```python
import os
import re
import glob

import h5py
import numpy as np
import pandas as pd

import matplotlib.pyplot as plt
from matplotlib.colors import LogNorm
from matplotlib.lines import Line2D
import seaborn as sns

from sklearn.model_selection import train_test_split, GridSearchCV,
cross_val_score
from sklearn.preprocessing import StandardScaler
from sklearn.metrics import (
    classification_report,
    confusion_matrix,
    mean_squared_error,
    mean_absolute_error,
    r2_score,
    f1_score
)
from sklearn.ensemble import RandomForestClassifier,
RandomForestRegressor
from sklearn.neural_network import MLPClassifier, MLPRegressor
from sklearn.tree import export_graphviz
from graphviz import Source

plt.rcParams.update({
    "font.family": "serif",
    "font.size": 10,
    "axes.labelsize": 10,
    "axes.titlesize": 10,
    "xtick.labelsize": 10,
    "ytick.labelsize": 10,
})
```

1.

Exploración de los datos

```python
f = h5py.File("Datos/fof_subhalo_tab_099.0.hdf5", "r")

pos = np.array(f["Subhalo/SubhaloPos"][:])
sfr = np.array(f["Subhalo/SubhaloSFR"][:])
ids = np.array(f["Subhalo/SubhaloIDMostbound"][:])
```

```python
# DataFrame de ejemplo
ex = pd.DataFrame({
    "ID": ids,
    "SFR": sfr,
    "X": pos[:, 0],
    "Y": pos[:, 1],
    "Z": pos[:, 2],
})
for key in f['Subhalo'].keys():
    if key not in ["SubhaloPos", "SubhaloSFR", "SubhaloIDMostbound"]:
        # Revisar dimensiones
        if len(f['Subhalo'][key][:].shape) == 1:
            data = np.array(f['Subhalo'][key][:])
            col_name = key.split("Subhalo")[-1]
            ex[col_name] = data
        else:
            print(f"⚠  {key}, {f['Subhalo'][key][:].shape[1]}D data")
```

```
⚠  SubhaloCM, 3D data
⚠  SubhaloGasMetalFractions, 10D data
⚠  SubhaloGasMetalFractionsHalfRad, 10D data
⚠  SubhaloGasMetalFractionsMaxRad, 10D data
⚠  SubhaloGasMetalFractionsSfr, 10D data
⚠  SubhaloGasMetalFractionsSfrWeighted, 10D data
⚠  SubhaloHalfmassRadType, 6D data
⚠  SubhaloLenType, 6D data
⚠  SubhaloMassInHalfRadType, 6D data
⚠  SubhaloMassInMaxRadType, 6D data
⚠  SubhaloMassInRadType, 6D data
⚠  SubhaloMassType, 6D data
⚠  SubhaloSpin, 3D data
⚠  SubhaloStarMetalFractions, 10D data
⚠  SubhaloStarMetalFractionsHalfRad, 10D data
⚠  SubhaloStarMetalFractionsMaxRad, 10D data
⚠  SubhaloStellarPhotometrics, 8D data
⚠  SubhaloVel, 3D data
```

a)

```python
# Ordenamos archivos por índice numérico
def numeric_index(path):
    return int(re.findall(r'\.(\d+)\.hdf5$', path)[0])


files = glob.glob("Datos/fof_subhalo_tab_099.*.hdf5")
files = sorted(files, key=numeric_index)

all_fields = set()
```

```python
for fpath in files:
    with h5py.File(fpath, "r") as f:
        if "Subhalo" in f:
            for key in f["Subhalo"].keys():
                all_fields.add(key)

all_fields = sorted(all_fields)
print("Campos encontrados:", all_fields)

data_chunks = {field: [] for field in all_fields}

for fpath in files:
    with h5py.File(fpath, "r") as f:
        if "Subhalo" not in f:
            continue

        g = f["Subhalo"]
        keys = list(g.keys())

        if len(keys) == 0:
            print(f"[WARNING] Subhalo vacio en: {fpath}, saltando.")
            continue

        ref_field = keys[0]
        nrows = len(g[ref_field])

        for field in all_fields:
            if field in g:
                data_chunks[field].append(g[field][:])
            else:
                arr = g[ref_field]
                if arr.ndim == 1:
                    missing = np.full(nrows, np.nan)
                else:
                    missing = np.full((nrows, arr.shape[1]), np.nan)

                data_chunks[field].append(missing)



# Juntar todos los fragmentos
final_data = {}
for field, chunks in data_chunks.items():
    final_data[field] = np.concatenate(chunks)
```

```
Campos encontrados: ['SubhaloBHMass', 'SubhaloBHMdot',
'SubhaloBfldDisk', 'SubhaloBfldHalo', 'SubhaloCM', 'SubhaloFlag',
'SubhaloGasMetalFractions', 'SubhaloGasMetalFractionsHalfRad',
'SubhaloGasMetalFractionsMaxRad', 'SubhaloGasMetalFractionsSfr',
'SubhaloGasMetalFractionsSfrWeighted', 'SubhaloGasMetallicity',
'SubhaloGasMetallicityHalfRad', 'SubhaloGasMetallicityMaxRad',
```

```
'SubhaloGasMetallicitySfr', 'SubhaloGasMetallicitySfrWeighted',
'SubhaloGrNr', 'SubhaloHalfmassRad', 'SubhaloHalfmassRadType',
'SubhaloIDMostbound', 'SubhaloLen', 'SubhaloLenType', 'SubhaloMass',
'SubhaloMassInHalfRad', 'SubhaloMassInHalfRadType',
'SubhaloMassInMaxRad', 'SubhaloMassInMaxRadType', 'SubhaloMassInRad',
'SubhaloMassInRadType', 'SubhaloMassType', 'SubhaloParent',
'SubhaloPos', 'SubhaloSFR', 'SubhaloSFRinHalfRad',
'SubhaloSFRinMaxRad', 'SubhaloSFRinRad', 'SubhaloSpin',
'SubhaloStarMetalFractions', 'SubhaloStarMetalFractionsHalfRad',
'SubhaloStarMetalFractionsMaxRad', 'SubhaloStarMetallicity',
'SubhaloStarMetallicityHalfRad', 'SubhaloStarMetallicityMaxRad',
'SubhaloStellarPhotometrics', 'SubhaloStellarPhotometricsMassInRad',
'SubhaloStellarPhotometricsRad', 'SubhaloVel', 'SubhaloVelDisp',
'SubhaloVmax', 'SubhaloVmaxRad', 'SubhaloWindMass']
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.1.hdf5,
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saltando.
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.3.hdf5,
saltando.
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.4.hdf5,
saltando.
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saltando.
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saltando.
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.182.hdf5,
saltando.
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.183.hdf5,
saltando.
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.185.hdf5,
saltando.
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.186.hdf5,
saltando.
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.187.hdf5,
saltando.
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.189.hdf5,
saltando.
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.190.hdf5,
saltando.
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.191.hdf5,
saltando.
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.193.hdf5,
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saltando.
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.198.hdf5,
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[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.215.hdf5,
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[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.218.hdf5,
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[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.227.hdf5,
saltando.
[WARNING] Subhalo vacio en: Datos/fof_subhalo_tab_099.233.hdf5,
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```

```python
# Construir DataFrame final
df = pd.DataFrame()

for field, arr in final_data.items():

    if arr.ndim == 1:
        df[field] = arr

    else:
        for i in range(arr.shape[1]):
            df[f"{field}_{i}"] = arr[:, i]


# Definimos IDs Subfind
df["SubhaloID"] = np.arange(len(df))

print(df.head())
print(df.shape)
```

```
/tmp/ipykernel_1726671/2860032548.py:11: PerformanceWarning: DataFrame
is highly fragmented.  This is usually the result of calling
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joining all columns at once using pd.concat(axis=1) instead. To get a
de-fragmented frame, use `newframe = frame.copy()`
  df[field] = arr
```

```
/tmp/ipykernel_1726671/2860032548.py:11: PerformanceWarning: DataFrame
is highly fragmented.  This is usually the result of calling
`frame.insert` many times, which has poor performance.  Consider
joining all columns at once using pd.concat(axis=1) instead. To get a
de-fragmented frame, use `newframe = frame.copy()`
  df[f"{field}_{i}"] = arr[:, i]
/tmp/ipykernel_1726671/2860032548.py:11: PerformanceWarning: DataFrame
is highly fragmented.  This is usually the result of calling
`frame.insert` many times, which has poor performance.  Consider
joining all columns at once using pd.concat(axis=1) instead. To get a
de-fragmented frame, use `newframe = frame.copy()`
  df[f"{field}_{i}"] = arr[:, i]
/tmp/ipykernel_1726671/2860032548.py:11: PerformanceWarning: DataFrame
is highly fragmented.  This is usually the result of calling
`frame.insert` many times, which has poor performance.  Consider
joining all columns at once using pd.concat(axis=1) instead. To get a
de-fragmented frame, use `newframe = frame.copy()`
  df[f"{field}_{i}"] = arr[:, i]
/tmp/ipykernel_1726671/2860032548.py:7: PerformanceWarning: DataFrame
is highly fragmented.  This is usually the result of calling
`frame.insert` many times, which has poor performance.  Consider
joining all columns at once using pd.concat(axis=1) instead. To get a
de-fragmented frame, use `newframe = frame.copy()`
  df[field] = arr
/tmp/ipykernel_1726671/2860032548.py:7: PerformanceWarning: DataFrame
is highly fragmented.  This is usually the result of calling
`frame.insert` many times, which has poor performance.  Consider
joining all columns at once using pd.concat(axis=1) instead. To get a
de-fragmented frame, use `newframe = frame.copy()`
  df[field] = arr
/tmp/ipykernel_1726671/2860032548.py:7: PerformanceWarning: DataFrame
is highly fragmented.  This is usually the result of calling
`frame.insert` many times, which has poor performance.  Consider
joining all columns at once using pd.concat(axis=1) instead. To get a
de-fragmented frame, use `newframe = frame.copy()`
  df[field] = arr
/tmp/ipykernel_1726671/2860032548.py:7: PerformanceWarning: DataFrame
is highly fragmented.  This is usually the result of calling
`frame.insert` many times, which has poor performance.  Consider
joining all columns at once using pd.concat(axis=1) instead. To get a
de-fragmented frame, use `newframe = frame.copy()`
  df[field] = arr
```

```
   SubhaloBHMass  SubhaloBHMdot  SubhaloBfldDisk  SubhaloBfldHalo  \
0       0.579029   1.852354e-04         2.008474         0.172786
1       0.054223   1.516171e-05         0.068316         0.069231
2       0.029711   2.138259e-06         0.134068         0.303128
3       0.020092   7.053461e-06         0.065826         0.120497
4       0.019615   3.058788e-07         0.817195         0.807718
```

```
   SubhaloCM_0   SubhaloCM_1   SubhaloCM_2  SubhaloFlag  \
0  7300.426270  24514.015625  21300.208984         True
1  6812.355469  24896.800781  21219.810547         True
2  6780.131348  23867.488281  21088.685547         True
3  7322.278809  25125.027344  20773.980469         True
4  7635.023438  24392.828125  21199.900391         True

   SubhaloGasMetalFractions_0  SubhaloGasMetalFractions_1  ...  \
0                    0.740028                    0.250430  ...
1                    0.680867                    0.277670  ...
2                    0.697962                    0.271066  ...
3                    0.680394                    0.276450  ...
4                    0.698260                    0.268986  ...

   SubhaloStellarPhotometricsMassInRad  SubhaloStellarPhotometricsRad
\
0                           249.120911                      47.998219

1                            21.635269                      13.419003

2                             9.841280                       9.637778

3                             5.365546                       5.830610

4                             5.449239                       5.833010


   SubhaloVel_0  SubhaloVel_1  SubhaloVel_2  SubhaloVelDisp
SubhaloVmax  \
0     14.129664      2.131469    -39.024796      501.291901
1093.472534
1    539.075134   -504.031250   -151.045761      212.091843
536.155640
2    266.607758    547.416016    838.099792      154.111832
354.704529
3   -235.743912   -496.904572    -93.513161      142.501022
367.130646
4    211.173889   -703.205444   -483.650330      158.472092
365.420197

   SubhaloVmaxRad  SubhaloWindMass  SubhaloID
0        0.020865         0.011895          0
1        1.107249         0.000000          1
2        0.863242         0.000000          2
3        0.949245         0.000000          3
4        1.008757         0.000000          4

[5 rows x 169 columns]
(5688113, 169)
```

```
/tmp/ipykernel_1726671/2860032548.py:15: PerformanceWarning: DataFrame
is highly fragmented.  This is usually the result of calling
`frame.insert` many times, which has poor performance.  Consider
joining all columns at once using pd.concat(axis=1) instead. To get a
de-fragmented frame, use `newframe = frame.copy()`
  df["SubhaloID"] = np.arange(len(df))
```

b)

```python
print("Total de propiedades:", len(df.columns))
for p in df.columns:
    print(p)
```

```
Total de propiedades: 169
SubhaloBHMass
SubhaloBHMdot
SubhaloBfldDisk
SubhaloBfldHalo
SubhaloCM_0
SubhaloCM_1
SubhaloCM_2
SubhaloFlag
SubhaloGasMetalFractions_0
SubhaloGasMetalFractions_1
SubhaloGasMetalFractions_2
SubhaloGasMetalFractions_3
SubhaloGasMetalFractions_4
SubhaloGasMetalFractions_5
SubhaloGasMetalFractions_6
SubhaloGasMetalFractions_7
SubhaloGasMetalFractions_8
SubhaloGasMetalFractions_9
SubhaloGasMetalFractionsHalfRad_0
SubhaloGasMetalFractionsHalfRad_1
SubhaloGasMetalFractionsHalfRad_2
SubhaloGasMetalFractionsHalfRad_3
SubhaloGasMetalFractionsHalfRad_4
SubhaloGasMetalFractionsHalfRad_5
SubhaloGasMetalFractionsHalfRad_6
SubhaloGasMetalFractionsHalfRad_7
SubhaloGasMetalFractionsHalfRad_8
SubhaloGasMetalFractionsHalfRad_9
SubhaloGasMetalFractionsMaxRad_0
SubhaloGasMetalFractionsMaxRad_1
SubhaloGasMetalFractionsMaxRad_2
SubhaloGasMetalFractionsMaxRad_3
SubhaloGasMetalFractionsMaxRad_4
SubhaloGasMetalFractionsMaxRad_5
SubhaloGasMetalFractionsMaxRad_6
```

