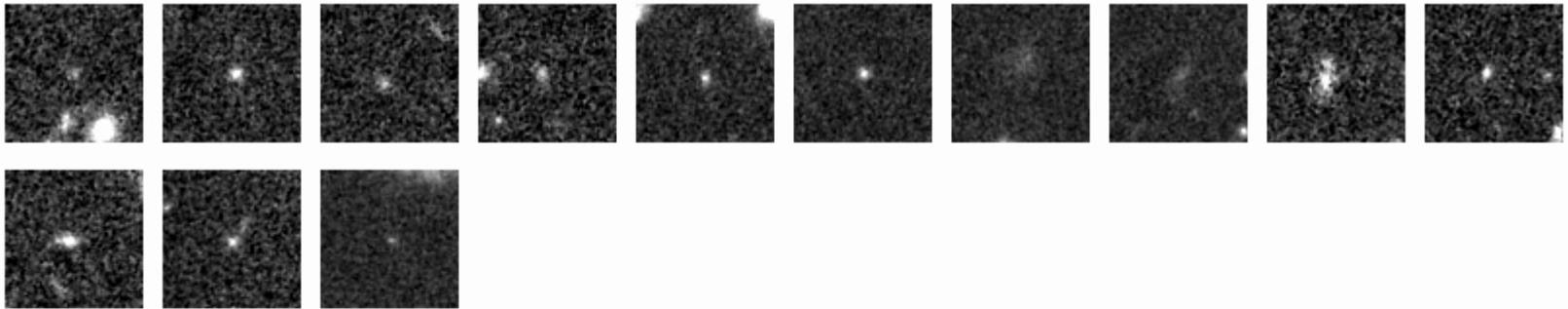
$1.5 < z < 2.5$

$\log(M_s) = 9.5 - 10$ $\log(\text{SSFR}) > -8.5$



