predictions2

June 15, 2021

1 Setup

[1]:
```
%load_ext autoreload
%autoreload 2
%aimport
```

```
Modules to reload:
all-except-skipped

Modules to skip:
```

[2]:
```
%matplotlib inline
```

[3]:
```
from relaxed.plot_defaults import *
```

[4]:
```
import astropy
from pathlib import Path
import numpy as np
import matplotlib.pyplot as plt
import re
from astropy.table import Table
import astropy.table
import json
from scipy import stats
from copy import deepcopy
import scipy
import warnings

import matplotlib as mpl
from sklearn.model_selection import train_test_split
```

[5]:
```
from relaxed.analysis import setup, get_quantiles, gaussian_conditional,␣
 ↪get_am, get_a2_from_am, get_lam
```

2 Data

[21]:
```
# catalog
hcat, indices, scales = setup('m11', path='../../output')
xoff = hcat.cat['xoff']
cvir = hcat.cat['cvir']
eta = hcat.cat['eta']

# obtain a_m
am, mass_bins = get_am('m11', min_mass=0.1, path='../../output')
a2 = get_a2_from_am(am, mass_bins)

# throw away first & last, useless bin (a = 1.00 always for that)
am = am[:, 1:-1]
mass_bins = mass_bins[1:-1]
print(am.shape, mass_bins.shape, a2.shape, cvir.shape, xoff.shape, eta.shape)
```

```
(30000, 98) (98,) (30000,) (30000,) (30000,) (30000,)
```

[22]:
```
 # remove nan's from lam along the way, like ~1k haloes.
keep, lam, cvir, a2, xoff, eta = get_lam(am, cvir, a2, xoff, eta)
am = am[keep]
print(sum(keep), lam.shape, cvir.shape, a2.shape, am.shape, xoff.shape, eta.
 ↪shape)
```

```
28366 (28366, 98) (28366,) (28366,) (28366, 98) (28366,) (28366,)
```

[23]:
```
# train/test split.
lam_train, lam_test, cvir_train, cvir_test,\
a2_train, a2_test, am_train, am_test, \
xoff_train, xoff_test, eta_train, eta_test = train_test_split(lam, cvir, a2,␣
 ↪am, xoff, eta, test_size=0.2)
print(cvir_train.shape)
print(cvir_test.shape)
```

```
(22692,)
(5674,)
```

3 Train

[25]:
```
from relaxed.analysis import training_suite
```

[26]:
```
cvir_models = training_suite(cvir_train, am_train, mass_bins=mass_bins,␣
 ↪suite=("LN-RS", "CAM", "MG-A2", "MV-LLR", "MV-LR", "MG-TFC"))
```

[27]:
```
xoff_models = training_suite(xoff_train, am_train, mass_bins=mass_bins,␣
 ↪suite=("LN-RS", "CAM", "MG-A2", "MV-LLR", "MV-LR", "MG-TFC"))
```

[28]:
```
eta_models = training_suite(eta_train, am_train, mass_bins=mass_bins,␣
↪suite=("LN-RS", "CAM", "MG-A2", "MV-LLR", "MV-LR", "MG-TFC"))
```