```
SubhaloGasMetalFractionsMaxRad_7
SubhaloGasMetalFractionsMaxRad_8
SubhaloGasMetalFractionsMaxRad_9
SubhaloGasMetalFractionsSfr_0
SubhaloGasMetalFractionsSfr_1
SubhaloGasMetalFractionsSfr_2
SubhaloGasMetalFractionsSfr_3
SubhaloGasMetalFractionsSfr_4
SubhaloGasMetalFractionsSfr_5
SubhaloGasMetalFractionsSfr_6
SubhaloGasMetalFractionsSfr_7
SubhaloGasMetalFractionsSfr_8
SubhaloGasMetalFractionsSfr_9
SubhaloGasMetalFractionsSfrWeighted_0
SubhaloGasMetalFractionsSfrWeighted_1
SubhaloGasMetalFractionsSfrWeighted_2
SubhaloGasMetalFractionsSfrWeighted_3
SubhaloGasMetalFractionsSfrWeighted_4
SubhaloGasMetalFractionsSfrWeighted_5
SubhaloGasMetalFractionsSfrWeighted_6
SubhaloGasMetalFractionsSfrWeighted_7
SubhaloGasMetalFractionsSfrWeighted_8
SubhaloGasMetalFractionsSfrWeighted_9
SubhaloGasMetallicity
SubhaloGasMetallicityHalfRad
SubhaloGasMetallicityMaxRad
SubhaloGasMetallicitySfr
SubhaloGasMetallicitySfrWeighted
SubhaloGrNr
SubhaloHalfmassRad
SubhaloHalfmassRadType_0
SubhaloHalfmassRadType_1
SubhaloHalfmassRadType_2
SubhaloHalfmassRadType_3
SubhaloHalfmassRadType_4
SubhaloHalfmassRadType_5
SubhaloIDMostbound
SubhaloLen
SubhaloLenType_0
SubhaloLenType_1
SubhaloLenType_2
SubhaloLenType_3
SubhaloLenType_4
SubhaloLenType_5
SubhaloMass
SubhaloMassInHalfRad
SubhaloMassInHalfRadType_0
SubhaloMassInHalfRadType_1
SubhaloMassInHalfRadType_2
```

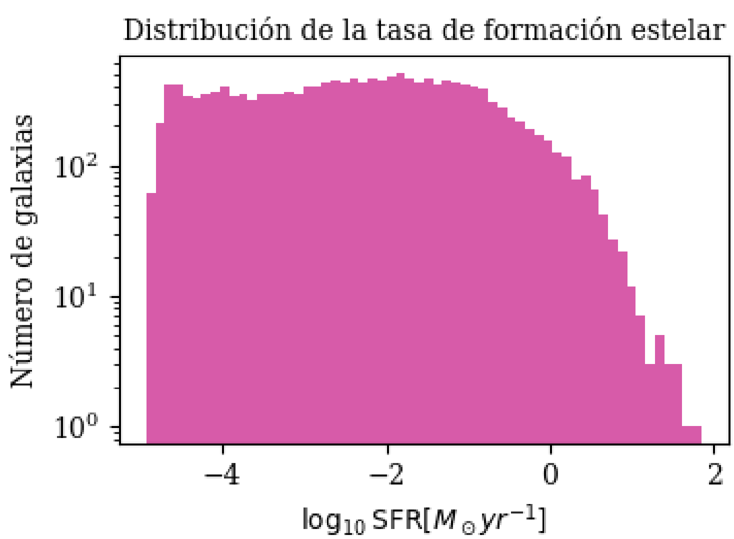
```
SubhaloMassInHalfRadType_3
SubhaloMassInHalfRadType_4
SubhaloMassInHalfRadType_5
SubhaloMassInMaxRad
SubhaloMassInMaxRadType_0
SubhaloMassInMaxRadType_1
SubhaloMassInMaxRadType_2
SubhaloMassInMaxRadType_3
SubhaloMassInMaxRadType_4
SubhaloMassInMaxRadType_5
SubhaloMassInRad
SubhaloMassInRadType_0
SubhaloMassInRadType_1
SubhaloMassInRadType_2
SubhaloMassInRadType_3
SubhaloMassInRadType_4
SubhaloMassInRadType_5
SubhaloMassType_0
SubhaloMassType_1
SubhaloMassType_2
SubhaloMassType_3
SubhaloMassType_4
SubhaloMassType_5
SubhaloParent
SubhaloPos_0
SubhaloPos_1
SubhaloPos_2
SubhaloSFR
SubhaloSFRinHalfRad
SubhaloSFRinMaxRad
SubhaloSFRinRad
SubhaloSpin_0
SubhaloSpin_1
SubhaloSpin_2
SubhaloStarMetalFractions_0
SubhaloStarMetalFractions_1
SubhaloStarMetalFractions_2
SubhaloStarMetalFractions_3
SubhaloStarMetalFractions_4
SubhaloStarMetalFractions_5
SubhaloStarMetalFractions_6
SubhaloStarMetalFractions_7
SubhaloStarMetalFractions_8
SubhaloStarMetalFractions_9
SubhaloStarMetalFractionsHalfRad_0
SubhaloStarMetalFractionsHalfRad_1
SubhaloStarMetalFractionsHalfRad_2
SubhaloStarMetalFractionsHalfRad_3
SubhaloStarMetalFractionsHalfRad_4
```

```
SubhaloStarMetalFractionsHalfRad_5
SubhaloStarMetalFractionsHalfRad_6
SubhaloStarMetalFractionsHalfRad_7
SubhaloStarMetalFractionsHalfRad_8
SubhaloStarMetalFractionsHalfRad_9
SubhaloStarMetalFractionsMaxRad_0
SubhaloStarMetalFractionsMaxRad_1
SubhaloStarMetalFractionsMaxRad_2
SubhaloStarMetalFractionsMaxRad_3
SubhaloStarMetalFractionsMaxRad_4
SubhaloStarMetalFractionsMaxRad_5
SubhaloStarMetalFractionsMaxRad_6
SubhaloStarMetalFractionsMaxRad_7
SubhaloStarMetalFractionsMaxRad_8
SubhaloStarMetalFractionsMaxRad_9
SubhaloStarMetallicity
SubhaloStarMetallicityHalfRad
SubhaloStarMetallicityMaxRad
SubhaloStellarPhotometrics_0
SubhaloStellarPhotometrics_1
SubhaloStellarPhotometrics_2
SubhaloStellarPhotometrics_3
SubhaloStellarPhotometrics_4
SubhaloStellarPhotometrics_5
SubhaloStellarPhotometrics_6
SubhaloStellarPhotometrics_7
SubhaloStellarPhotometricsMassInRad
SubhaloStellarPhotometricsRad
SubhaloVel_0
SubhaloVel_1
SubhaloVel_2
SubhaloVelDisp
SubhaloVmax
SubhaloVmaxRad
SubhaloWindMass
SubhaloID

# Columnas de interés
columns_keep = ['SubhaloGasMetallicity',
                'SubhaloMass',
                'SubhaloMassType_0',
                'SubhaloMassType_1',
                'SubhaloMassType_2',
                'SubhaloMassType_3',
                'SubhaloMassType_4',
                'SubhaloMassType_5',
                'SubhaloPos_0',
                'SubhaloPos_1',
                'SubhaloPos_2',
                'SubhaloSFR',
```

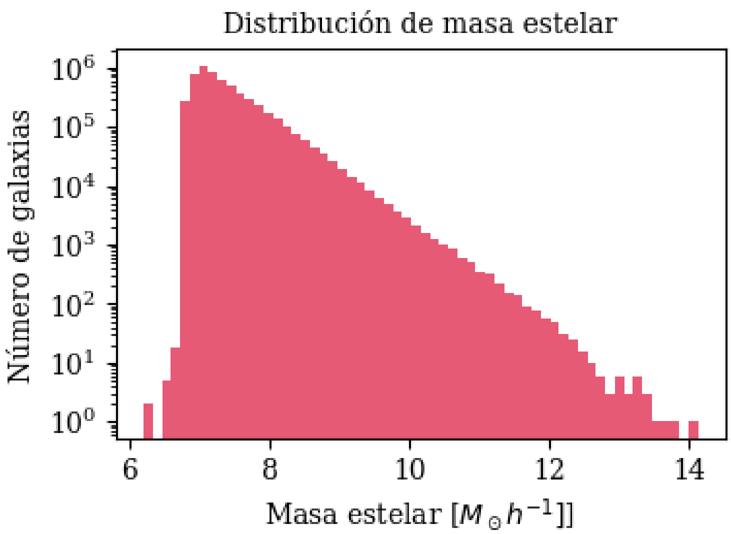
```
                'SubhaloSpin_0',
                'SubhaloSpin_1',
                'SubhaloSpin_2',
                'SubhaloStarMetallicity',
                'SubhaloVel_0',
                'SubhaloVel_1',
                'SubhaloVel_2',
                'SubhaloVelDisp',
                'SubhaloVmax',
                'SubhaloVmaxRad',
                'SubhaloWindMass',
                'SubhaloID'
                ]

# Quitamos subhalos con Flag = False
df = df[df['SubhaloFlag']]
df = df[[col for col in df.columns if col in columns_keep]]
```

c)

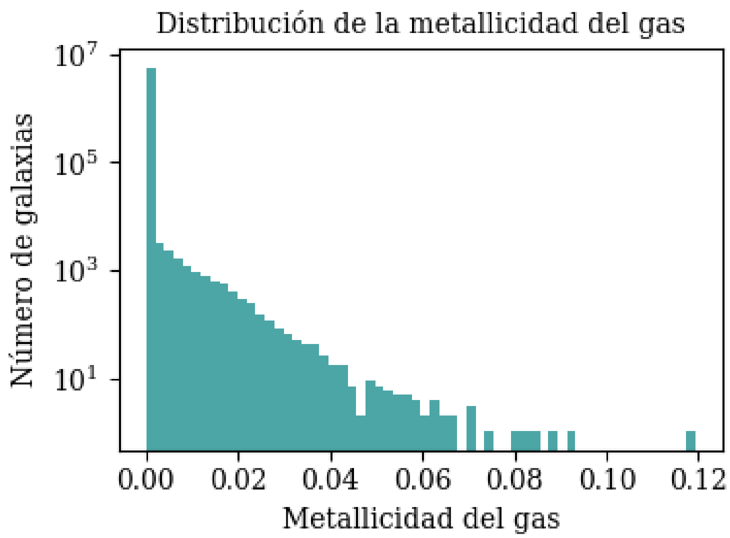
```
plt.figure(figsize=(4, 3))
mask = df['SubhaloSFR'] > 0
plt.hist(np.log10(df.loc[mask, 'SubhaloSFR']), bins=60, log=True,
color="mediumvioletred", alpha=0.7)
plt.xlabel(r"$\log_{10} \mathrm{SFR} [M_\odot yr^{-1}]$")
plt.ylabel("Número de galaxias")
plt.title("Distribución de la tasa de formación estelar")
plt.tight_layout()
plt.show()
```



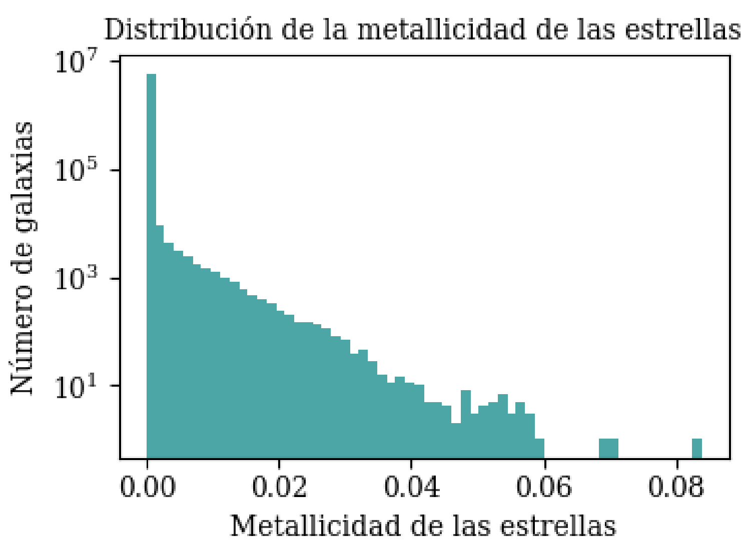
```
plt.figure(figsize=(4, 3))
plt.hist(np.log10(df['SubhaloMass'] * 1e10), bins=60, log=True,
color="crimson", alpha=0.7)
plt.xlabel("Masa estelar [$M_\odot h^{-1}]$]")
plt.ylabel("Número de galaxias")
plt.title("Distribución de masa estelar")
plt.tight_layout()
plt.show()
```




```
plt.figure(figsize=(4, 3))
plt.hist(df['SubhaloGasMetallicity'], bins=60, log=True, color="teal",
alpha=0.7)
plt.xlabel("Metallicidad del gas")
plt.ylabel("Número de galaxias")
plt.title("Distribución de la metallicidad del gas")
plt.tight_layout()
plt.show()
```

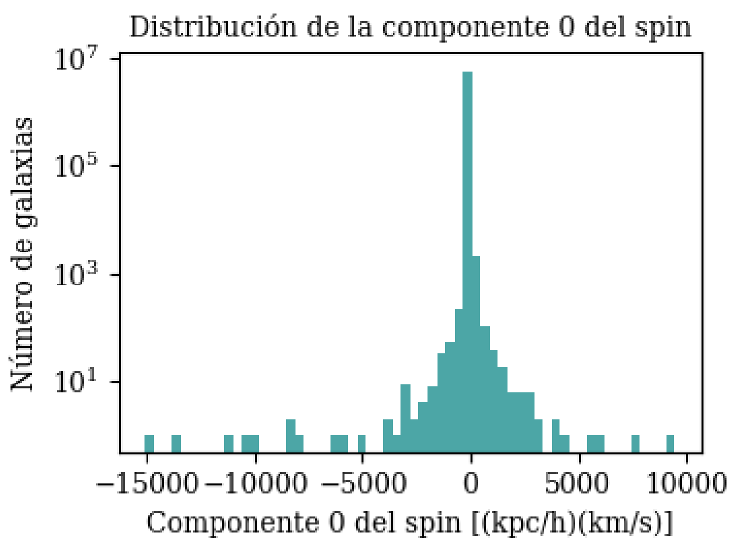


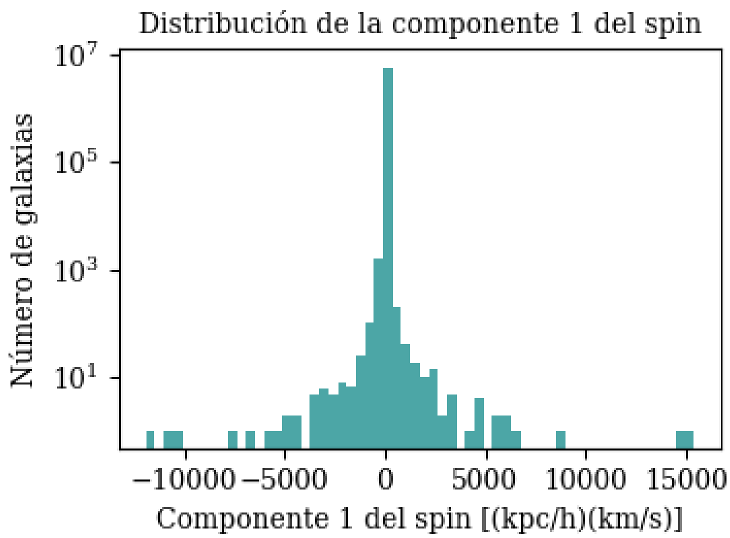