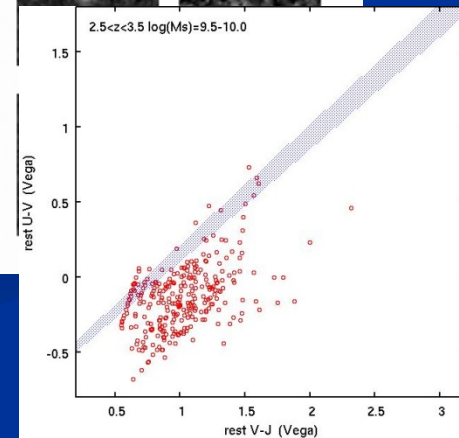
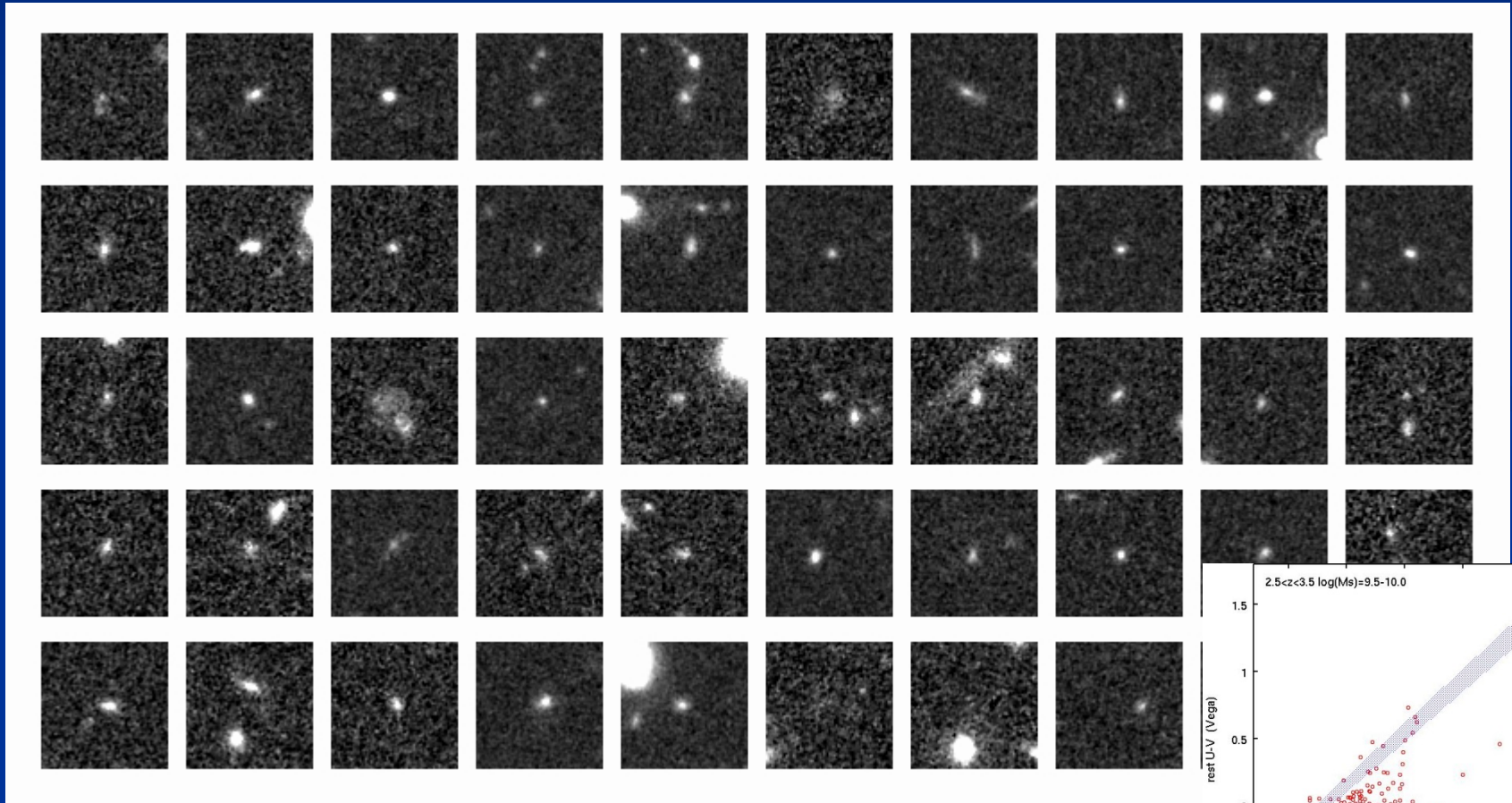
$2.5 < z < 3.5$