4 Plots

4.1 Combined histogram of residuals

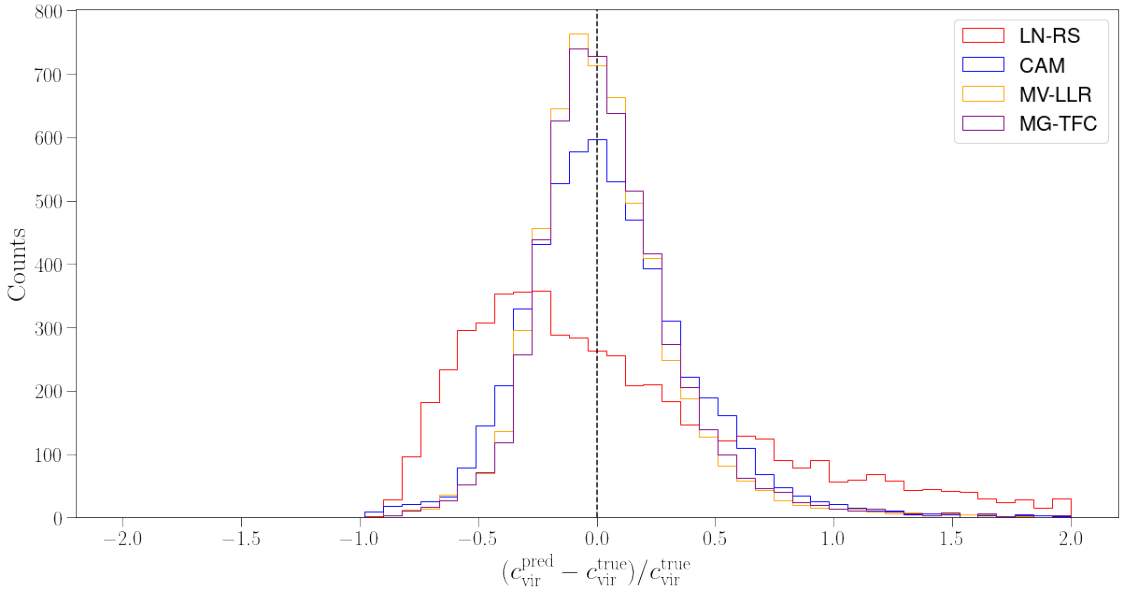
[37]:
```
# funcs are trained functions that take in lam_test and return cvir_pred,␣
↪colors are color for each function.
def combined_histogram(lam_test, X_test, trained_models, colors=('r', 'b',␣
↪'g'), names=("CAM"),
                       n_bins=51, latex_var="", xrange=(-2, 2)):
    fig, ax = plt.subplots(1, 1, figsize=(20, 10))
    bins = None
    correlations = []
    for i, name in enumerate(names):
        model = trained_models[name]
        X_pred = model(lam_test)
        x = (X_pred - X_test) / X_test
        if bins is None:
            bins = get_bins(x, range=xrange, bins=n_bins) # share bins between␣
↪all histograms.
        draw_histogram(ax, x, vline=None, label=name, color=colors[i],
                       bins=bins, density=False)

        print(f'{name} corr: {scipy.stats.spearmanr(X_pred, X_test)[0]}')

    ax.axvline(0, color='k', ls='--')
    ax.legend()
    ax.set_ylabel(r"\rm Counts", size=28)

    v_pred = latex_var + r"^{\rm pred}"
    v_test = latex_var + r"^{\rm true}"

    ax.set_xlabel(f"$({v_pred} - {v_test}) / {v_test}$", size=28)
```

4.1.1 Cvir

[38]:
```
names = ['LN-RS', 'CAM', "MV-LLR", "MG-TFC"]
colors = ['r', 'b', 'orange', 'purple', 'g']
combined_histogram(lam_test, cvir_test, cvir_models, colors=colors,␣
↪names=names, latex_var=r'c_{\rm vir}', n_bins=51)
```

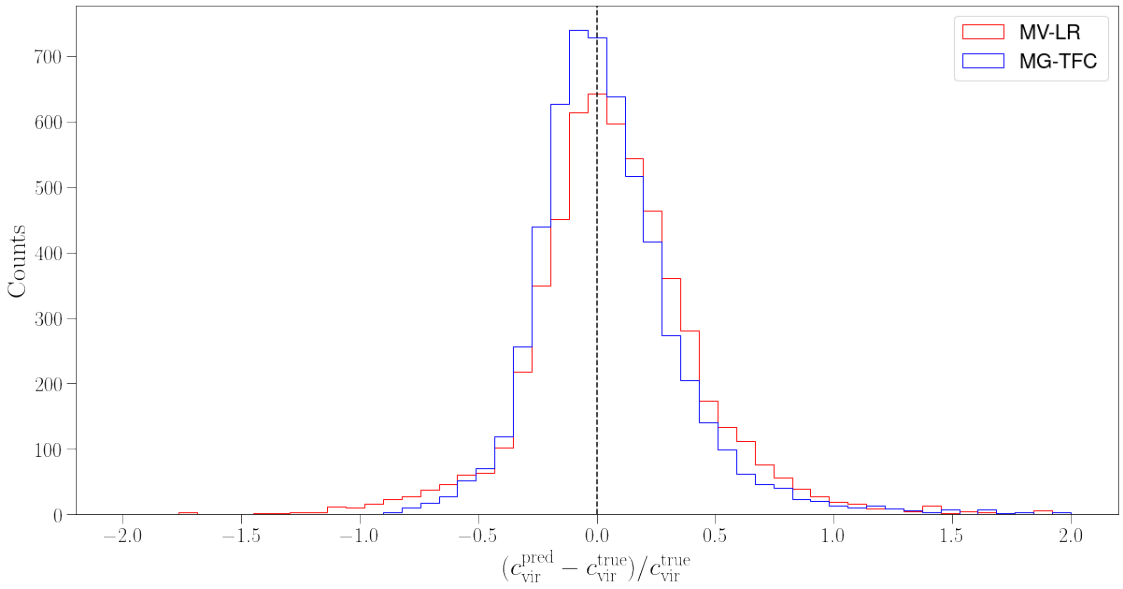
```
LN-RS corr: -0.014531819012609826
CAM corr: 0.6858815242140845
MV-LLR corr: 0.7634554270106592
```

```
MG-TFC corr: 0.7652705110332769
```