```
plt.figure(figsize=(4, 3))
plt.hist(df['SubhaloStarMetallicity'], bins=60, log=True,
color="teal", alpha=0.7)
plt.xlabel("Metallicidad de las estrellas")
plt.ylabel("Número de galaxias")
plt.title("Distribución de la metallicidad de las estrellas")
plt.tight_layout()
plt.show()
```

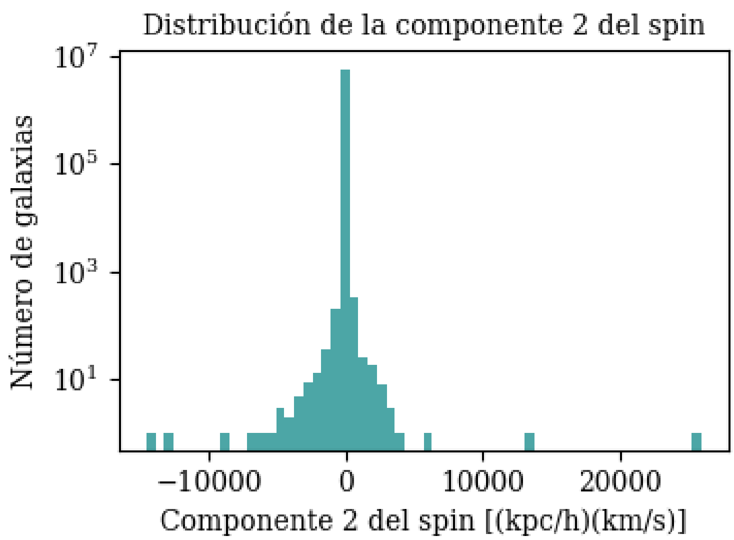



```
plt.figure(figsize=(4, 3))
plt.hist(df['SubhaloSpin_0'], bins=60, log=True, color="teal",
alpha=0.7)
plt.xlabel("Componente 0 del spin [(kpc/h)(km/s)]")
plt.ylabel("Número de galaxias")
```

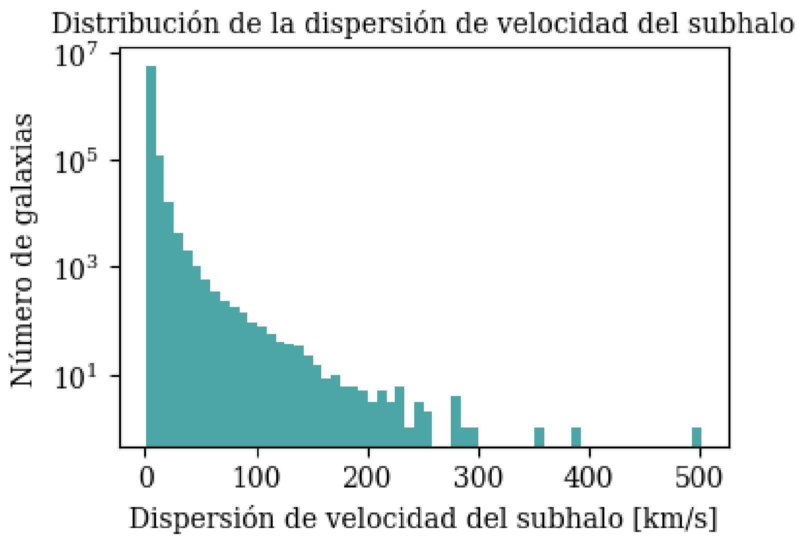
```python
plt.title("Distribución de la componente 0 del spin")
plt.tight_layout()
plt.show()

plt.figure(figsize=(4, 3))
plt.hist(df['SubhaloSpin_1'], bins=60, log=True, color="teal",
alpha=0.7)
plt.xlabel("Componente 1 del spin [(kpc/h)(km/s)]")
plt.ylabel("Número de galaxias")
plt.title("Distribución de la componente 1 del spin")
plt.tight_layout()
plt.show()

plt.figure(figsize=(4, 3))
plt.hist(df['SubhaloSpin_2'], bins=60, log=True, color="teal",
alpha=0.7)
plt.xlabel("Componente 2 del spin [(kpc/h)(km/s)]")
plt.ylabel("Número de galaxias")
plt.title("Distribución de la componente 2 del spin")
plt.tight_layout()
plt.show()
```





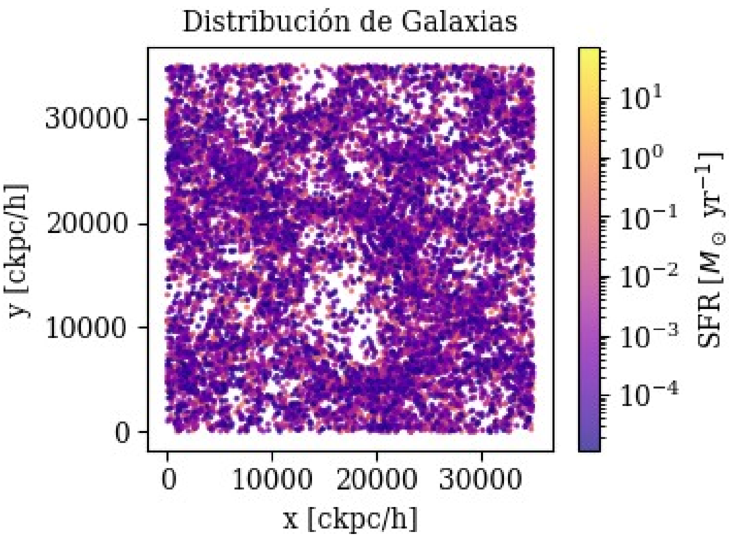



```
plt.figure(figsize=(4, 3))
plt.hist(df['SubhaloVelDisp'], bins=60, log=True, color="teal",
alpha=0.7)
plt.xlabel("Dispersión de velocidad del subhalo [km/s]")
plt.ylabel("Número de galaxias")
plt.title("Distribución de la dispersión de velocidad del subhalo")
plt.tight_layout()
plt.show()
```



d)

```
plt.figure(figsize=(4, 3))
sfr = df['SubhaloSFR']
mask = sfr > 0
x = df['SubhaloPos_0']
y = df['SubhaloPos_1']
sfr = sfr[mask]
x = x[mask]
y = y[mask]
sc = plt.scatter(
    x, y, c=sfr,
    s=1.5, cmap="plasma",
    norm=LogNorm(vmin=min(sfr), vmax=max(sfr)),
    alpha=0.7
)
plt.xlabel("x [ckpc/h]")
plt.ylabel("y [ckpc/h]")
plt.title("Distribución de Galaxias")
plt.colorbar(sc, label="SFR [$M_\\odot$ yr$^{-1}$]")
plt.axis("equal")
plt.tight_layout()
plt.show()
```



Merge con Jellyfish

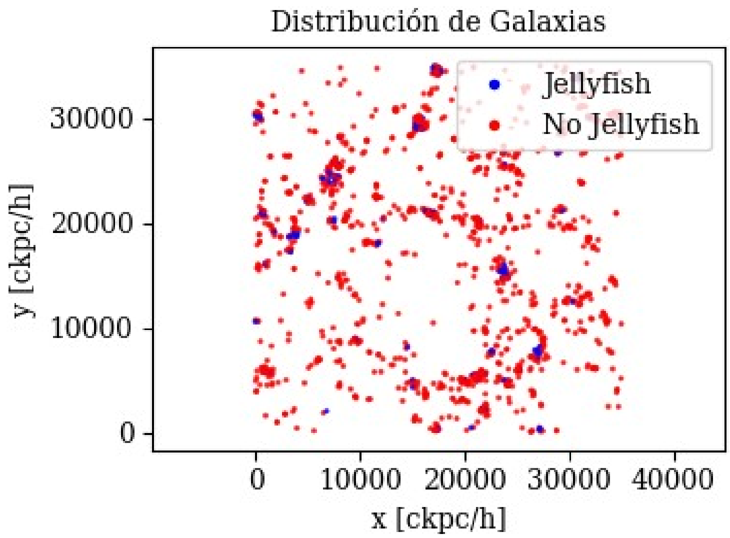
```
jf = h5py.File("Datos/jellyfish.hdf5", "r")['Snapshot_099']

jf = pd.DataFrame({
    "SubhaloID": jf["SubhaloIDs"][:],
    "ScoreAdjusted": jf["ScoreAdjusted"][:],
    "ScoreRaw": jf["ScoreRaw"][:],
    "ClassificationNumRaw": jf["ClassificationNumRaw"][:],
    "ClassificationNumAdjusted": jf["ClassificationNumAdjusted"][:],
    "expertNum": jf["expertNum"][:],
    "ScoreRawTotal": jf["ScoreRawTotal"][:],
})

df_merged = df.merge(
    jf,
    how="inner",
    on="SubhaloID"
)

df_merged
```

	SubhaloGasMetallicity	SubhaloMass	SubhaloMassType_0	\
0	0.030973	157.060089	0.227375	
1	0.026935	31.240942	1.741229	
2	0.034762	18.749269	0.673523	
3	0.054017	16.190680	0.086507	
4	0.016528	15.664657	0.553931	
...	...	...	...	
1412	0.009478	1.032192	0.070051	
1413	0.016909	1.141478	0.006954	
1414	0.015397	2.020072	0.145087	
1415	0.008570	1.561543	0.151737	
1416	0.021838	0.293591	0.004832	

```
      SubhaloMassType_1  SubhaloMassType_2  SubhaloMassType_3  \
0            143.777634                0.0                0.0
1             26.965401                0.0                0.0
2             15.532797                0.0                0.0
3             13.610888                0.0                0.0
4             14.531116                0.0                0.0
...                 ...                ...                ...
1412           0.932277                0.0                0.0
1413           1.114638                0.0                0.0
1414           1.848356                0.0                0.0
1415           1.376577                0.0                0.0
1416           0.201387                0.0                0.0

      SubhaloMassType_4  SubhaloMassType_5  SubhaloPos_0  SubhaloPos_1
...  \
0             13.025371           0.029711   6774.915527  23864.580078
...
1              2.528330           0.005984   8070.635254  24389.376953
...
2              2.539410           0.003540   7051.789551  23817.816406
...
3              2.489373           0.003911   7731.748047  24314.457031
...
4              0.577643           0.001967   6440.559570  24252.548828
...
...                 ...                ...           ...           ...
...
1412           0.029713           0.000151   8157.603027  33193.878906
...
1413           0.019802           0.000084   8376.555664  25888.294922
...
1414           0.026629           0.000000   5366.706055   6400.820801
...
1415           0.032981           0.000248  33406.449219  13711.583008
...
1416           0.086880           0.000492   8424.110352   6316.362793
...

      SubhaloVmax  SubhaloVmaxRad  SubhaloWindMass  SubhaloID
ScoreAdjusted  \
0      354.704529        0.863242              0.0          2
0.064791
1      191.930206        0.951246              0.0          8
0.031838
2      164.306885        8.905804              0.0         11
0.878533
3      171.295380        8.767321              0.0         12
0.077787
4      129.189194        3.455755              0.0         17
```

```
0.063565
...           ...            ...             ...        ...
...
1412    66.680740        4.158565             0.0     727826
0.059520
1413    55.774853        4.519668             0.0     733422
0.062293
1414    64.223572        9.054040             0.0     734091
0.045806
1415    67.757835        5.632882             0.0     738605
0.066849
1416    71.739502        0.649579             0.0     742091
0.000000

      ScoreRaw  ClassificationNumRaw  ClassificationNumAdjusted
expertNum  \
0         0.05                  20.0                       19.0
0.0
1         0.05                  20.0                       20.0
0.0
2         0.85                  20.0                       20.0
0.0
3         0.20                  20.0                       20.0
6.0
4         0.05                  20.0                       20.0
0.0
...        ...                   ...                        ...
...
1412      0.05                  20.0                       19.0
0.0
1413      0.05                  20.0                       19.0
0.0
1414      0.15                  20.0                       18.0
0.0
1415      0.05                  20.0                       18.0
0.0
1416      0.00                  20.0                       19.0
0.0

      ScoreRawTotal
0               1.0
1               1.0
2              17.0
3               4.0
4               1.0
...             ...
1412            1.0
1413            1.0
1414            3.0
```

```
1415            1.0
1416            0.0

[1417 rows x 30 columns]

# Definimos como Jellyfish las filas con ScoreAdjusted >= 0.7
df_merged['isJellyfish'] = np.where(df_merged['ScoreAdjusted'] >= 0.7,
1, 0)

plt.figure(figsize=(4, 3))

x = df_merged['SubhaloPos_0']
y = df_merged['SubhaloPos_1']
isJf = df_merged['isJellyfish']

colors = np.where(isJf == 1, 'blue', 'red')

plt.scatter(x, y, c=colors, s=1.5, alpha=0.7)

plt.xlabel("x [ckpc/h]")
plt.ylabel("y [ckpc/h]")
plt.title("Distribución de Galaxias")

legend_elements = [
    Line2D([0], [0], marker='o', color='w', label='Jellyfish',
markerfacecolor='blue', markersize=5),
    Line2D([0], [0], marker='o', color='w', label='No Jellyfish',
markerfacecolor='red', markersize=5)
]
plt.legend(handles=legend_elements, loc='best')

plt.axis("equal")
plt.tight_layout()
plt.show()
```



2.