$\log(M_s) = 9.5 - 10$ $\log(SSFR) < -11$



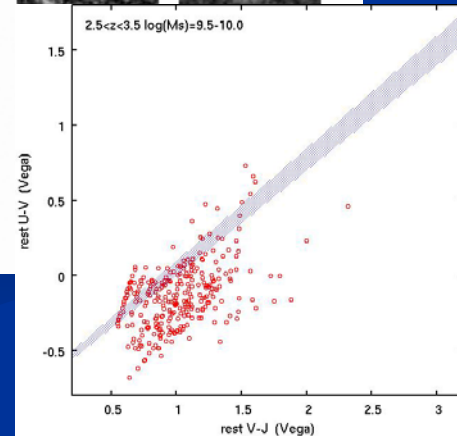
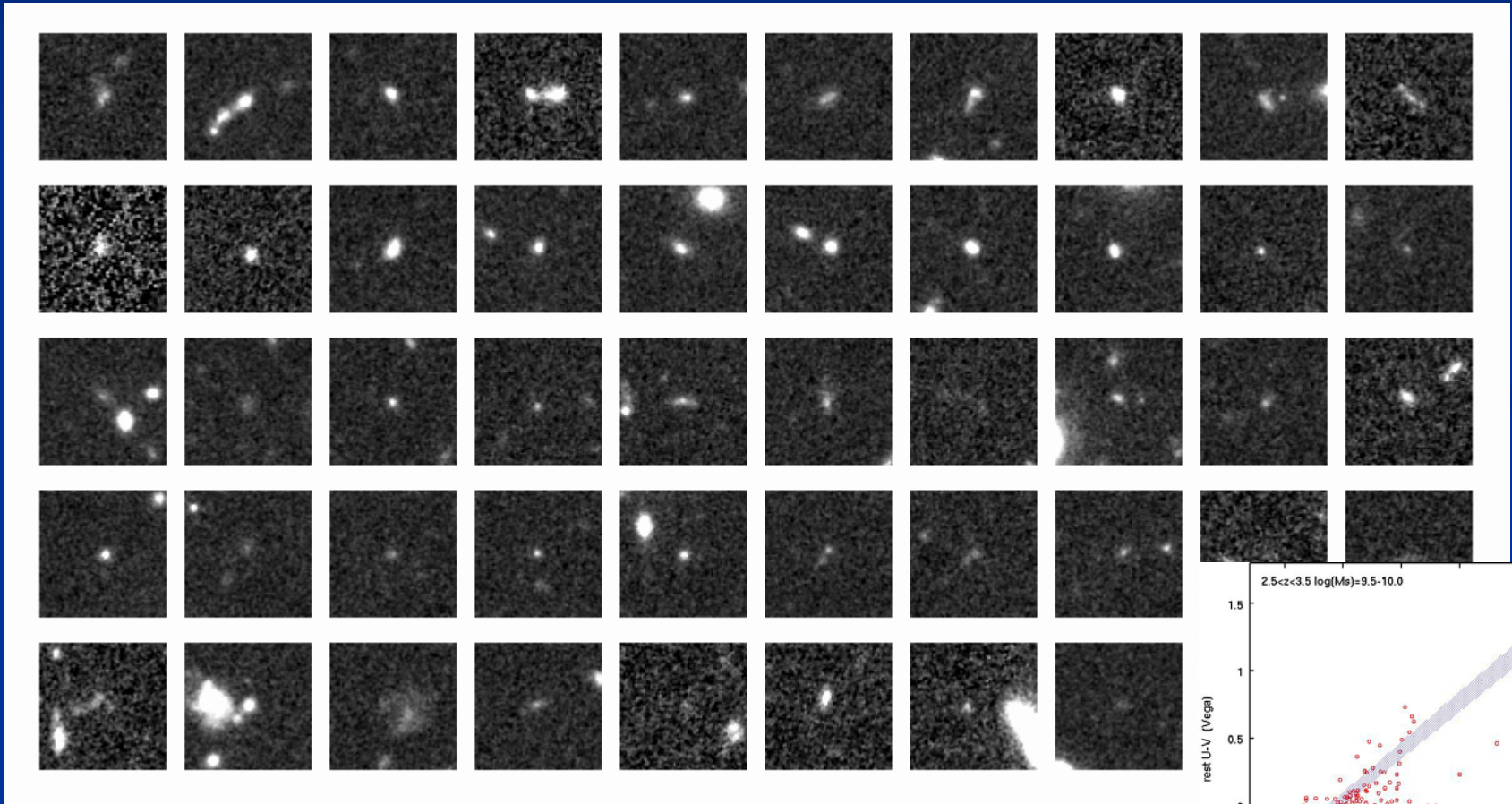
$2.5 < z < 3.5$