[39]:
```
names = ["MV-LR", "MG-TFC"]
colors = ['r', 'b']
combined_histogram(lam_test, cvir_test, cvir_models, colors=colors,␣
 ↪names=names, latex_var=r'c_{\rm vir}')

# we note that the quantile transformer is actually doing work in finding an␣
 ↪optimal subspace in which to do the regression.
```

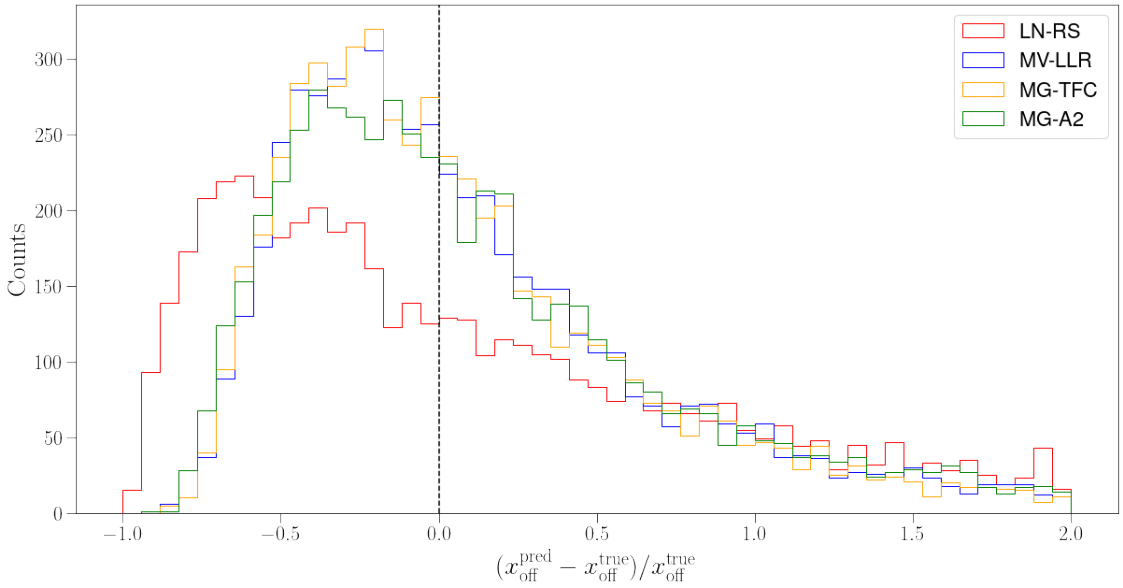
```
MV-LR corr: 0.7355992519954224
MG-TFC corr: 0.7652705110332769
```



4.1.2 Xoff

[53]:
```
names = ['LN-RS', "MV-LLR", "MG-TFC", "MG-A2"]
colors = ['r', 'b', 'orange', 'g']
combined_histogram(lam_test, xoff_test, xoff_models, colors=colors,␣
↪names=names, latex_var=r'x_{\rm off}', n_bins=51, xrange=(-1, 2))
```