```
coord  = ['X', 'Y', 'Z']

rename_map = {}

for col in df_merged.columns:
    new = col

    if re.match(r".*_\d$", col):
        idx = int(col.split("_")[-1])
        if "Pos" in col or "Vel" in col or "Spin" in col or "CM" in 
col:
            new = col.replace(f"_{idx}", f"_{coord[idx]}")

    rename_map[col] = new

df_merged = df_merged.rename(columns=rename_map)

list(df_merged.columns)
```

```
['SubhaloGasMetallicity',
 'SubhaloMass',
 'SubhaloMassType_0',
 'SubhaloMassType_1',
 'SubhaloMassType_2',
 'SubhaloMassType_3',
 'SubhaloMassType_4',
 'SubhaloMassType_5',
 'SubhaloPos_X',
 'SubhaloPos_Y',
 'SubhaloPos_Z',
```

```
 'SubhaloSFR',
 'SubhaloSpin_X',
 'SubhaloSpin_Y',
 'SubhaloSpin_Z',
 'SubhaloStarMetallicity',
 'SubhaloVel_X',
 'SubhaloVel_Y',
 'SubhaloVel_Z',
 'SubhaloVelDisp',
 'SubhaloVmax',
 'SubhaloVmaxRad',
 'SubhaloWindMass',
 'SubhaloID',
 'ScoreAdjusted',
 'ScoreRaw',
 'ClassificationNumRaw',
 'ClassificationNumAdjusted',
 'expertNum',
 'ScoreRawTotal',
 'isJellyfish']
```

```
# conversión usando h = 0.704
h = 0.704

# Limites inferiores
min_sfr = -15
min_mass = 5

# Conversión de unidades

df_merged['logGasMass'] = np.log10((df_merged['SubhaloMassType_0'] *
1e10 / h).clip(lower=10**min_mass))

df_merged['logSFR'] =
(np.log10(df_merged['SubhaloSFR']).clip(lower=min_sfr))

# Filtro de infinitos
has_inf = df_merged.apply(np.isinf).any(axis=1)
df_filtro = df_merged[~has_inf].copy()
```

```
/home/2025/AST0421-1/svtroncoso/.local/lib/python3.10/site-packages/
pandas/core/arraylike.py:399: RuntimeWarning: divide by zero
encountered in log10
  result = getattr(ufunc, method)(*inputs, **kwargs)
```

```
df_filtro.shape
```

```
(1417, 33)
```

```
list(df_filtro.columns)
```

```
['SubhaloGasMetallicity',
 'SubhaloMass',
 'SubhaloMassType_0',
 'SubhaloMassType_1',
 'SubhaloMassType_2',
 'SubhaloMassType_3',
 'SubhaloMassType_4',
 'SubhaloMassType_5',
 'SubhaloPos_X',
 'SubhaloPos_Y',
 'SubhaloPos_Z',
 'SubhaloSFR',
 'SubhaloSpin_X',
 'SubhaloSpin_Y',
 'SubhaloSpin_Z',
 'SubhaloStarMetallicity',
 'SubhaloVel_X',
 'SubhaloVel_Y',
 'SubhaloVel_Z',
 'SubhaloVelDisp',
 'SubhaloVmax',
 'SubhaloVmaxRad',
 'SubhaloWindMass',
 'SubhaloID',
 'ScoreAdjusted',
 'ScoreRaw',
 'ClassificationNumRaw',
 'ClassificationNumAdjusted',
 'expertNum',
 'ScoreRawTotal',
 'isJellyfish',
 'logGasMass',
 'logSFR']
```

2.

```python
def clean_df(df_f, columns):

    df_f = df_f.copy()
    # No limpiamos las clasificaciones
    skip =  ['ScoreAdjusted',
             'ScoreRaw',
             'ClassificationNumRaw',
             'ClassificationNumAdjusted',
             'expertNum',
             'ScoreRawTotal',
             'isJellyfish']
```

```
    # No queremos columnas con muchos ceros ni outliers
    cols_to_drop = []
    for col in columns:
        if col in skip:
            continue

        if pd.api.types.is_numeric_dtype(df_f[col]):
            zero_fraction = (df_f[col] == 0).mean()
            if zero_fraction > 0.95:
                cols_to_drop.append(col)

    df_f = df_f.drop(columns=cols_to_drop)


    mask = np.ones(len(df_f), dtype=bool)

    for col in df_f.columns:
        if col in skip:
            continue
        if not pd.api.types.is_numeric_dtype(df_f[col]) or
df_f[col].dtype == bool:
            continue

        Q1 = df_f[col].quantile(0.25)
        Q3 = df_f[col].quantile(0.75)
        if Q3 == Q1:
            continue

        IQR = Q3 - Q1
        lower = Q1 - 4.5 * IQR
        upper = Q3 + 4.5 * IQR

        col_mask = df_f[col].between(lower, upper)
        mask &= col_mask

    return df_f[mask].reset_index(drop=True)

df_clean = clean_df(df_filtro, df_filtro.columns)

# El Spin y la Velocidad nos interesan como magnitudes absolutas
df_clean['SubhaloSpin_abs'] = np.sqrt(
    df_clean['SubhaloSpin_X']**2 +
    df_clean['SubhaloSpin_Y']**2 +
    df_clean['SubhaloSpin_Z']**2
)


df_clean['SubhaloVel_abs'] = np.sqrt(
    df_clean['SubhaloVel_X']**2 +
    df_clean['SubhaloVel_Y']**2 +
    df_clean['SubhaloVel_Z']**2
```

```
)


# Drop the original components
df_clean = df_clean.drop(columns=[
    'SubhaloSpin_X', 'SubhaloSpin_Y', 'SubhaloSpin_Z',
    'SubhaloVel_X', 'SubhaloVel_Y', 'SubhaloVel_Z'
])

# Check the new columns
df_clean.head()
```

```
   SubhaloGasMetallicity  SubhaloMass  SubhaloMassType_0
SubhaloMassType_1  \
0               0.043184    10.595651           0.125320
9.019890
1               0.021653    10.517558           0.232931
9.039531
2               0.035823     9.338154           0.036069
8.747470
3               0.028527     8.275965           0.309192
7.574585
4               0.012829     6.200198           0.350026
5.585394

   SubhaloMassType_4  SubhaloMassType_5  SubhaloPos_X  SubhaloPos_Y  \
0           1.448305           0.002135   6960.160156  24176.779297
1           1.241080           0.004017   6806.443848  23920.992188
2           0.551810           0.002804   6932.848145  25314.691406
3           0.389886           0.002301   8018.007812  24417.718750
4           0.264055           0.000722   6932.467773  24532.806641

   SubhaloPos_Z  SubhaloSFR  ...  ScoreRaw  ClassificationNumRaw  \
0  21699.187500    0.257232  ...      0.70                  20.0
1  21184.021484    0.831690  ...      0.55                  20.0
2  21618.541016    0.052089  ...      0.15                  20.0
3  21512.447266    0.445549  ...      0.20                  20.0
4  20780.181641    0.409650  ...      0.55                  20.0

   ClassificationNumAdjusted  expertNum  ScoreRawTotal  isJellyfish  \
0                       19.0        6.0           14.0            1
1                       20.0        0.0           11.0            0
2                       19.0        0.0            3.0            0
3                       19.0        0.0            4.0            0
4                       20.0        6.0           11.0            0

   logGasMass    logSFR  SubhaloSpin_abs  SubhaloVel_abs
0    9.250448 -0.589675       222.279388      634.431519
1    9.519654 -0.080038       256.347534      995.734253
2    8.709561 -1.283252       168.667404      933.498169
```

```
3    9.642655 -0.351105       173.211090     1160.505981
4    9.696527 -0.387587       274.983948     1187.741211

[5 rows x 26 columns]
```

```python
df_filtro.shape, df_clean.shape
```

```
((1417, 33), (1163, 26))
```

```python
for col in df_filtro.columns:
    if col not in df_clean.columns:
        print("Columnas dropeadas:", col)
```

```
Columnas dropeadas: SubhaloMassType_2
Columnas dropeadas: SubhaloMassType_3
Columnas dropeadas: SubhaloSpin_X
Columnas dropeadas: SubhaloSpin_Y
Columnas dropeadas: SubhaloSpin_Z
Columnas dropeadas: SubhaloVel_X
Columnas dropeadas: SubhaloVel_Y
Columnas dropeadas: SubhaloVel_Z
Columnas dropeadas: SubhaloWindMass
```

```python
df_clean.head()
```

```
   SubhaloGasMetallicity  SubhaloMass  SubhaloMassType_0
SubhaloMassType_1  \
0                0.043184    10.595651           0.125320
9.019890
1                0.021653    10.517558           0.232931
9.039531
2                0.035823     9.338154           0.036069
8.747470
3                0.028527     8.275965           0.309192
7.574585
4                0.012829     6.200198           0.350026
5.585394

   SubhaloMassType_4  SubhaloMassType_5  SubhaloPos_X  SubhaloPos_Y  \
0           1.448305           0.002135   6960.160156  24176.779297
1           1.241080           0.004017   6806.443848  23920.992188
2           0.551810           0.002804   6932.848145  25314.691406
3           0.389886           0.002301   8018.007812  24417.718750
4           0.264055           0.000722   6932.467773  24532.806641

   SubhaloPos_Z  SubhaloSFR  ...  ScoreRaw  ClassificationNumRaw  \
0  21699.187500    0.257232  ...      0.70                  20.0
1  21184.021484    0.831690  ...      0.55                  20.0
2  21618.541016    0.052089  ...      0.15                  20.0
3  21512.447266    0.445549  ...      0.20                  20.0
4  20780.181641    0.409650  ...      0.55                  20.0
```

```
   ClassificationNumAdjusted  expertNum  ScoreRawTotal  isJellyfish  \
0                       19.0        6.0           14.0            1
1                       20.0        0.0           11.0            0
2                       19.0        0.0            3.0            0
3                       19.0        0.0            4.0            0
4                       20.0        6.0           11.0            0

   logGasMass    logSFR  SubhaloSpin_abs  SubhaloVel_abs
0    9.250448 -0.589675       222.279388      634.431519
1    9.519654 -0.080038       256.347534      995.734253
2    8.709561 -1.283252       168.667404      933.498169
3    9.642655 -0.351105       173.211090     1160.505981
4    9.696527 -0.387587       274.983948     1187.741211

[5 rows x 26 columns]
```

```
print('total jellyfish:', df_clean['isJellyfish'].sum())
```

```
total jellyfish: 129
```

```
df_clean = df_clean.drop(columns=['ScoreAdjusted', 'ScoreRaw',
'ClassificationNumRaw',
       'ClassificationNumAdjusted', 'expertNum', 'ScoreRawTotal',
'SubhaloMassType_0',
       'SubhaloMassType_1', 'SubhaloMassType_4', 'SubhaloMassType_5',
'SubhaloSFR'])

df_clean.head()
```

```
   SubhaloGasMetallicity  SubhaloMass  SubhaloPos_X  SubhaloPos_Y  \
0               0.043184    10.595651   6960.160156  24176.779297
1               0.021653    10.517558   6806.443848  23920.992188
2               0.035823     9.338154   6932.848145  25314.691406
3               0.028527     8.275965   8018.007812  24417.718750
4               0.012829     6.200198   6932.467773  24532.806641

   SubhaloPos_Z  SubhaloStarMetallicity  SubhaloVelDisp
SubhaloVmax  \
0  21699.187500                0.021738       72.564430   135.308228

1  21184.021484                0.024509       85.644264   155.352066

2  21618.541016                0.022594       63.766693   138.750046

3  21512.447266                0.020835       62.479771   131.933731

4  20780.181641                0.012193       52.729660    95.565742


   SubhaloVmaxRad  SubhaloID  isJellyfish  logGasMass    logSFR  \
```

0	9.468564	18	1	9.250448	-0.589675
1	4.401894	20	0	9.519654	-0.080038
2	0.866845	28	0	8.709561	-1.283252
3	1.173695	29	0	9.642655	-0.351105
4	9.623796	37	0	9.696527	-0.387587

	SubhaloSpin_abs	SubhaloVel_abs
0	222.279388	634.431519
1	256.347534	995.734253
2	168.667404	933.498169
3	173.211090	1160.505981
4	274.983948	1187.741211

```python
from sklearn.tree import DecisionTreeClassifier

jelly_cols = [col for col in df_clean.columns if 'jelly' in
col.lower()]
X_clf = df_clean.drop(columns=jelly_cols + ['SubhaloID'])
y_clf = df_clean['isJellyfish']

Xc_train, Xc_test, yc_train, yc_test = train_test_split(
    X_clf, y_clf, test_size=0.2, random_state=42, stratify=y_clf
)

tree_clf = DecisionTreeClassifier(max_depth=3, random_state=42)
tree_clf.fit(Xc_train, yc_train)

y_pred_tree = tree_clf.predict(Xc_test)
cm_tree = confusion_matrix(yc_test, y_pred_tree)

print("Matriz de confusión (árbol de decisión):")
print(cm_tree)
print("\nReporte de clasificación:")
print(classification_report(yc_test, y_pred_tree))
print(f"\nF1-score Jellyfish: {f1_score(yc_test, y_pred_tree):.3f}")

dot_data = export_graphviz(
    tree_clf,
    out_file=None,
    feature_names=X_clf.columns,
    class_names=["No Jellyfish", "Jellyfish"],
    filled=True,
    rounded=True,
    proportion=True,
    max_depth=3,
    special_characters=True
)

lines = dot_data.split("\n")
lines.insert(1, 'node [fontsize=69];')
```

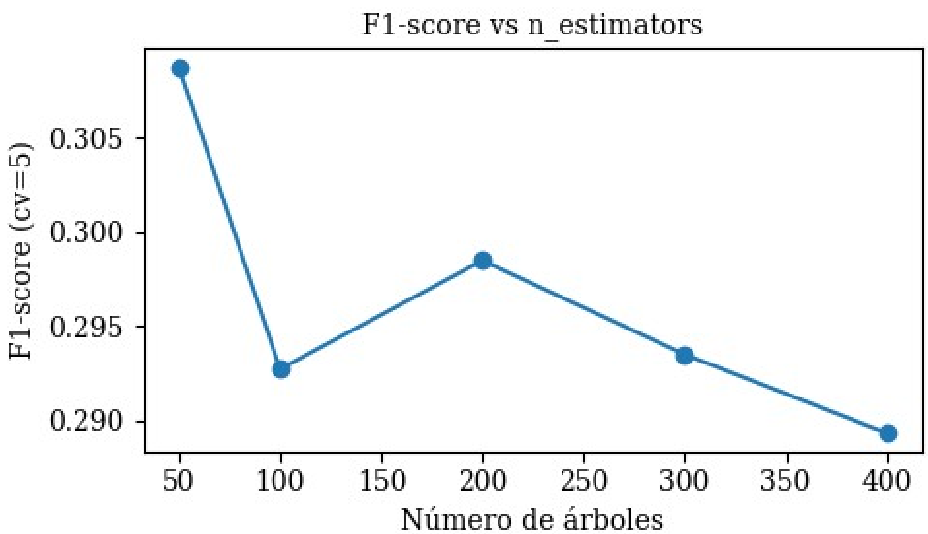
```python
lines.insert(2, 'edge [fontsize=50];')
lines.insert(3, 'graph [ranksep=1.5, nodesep=0.5];')
dot_data = "\n".join(lines)

graph = Source(dot_data)
graph.format = "png"
graph.render("decision_tree_graphviz", cleanup=True)
graph
```

```
Matriz de confusión (árbol de decisión):
[[196  11]
 [ 20   6]]

Reporte de clasificación:
              precision    recall  f1-score   support

           0       0.91      0.95      0.93       207
           1       0.35      0.23      0.28        26

    accuracy                           0.87       233
   macro avg       0.63      0.59      0.60       233
weighted avg       0.85      0.87      0.85       233


F1-score Jellyfish: 0.279
```

3.