$\log(M_s) = 9.5 - 10$ $-11 < \log(\text{SSFR}) < -10$



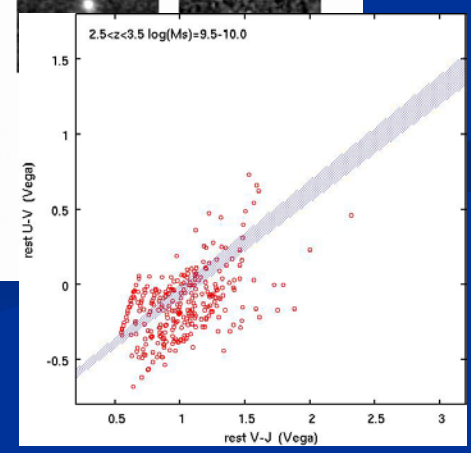
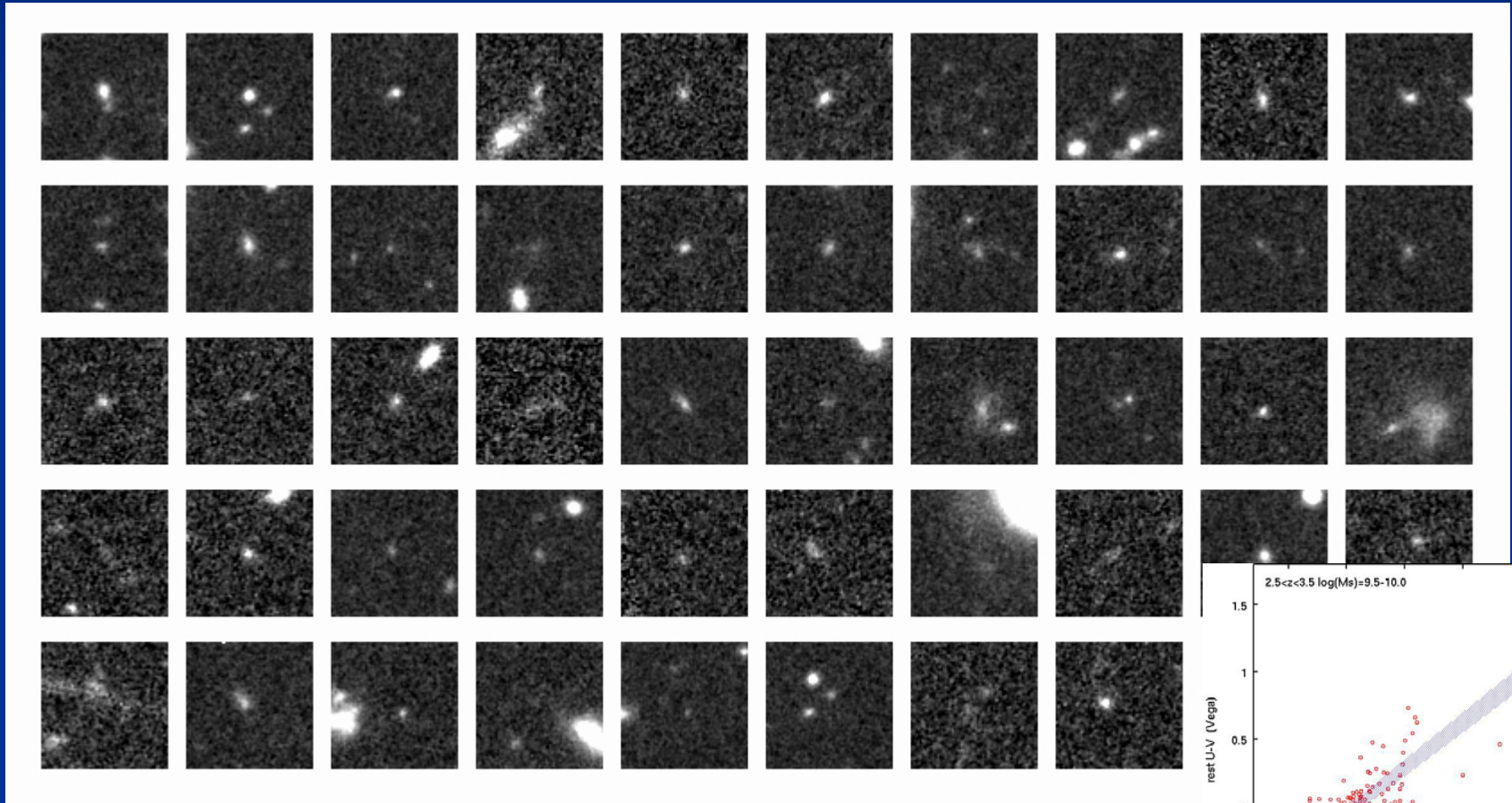
$2.5 < z < 3.5$