```python
# Quitamos columnas que no son predictoras
X = df_clean.drop(columns=['isJellyfish', 'SubhaloID'])
y = df_clean['isJellyfish']

# 20% de test, 80% de entrenamiento
X_train, X_test, y_train, y_test = train_test_split(
    X, y, test_size=0.2, random_state=42, stratify=y
)
```

```python
estimators = [50, 100, 200, 300, 400]
f1_scores = []

for n in estimators:
    rf_tmp = RandomForestClassifier(n_estimators=n, random_state=42,
n_jobs=-1)
    score = cross_val_score(rf_tmp, X_train, y_train, cv=5,
scoring='f1')
    f1_scores.append(np.mean(score))

plt.figure(figsize=(5, 3))
plt.plot(estimators, f1_scores, marker='o')
plt.xlabel("Número de árboles")
plt.ylabel("F1-score (cv=5)")
plt.title("F1-score vs n_estimators")
plt.tight_layout()
plt.show()
```

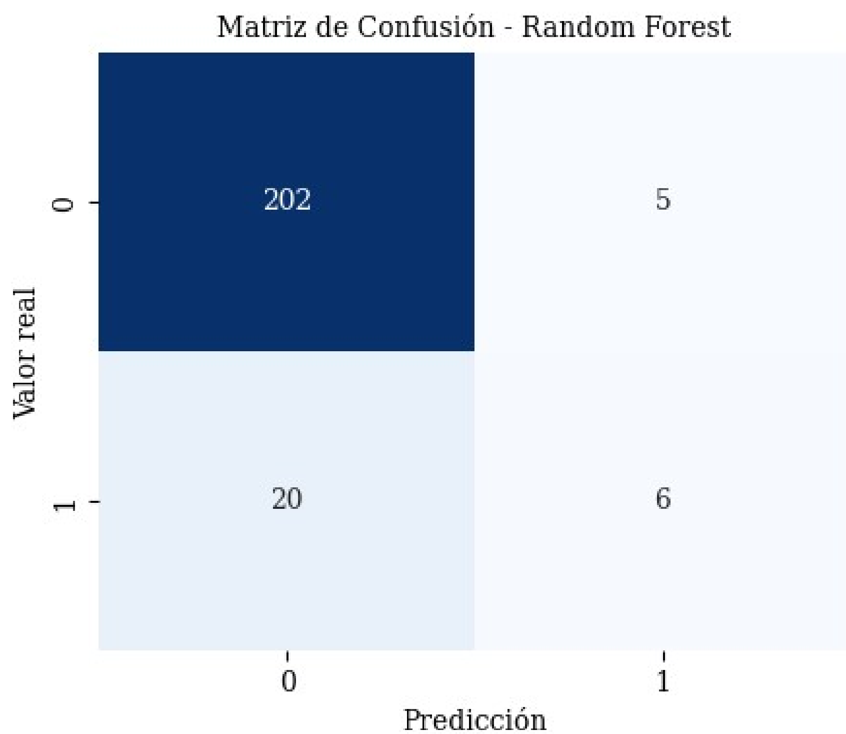



```python
rf = RandomForestClassifier(
    n_estimators=200,
    max_depth=None,
    random_state=42,
    n_jobs=4
)
rf.fit(X_train, y_train)

y_pred = rf.predict(X_test)

cm = confusion_matrix(y_test, y_pred)
print("Matriz de confusión:")
print(cm)
```

```
print("\nReporte de clasificación:")
print(classification_report(y_test, y_pred))

f1 = f1_score(y_test, y_pred)
print(f"\nF1-score: {f1:.3f}")

param_grid = {
    'n_estimators': [100, 200, 300],
    'max_depth': [None, 10, 20],
    'min_samples_split': [2, 5],
    'min_samples_leaf': [1, 2]
}

grid = GridSearchCV(
    RandomForestClassifier(random_state=42, n_jobs=-1),
    param_grid,
    cv=5,
    scoring='f1',
    n_jobs=-1
)

grid.fit(X_train, y_train)

print("\nMejores hiperparámetros:")
print(grid.best_params_)

y_pred_best = grid.best_estimator_.predict(X_test)
print("\nReporte con mejor modelo:")
print(classification_report(y_test, y_pred_best))
```

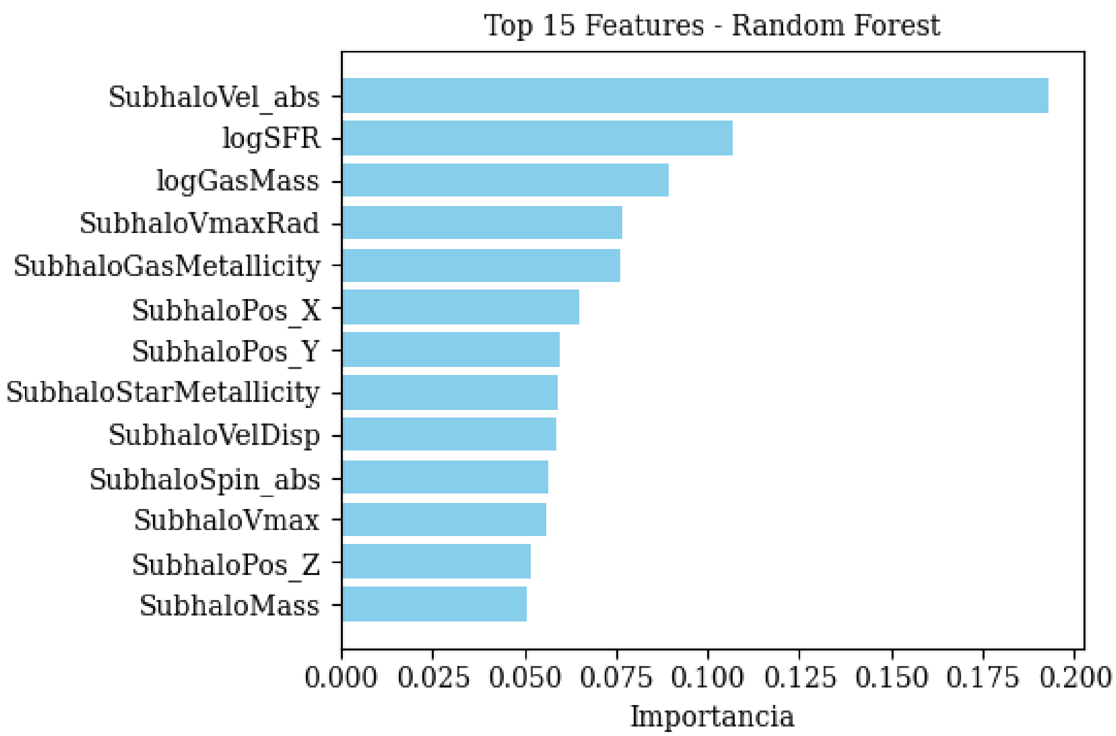
```
Matriz de confusión:
[[201   6]
 [ 20   6]]

Reporte de clasificación:
              precision    recall  f1-score   support

           0       0.91      0.97      0.94       207
           1       0.50      0.23      0.32        26

    accuracy                           0.89       233
   macro avg       0.70      0.60      0.63       233
weighted avg       0.86      0.89      0.87       233


F1-score: 0.316

Mejores hiperparámetros:
{'max_depth': None, 'min_samples_leaf': 1, 'min_samples_split': 5,
'n_estimators': 100}
```

```
Reporte con mejor modelo:
              precision    recall  f1-score   support

           0       0.91      0.98      0.94       207
           1       0.55      0.23      0.32        26

    accuracy                           0.89       233
   macro avg       0.73      0.60      0.63       233
weighted avg       0.87      0.89      0.87       233


cm = confusion_matrix(y_test, y_pred_best)
plt.figure(figsize=(5, 4))
sns.heatmap(cm, annot=True, fmt="d", cmap="Blues", cbar=False)
plt.xlabel("Predicción")
plt.ylabel("Valor real")
plt.title("Matriz de Confusión - Random Forest")
plt.show()
```




```
# Obtener importancia de features
importances = grid.best_estimator_.feature_importances_
features = X.columns

feat_df = pd.DataFrame({'feature': features, 'importance':
importances})
feat_df = feat_df.sort_values(by='importance',
```

```
ascending=False).head(15)  # Top 15 features

plt.figure(figsize=(6, 4))
plt.barh(feat_df['feature'][::-1], feat_df['importance'][::-1],
color='skyblue')
plt.xlabel("Importancia")
plt.title("Top 15 Features - Random Forest")
plt.tight_layout()
plt.show()
```



4.

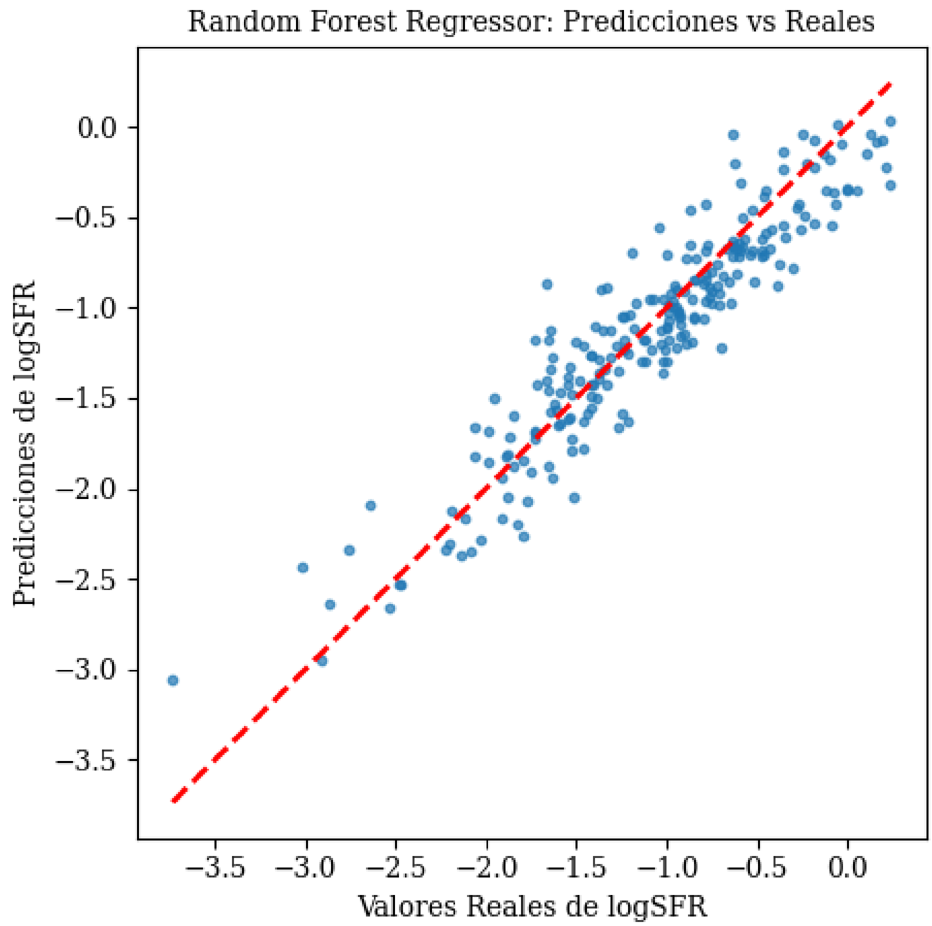
```
list(df_clean.columns)

['SubhaloGasMetallicity',
 'SubhaloMass',
 'SubhaloPos_X',
 'SubhaloPos_Y',
 'SubhaloPos_Z',
 'SubhaloStarMetallicity',
 'SubhaloVelDisp',
 'SubhaloVmax',
 'SubhaloVmaxRad',
 'SubhaloID',
 'isJellyfish',
```

```
 'logGasMass',
 'logSFR',
 'SubhaloSpin_abs',
 'SubhaloVel_abs']

# Predecir 'logSFR'
# Quitamos columnas que no son predictoras y las que no nos interesan
X = df_clean.drop(columns=['logSFR', 'SubhaloID', 'isJellyfish'])
y = df_clean['logSFR']

X_train, X_test, y_train, y_test = train_test_split(
    X, y, test_size=0.2, random_state=42
)

rf_reg = RandomForestRegressor(
    n_estimators=200,
    max_depth=None,
    random_state=42,
    n_jobs=-1
)
rf_reg.fit(X_train, y_train)

y_pred = rf_reg.predict(X_test)

mse = mean_squared_error(y_test, y_pred)
rmse = mse**0.5
mae = mean_absolute_error(y_test, y_pred)
r2 = r2_score(y_test, y_pred)

print(f"RMSE: {rmse:.3f}")
print(f"MAE: {mae:.3f}")
print(f"R²: {r2:.3f}")

param_grid = {
    'n_estimators': [100, 200, 300],
    'max_depth': [None, 10, 20],
    'min_samples_split': [2, 5],
    'min_samples_leaf': [1, 2]
}

grid_reg = GridSearchCV(
    RandomForestRegressor(random_state=42, n_jobs=-1),
    param_grid,
    cv=5,
    scoring='r2',
    n_jobs=-1
)

grid_reg.fit(X_train, y_train)
```

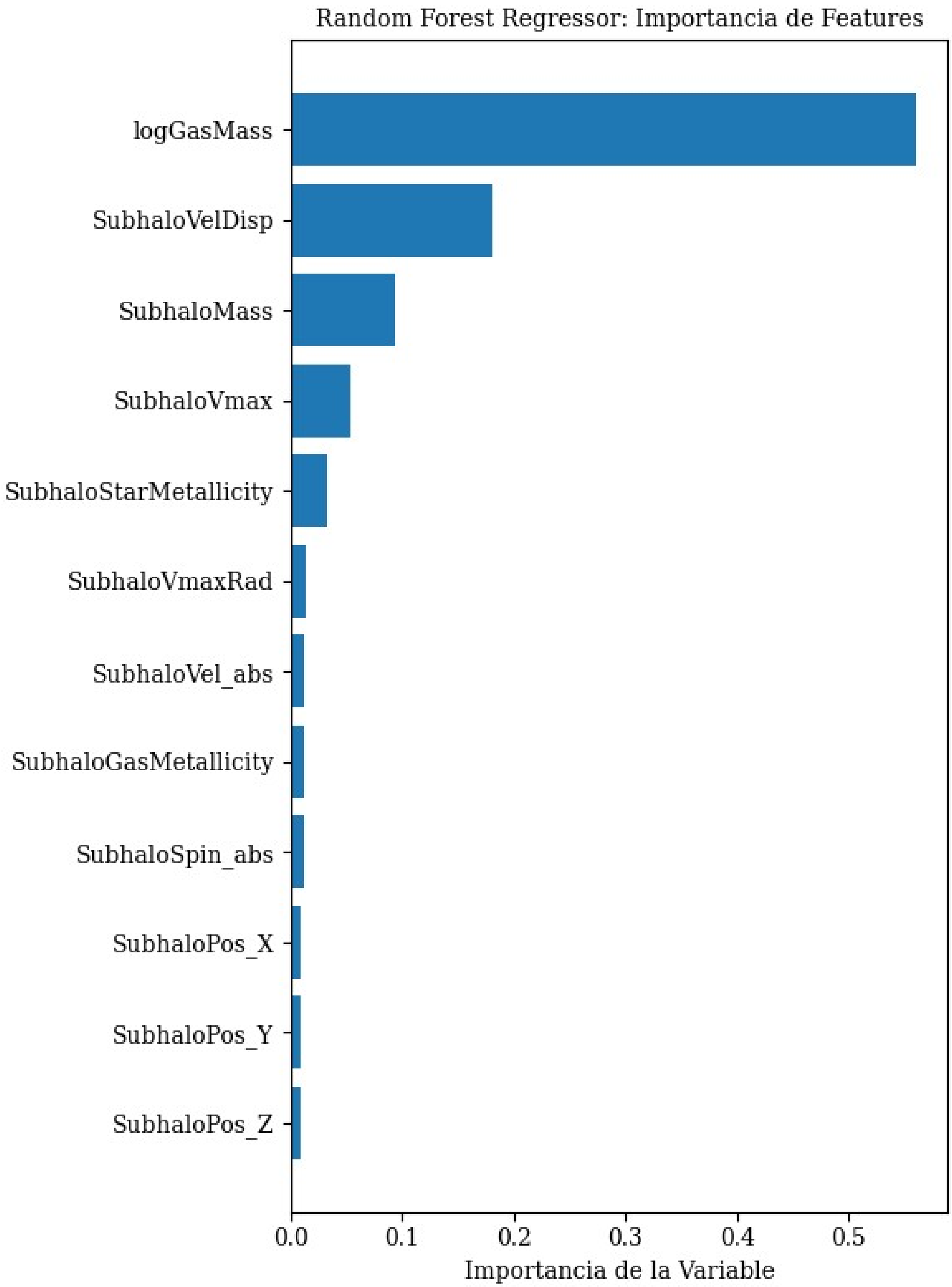
```python
print("\nMejores hiperparámetros:")
print(grid_reg.best_params_)

y_pred_best = grid_reg.best_estimator_.predict(X_test)

mse = mean_squared_error(y_test, y_pred_best)
rmse = np.sqrt(mse)  # √MSE
mae = mean_absolute_error(y_test, y_pred_best)
r2 = r2_score(y_test, y_pred_best)

print(f"R² del mejor modelo: {r2:.3f}")
print(f"RMSE del mejor modelo: {rmse:.3f}")
print(f"MAE del mejor modelo: {mae:.3f}")
```

```
RMSE: 0.240
MAE: 0.190
R²: 0.871

Mejores hiperparámetros:
{'max_depth': 10, 'min_samples_leaf': 2, 'min_samples_split': 2,
'n_estimators': 300}
R² del mejor modelo: 0.868
RMSE del mejor modelo: 0.243
MAE del mejor modelo: 0.191
```

```python
plt.figure(figsize=(5, 5))
plt.scatter(y_test, y_pred_best, s=10, alpha=0.7)
plt.plot([y_test.min(), y_test.max()],
         [y_test.min(), y_test.max()],
         'r--', lw=2)
plt.xlabel("Valores Reales de logSFR")
plt.ylabel("Predicciones de logSFR")
plt.title("Random Forest Regressor: Predicciones vs Reales")
plt.tight_layout()
plt.show()
```

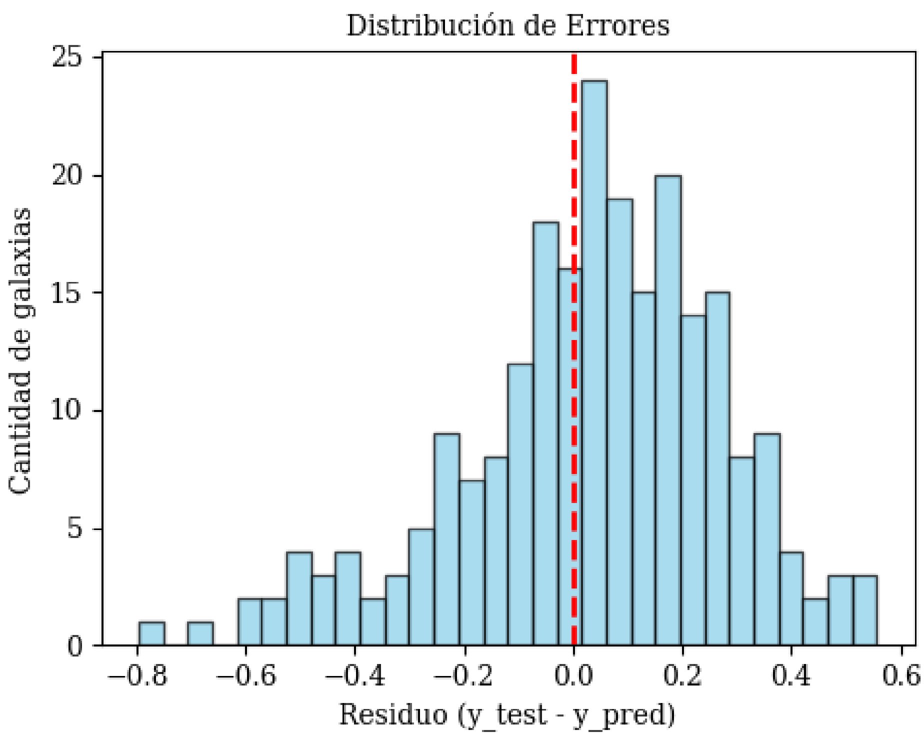



```
importances = grid_reg.best_estimator_.feature_importances_
features = X.columns
indices = np.argsort(importances)[::-1]

plt.figure(figsize=(6, 8))
plt.barh(range(len(features)), importances[indices], align='center')
plt.yticks(range(len(features)), [features[i] for i in indices])
plt.gca().invert_yaxis()
plt.xlabel("Importancia de la Variable")
plt.title("Random Forest Regressor: Importancia de Features")
plt.tight_layout()
plt.show()
```




```
residuals = y_test - y_pred_best

plt.figure(figsize=(5, 4))
plt.hist(residuals, bins=30, color='skyblue', edgecolor='k',
```

```
alpha=0.7)
plt.axvline(0, color='red', linestyle='--', lw=2)
plt.xlabel("Residuo (y_test - y_pred)")
plt.ylabel("Cantidad de galaxias")
plt.title("Distribución de Errores")
plt.tight_layout()
plt.show()
```



5.

```
features = df_clean.drop(columns=['isJellyfish', 'logSFR',
'SubhaloID'])
X = features.values

scaler = StandardScaler()
X_scaled = scaler.fit_transform(X)

y_class = df_clean['isJellyfish'].values

X_train_c, X_test_c, y_train_c, y_test_c = train_test_split(
    X_scaled, y_class, test_size=0.2, random_state=42
)

mlp_class = MLPClassifier(
    hidden_layer_sizes=(128, 64),
```

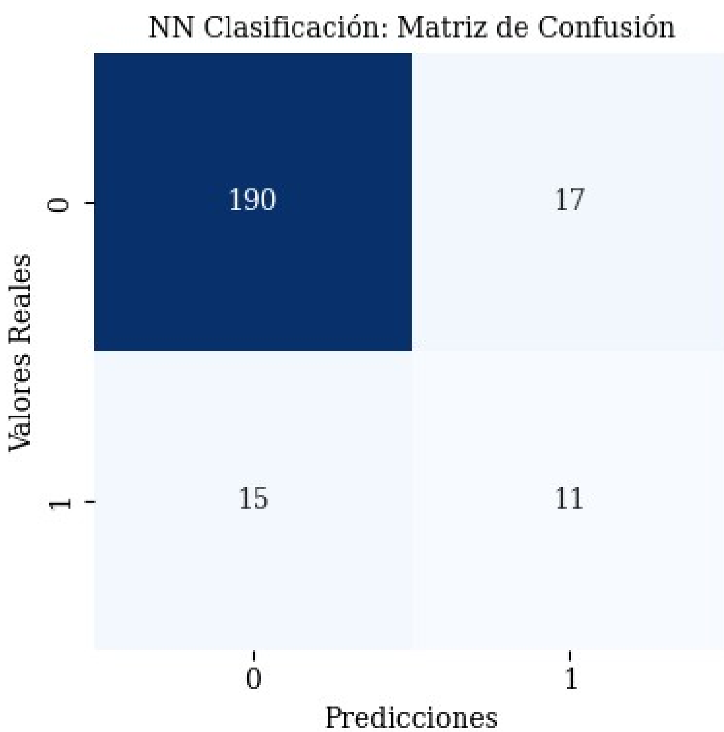
```python
    activation='relu',
    solver='adam',
    max_iter=200,
    random_state=42
)

mlp_class.fit(X_train_c, y_train_c)

y_pred_c = mlp_class.predict(X_test_c)
print("Clasificación - reporte:")
print(classification_report(y_test_c, y_pred_c))
print("Matriz de confusión:")
print(confusion_matrix(y_test_c, y_pred_c))


y_reg = df_clean['logSFR'].values

X_train_r, X_test_r, y_train_r, y_test_r = train_test_split(
    X_scaled, y_reg, test_size=0.2, random_state=42
)

mlp_reg = MLPRegressor(
    hidden_layer_sizes=(128, 64),
    activation='relu',
    solver='adam',
    max_iter=200,
    random_state=42
)

mlp_reg.fit(X_train_r, y_train_r)

y_pred_r = mlp_reg.predict(X_test_r)
mse = mean_squared_error(y_test_r, y_pred_r)
rmse = np.sqrt(mse)
r2 = r2_score(y_test_r, y_pred_r)

print(f"Regresión - RMSE: {rmse:.3f}, R²: {r2:.3f}")
```

```
/home/2025/AST0421-1/svtroncoso/.local/lib/python3.10/site-packages/
sklearn/neural_network/_multilayer_perceptron.py:781:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (200)
reached and the optimization hasn't converged yet.
  warnings.warn(

Clasificación - reporte:
              precision    recall  f1-score   support

           0       0.93      0.92      0.92       207
           1       0.39      0.42      0.41        26

    accuracy                           0.86       233
```

```
   macro avg       0.66      0.67      0.66       233
weighted avg       0.87      0.86      0.86       233

Matriz de confusión:
[[190  17]
 [ 15  11]]
Regresión - RMSE: 0.291, R²: 0.812
```

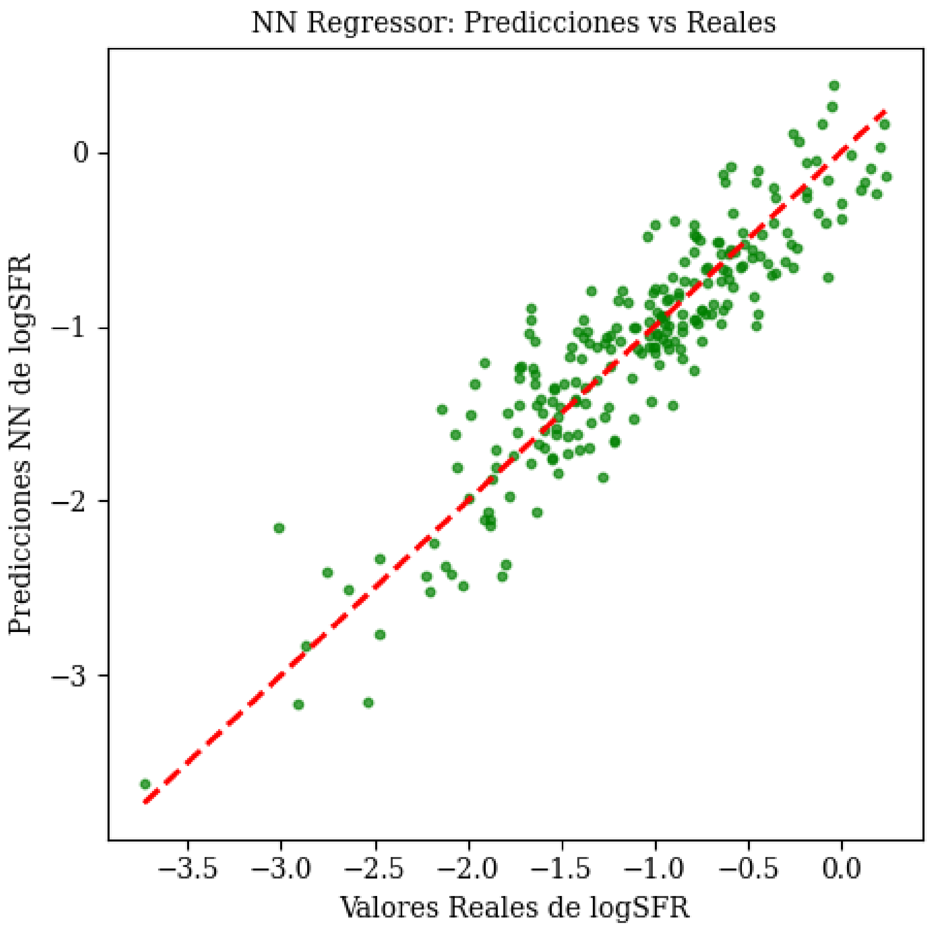
```
/home/2025/AST0421-1/svtroncoso/.local/lib/python3.10/site-packages/
sklearn/neural_network/_multilayer_perceptron.py:781:
ConvergenceWarning: Stochastic Optimizer: Maximum iterations (200)
reached and the optimization hasn't converged yet.
  warnings.warn(
```