$\log(M_s) = 9.5 - 10$ $-10 < \log(SSFR) < -9.5$



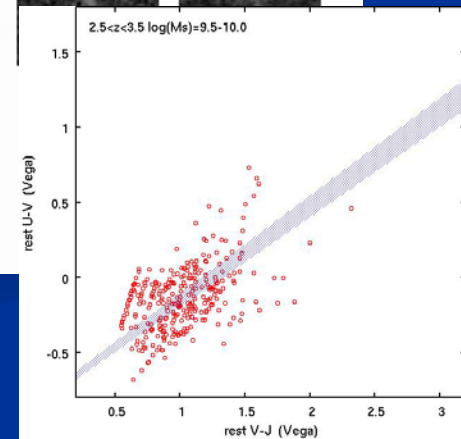
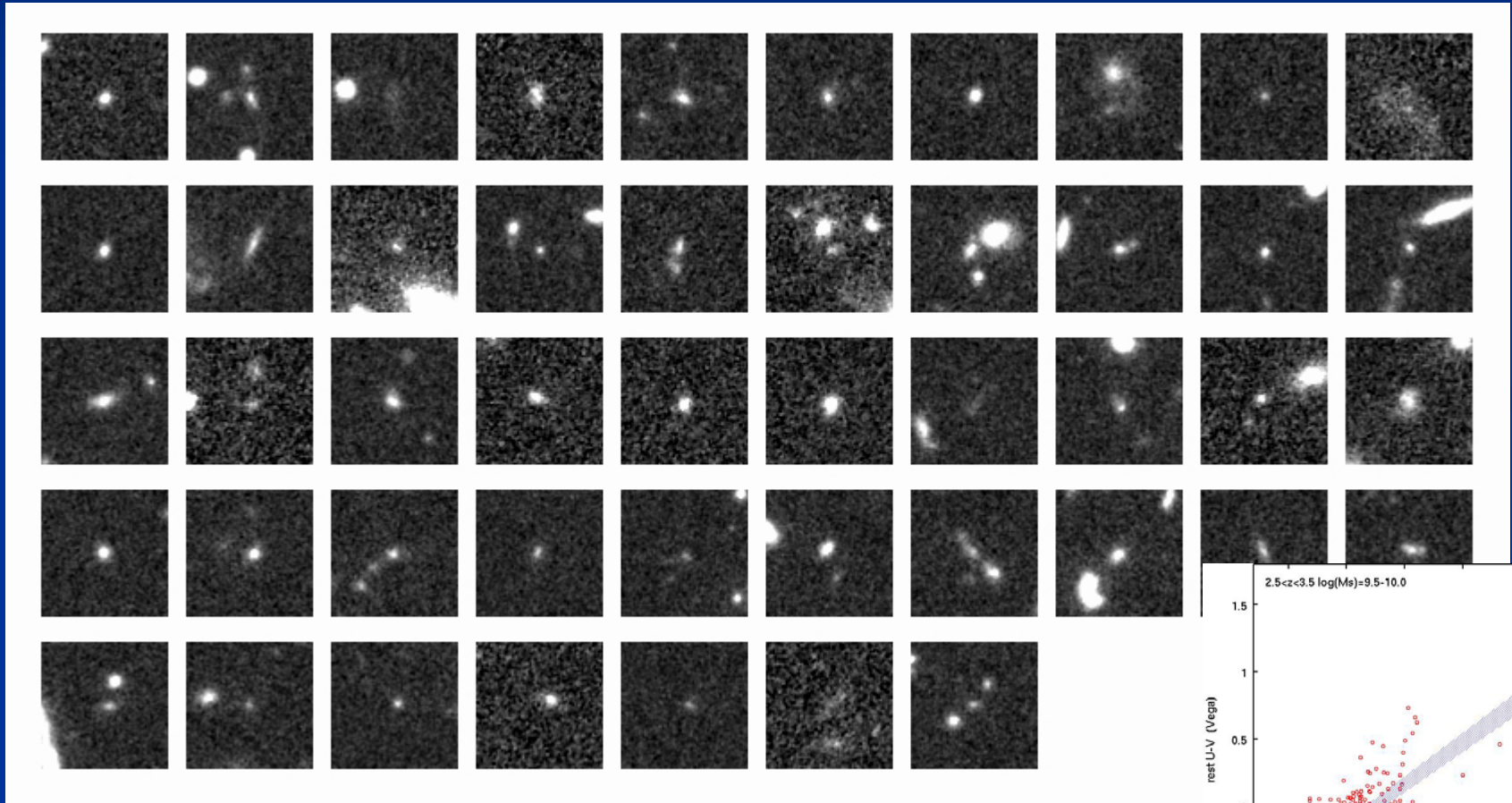
$2.5 < z < 3.5$

$\log(M_s) = 9.5 - 10$ $-9.5 < \log(\text{SSFR}) < -9$



$2.5 < z < 3.5$

$\log(M_s) = 9.5 - 10$ $-9 < \log(\text{SSFR}) < -8.5$



$2.5 < z < 3.5$

$\log(M_s) = 9.5 - 10$ $\log(\text{SSFR}) > -8.5$