```
cm = confusion_matrix(y_test_c, y_pred_c)
plt.figure(figsize=(4, 4))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues', cbar=False)
plt.xlabel("Predicciones")
plt.ylabel("Valores Reales")
plt.title("NN Clasificación: Matriz de Confusión")
plt.tight_layout()
plt.show()
```

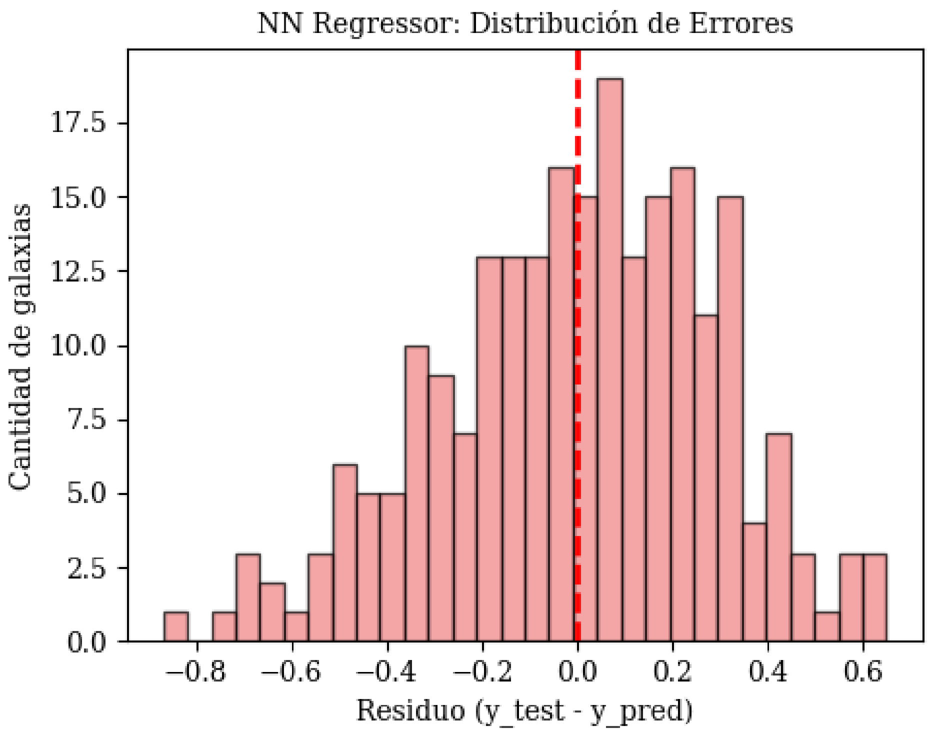



```
plt.figure(figsize=(5, 5))
plt.scatter(y_test_r, y_pred_r, s=10, alpha=0.7, color='green')
plt.plot([y_test_r.min(), y_test_r.max()],
```

```
        [y_test_r.min(), y_test_r.max()],
        'r--', lw=2)
plt.xlabel("Valores Reales de logSFR")
plt.ylabel("Predicciones NN de logSFR")
plt.title("NN Regressor: Predicciones vs Reales")
plt.tight_layout()
plt.show()
```



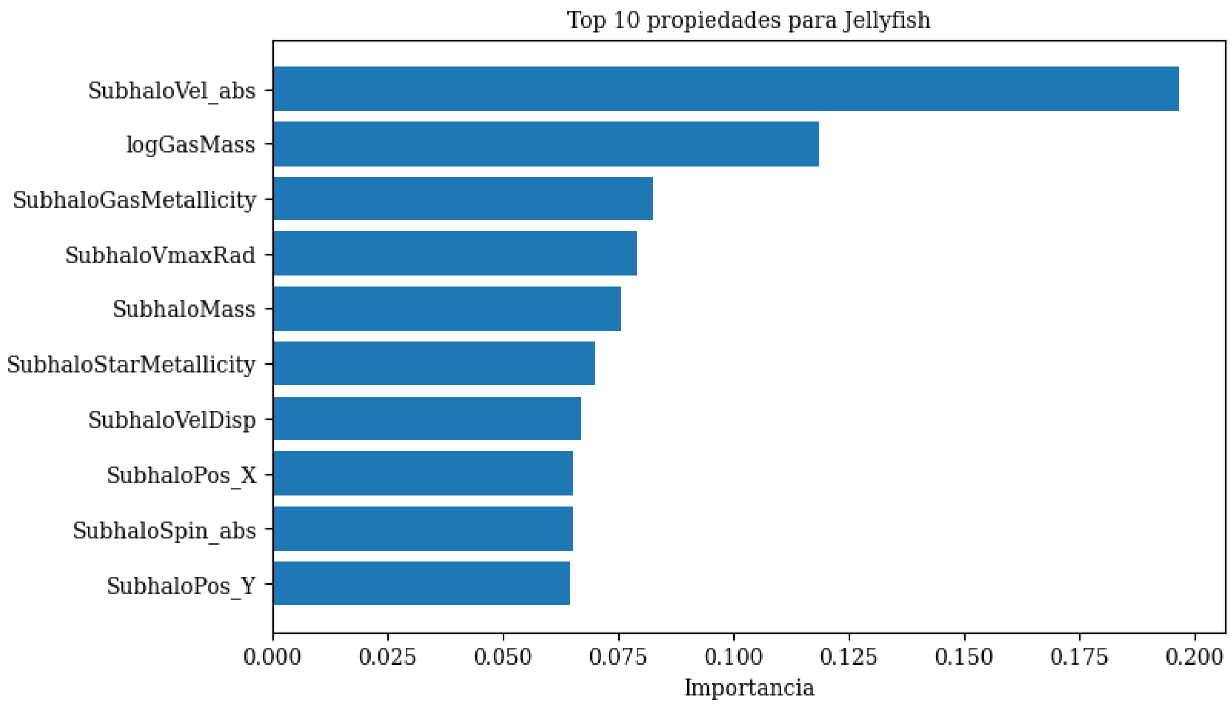

```
residuals = y_test_r - y_pred_r
plt.figure(figsize=(5, 4))
plt.hist(residuals, bins=30, color='lightcoral', edgecolor='k',
alpha=0.7)
plt.axvline(0, color='red', linestyle='--', lw=2)
plt.xlabel("Residuo (y_test - y_pred)")
plt.ylabel("Cantidad de galaxias")
plt.title("NN Regressor: Distribución de Errores")
plt.tight_layout()
plt.show()
```

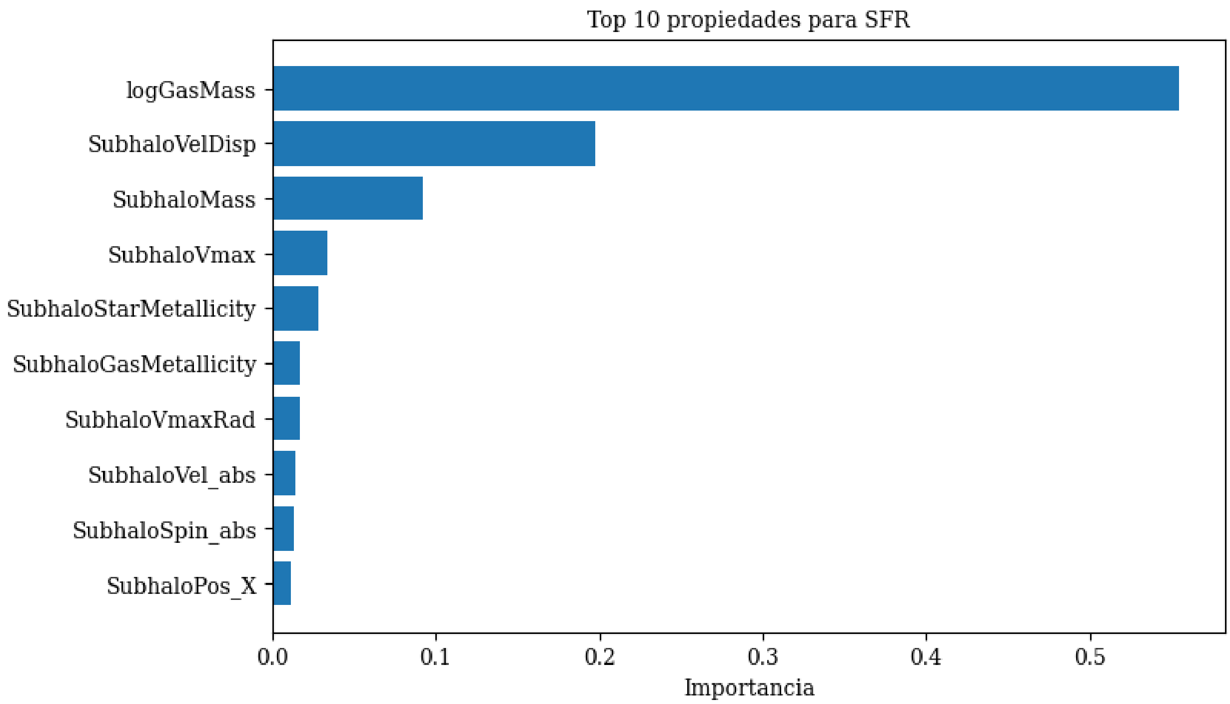


6.

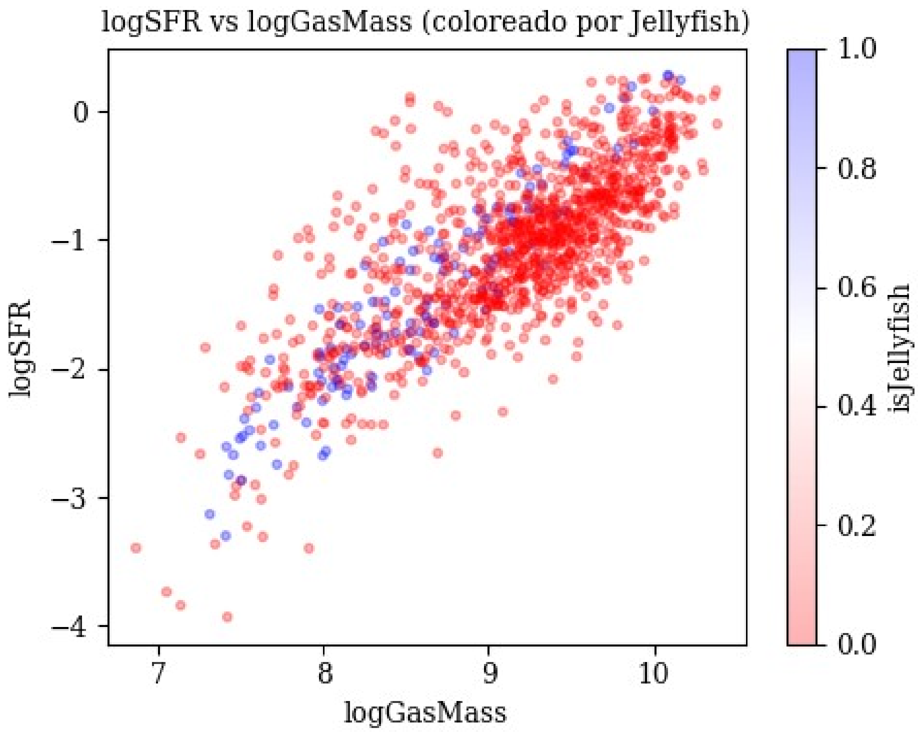
```
features = df_clean.drop(columns=['isJellyfish', 'logSFR',
'SubhaloID'])
X = features.values
feature_names = features.columns

y_class = df_clean['isJellyfish'].values

y_reg = df_clean['logSFR'].values

rf_class = RandomForestClassifier(n_estimators=200, random_state=42)
rf_class.fit(X, y_class)
importances_class = rf_class.feature_importances_

rf_reg = RandomForestRegressor(n_estimators=200, random_state=42)
rf_reg.fit(X, y_reg)
importances_reg = rf_reg.feature_importances_

def plot_importances(importances, names, top=10, title="Importancia de
variables"):
    idx = np.argsort(importances)[::-1][:top]
    plt.figure(figsize=(8,5))
    plt.barh(range(top), importances[idx][::-1], align='center')
    plt.yticks(range(top), names[idx][::-1])
    plt.xlabel("Importancia")
```

```python
    plt.title(title)
    plt.show()


plot_importances(importances_class, feature_names, top=10, title="Top
10 propiedades para Jellyfish")
plot_importances(importances_reg, feature_names, top=10, title="Top 10
propiedades para SFR")
```

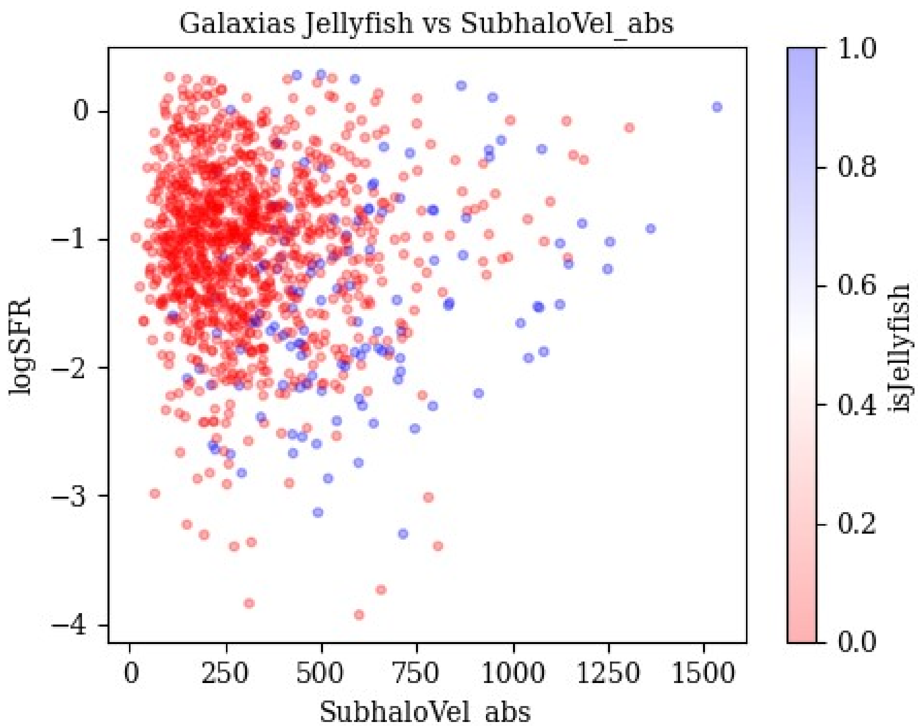




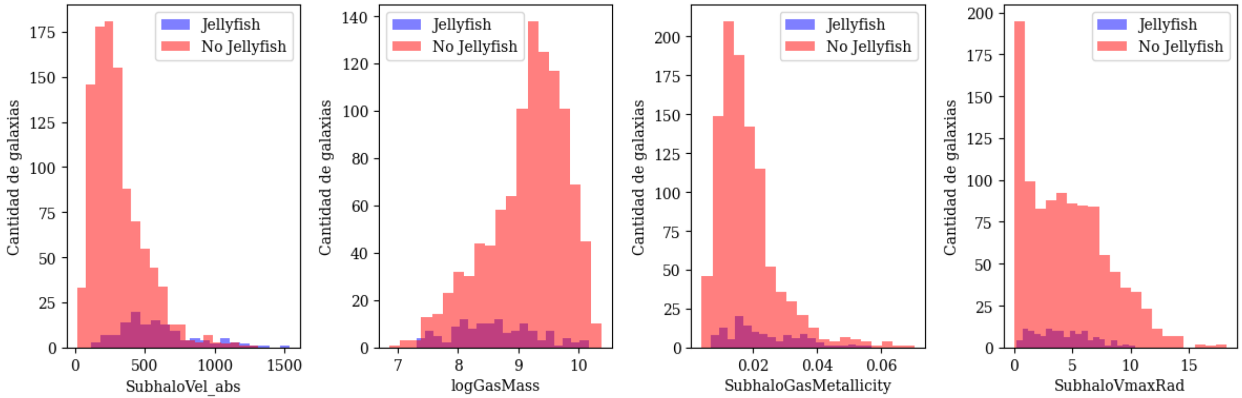

```
# Tomamos la propiedad más importante según RF regresor
top_feature = feature_names[np.argmax(importances_reg)]

plt.figure(figsize=(5,4))
plt.scatter(df_clean[top_feature], df_clean['logSFR'],
c=df_clean['isJellyfish'],
            cmap='bwr_r', s=10, alpha=0.3)
plt.xlabel(top_feature)
plt.ylabel("logSFR")
plt.title(f"logSFR vs {top_feature} (coloreado por Jellyfish)")
plt.colorbar(label="isJellyfish")
plt.tight_layout()
plt.show()
```



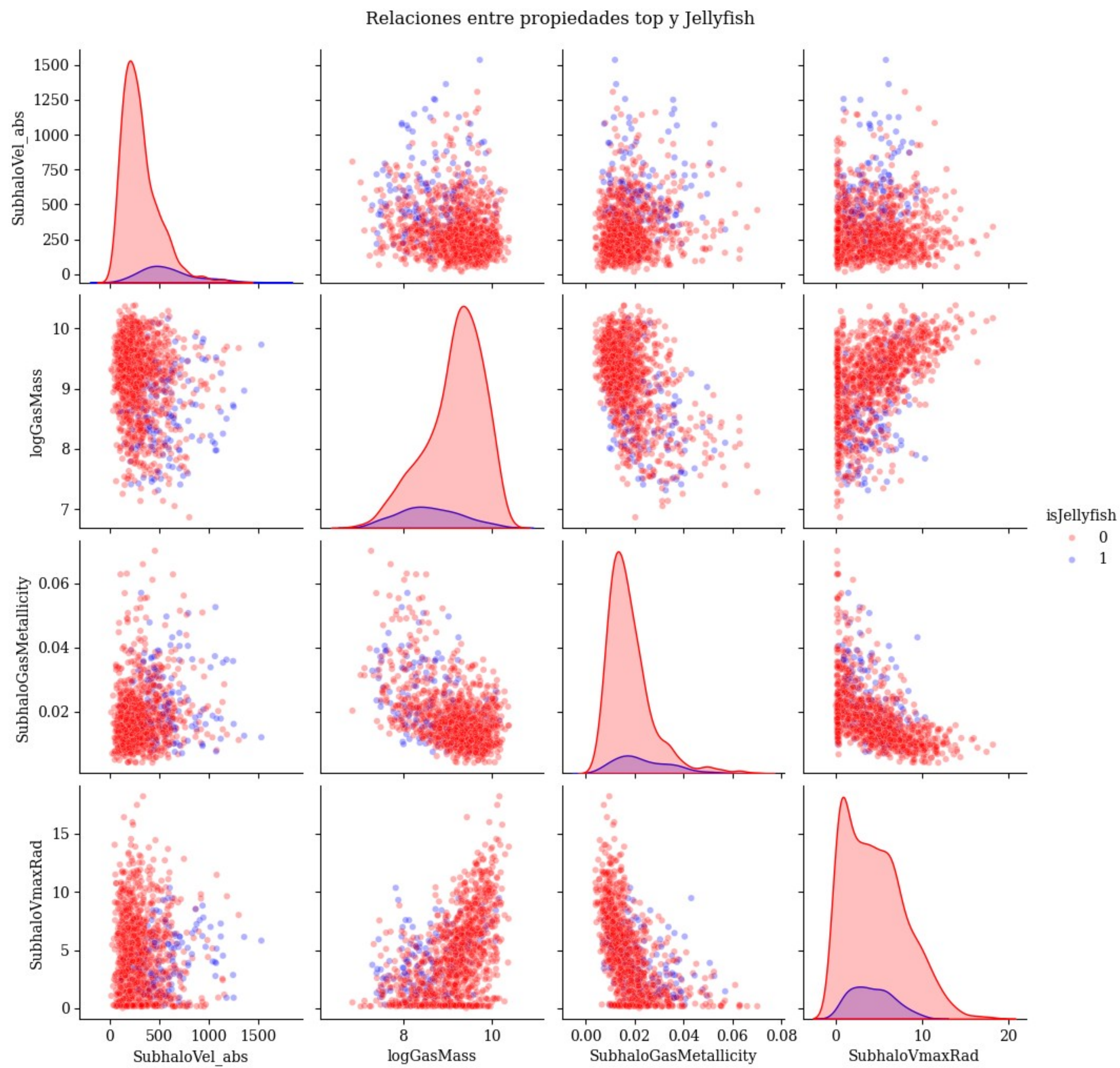

```
top_feature_class = feature_names[np.argmax(importances_class)]

plt.figure(figsize=(5,4))
plt.scatter(df_clean[top_feature_class], df_clean['logSFR'],
c=df_clean['isJellyfish'],
            cmap='bwr_r', s=10, alpha=0.3)
plt.xlabel(top_feature_class)
plt.ylabel("logSFR")
plt.title(f"Galaxias Jellyfish vs {top_feature_class}")
plt.colorbar(label="isJellyfish")
plt.tight_layout()
plt.show()
```



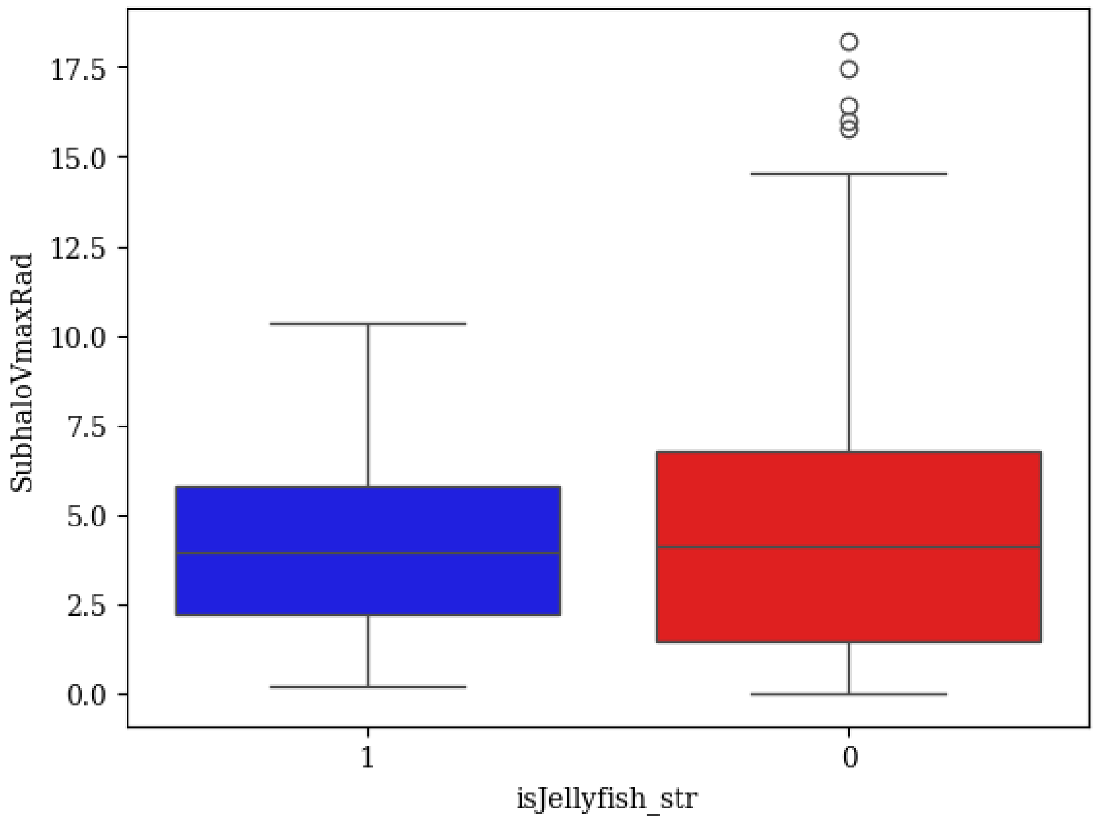

```
top_features_class = feature_names[np.argsort(importances_class)[::-1]
[:4]]  # top 4
plt.figure(figsize=(12,4))

for i, feat in enumerate(top_features_class):
    plt.subplot(1,4,i+1)
    plt.hist(df_clean.loc[df_clean['isJellyfish']==1, feat], bins=20,
alpha=0.5, label='Jellyfish', color='blue')
    plt.hist(df_clean.loc[df_clean['isJellyfish']==0, feat], bins=20,
alpha=0.5, label='No Jellyfish', color='red')
    plt.xlabel(feat)
    plt.ylabel("Cantidad de galaxias")
    plt.legend()

plt.tight_layout()
plt.show()
```



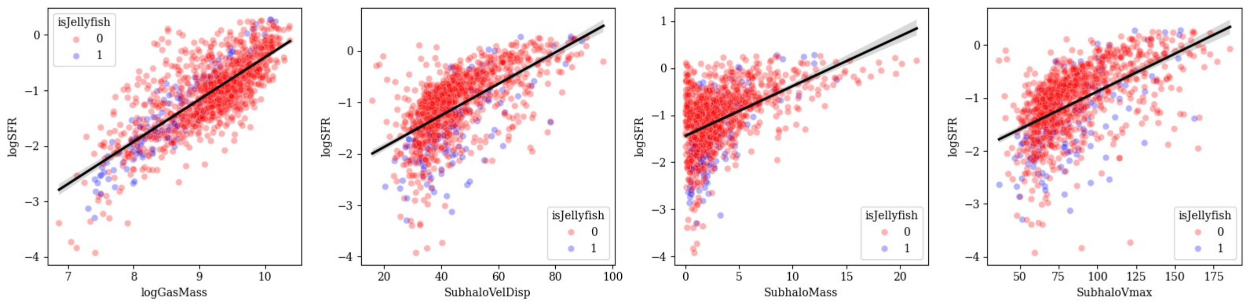

```python
# Seleccionamos top 4 propiedades del RF de clasificación
top_features = feature_names[np.argsort(importances_class)[::-1][:4]]
df_plot = df_clean[top_features.tolist() + ['isJellyfish']]

sns.pairplot(df_plot, hue='isJellyfish', palette={0:'red', 1:'blue'},
diag_kind='kde', plot_kws={'alpha':0.3, 's':20})
plt.suptitle("Relaciones entre propiedades top y Jellyfish", y=1.02)
plt.show()
```




```
df_clean['isJellyfish_str'] = df_clean['isJellyfish'].astype(str)
sns.boxplot(x='isJellyfish_str', y=feat, data=df_clean,
palette={'0':'red','1':'blue'})

/tmp/ipykernel_1726671/1133309729.py:2: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be
removed in v0.14.0. Assign the `x` variable to `hue` and set
`legend=False` for the same effect.

  sns.boxplot(x='isJellyfish_str', y=feat, data=df_clean,
palette={'0':'red','1':'blue'})

<Axes: xlabel='isJellyfish_str', ylabel='SubhaloVmaxRad'>
```




```
top_features_reg = feature_names[np.argsort(importances_reg)[::-1]
[:4]]

plt.figure(figsize=(16,4))
for i, feat in enumerate(top_features_reg):
    plt.subplot(1,4,i+1)
    sns.scatterplot(x=feat, y='logSFR',
hue=df_clean['isJellyfish'].astype(int),
                    palette={0:'red', 1:'blue'}, data=df_clean,
alpha=0.3)
    sns.regplot(x=feat, y='logSFR', data=df_clean, scatter=False,
color='black')  # sin lowess
    plt.xlabel(feat)
    plt.ylabel('logSFR')
plt.tight_layout()
plt.show()
```




```
plt.figure(figsize=(10,8))
corr = df_clean.corr()
sns.heatmap(corr, annot=True, fmt=".2f", cmap='coolwarm',
cbar_kws={'label':'Correlación'})
plt.title("Mapa de correlación entre propiedades")
plt.show()
```