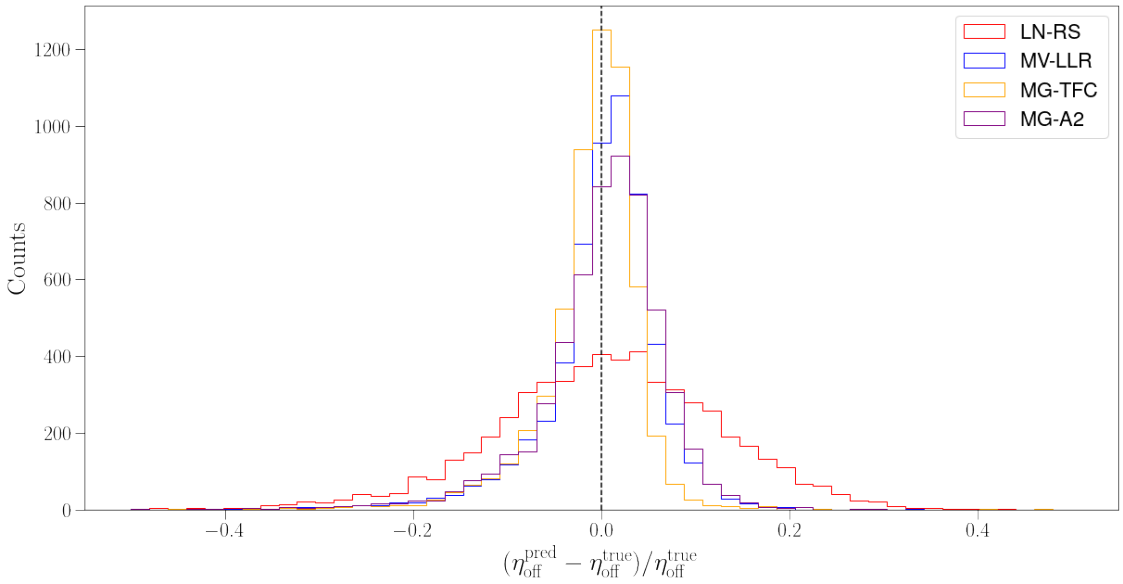
```
LN-RS corr: -0.008278319251520441
MV-LLR corr: 0.5358589501219698
MG-TFC corr: 0.5478754675151067
MG-A2 corr: 0.4425207601563688
```



4.1.3 eta

[54]:
```
names = ['LN-RS', "MV-LLR", "MG-TFC", "MG-A2"]
colors = ['r', 'b', 'orange', 'purple', 'g']
combined_histogram(lam_test, eta_test, eta_models, colors=colors, names=names,␣
↪latex_var=r'\eta_{\rm off}',
                   n_bins=51,
                   xrange=(-0.5, 0.5))
```

```
LN-RS corr: 0.007133833191152982
MV-LLR corr: 0.6834076176157013
MG-TFC corr: 0.7220360078739999
MG-A2 corr: 0.5867435507585897
```



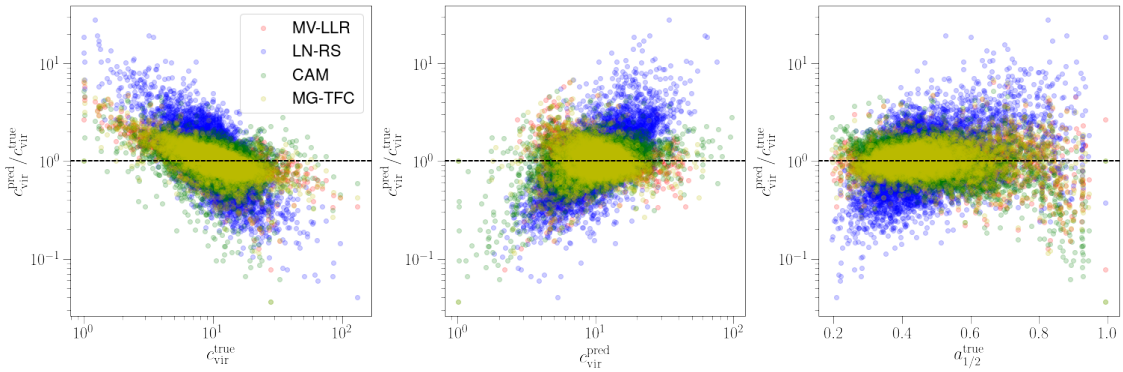
4.2 Scatter plots of residuals

[48]:
```
def scatter_plots(lam_test, X_test, trained_models, colors=('r',),␣
↪names=('CAM',), alpha=0.5, latex_var=""):
    fig, axes = plt.subplots(1, 3, figsize=(21, 7))
    ax1, ax2, ax3 = axes.flatten()
    for i, name in enumerate(names):
        model = trained_models[name]
        X_pred = model(lam_test)
        a_2_test = get_a2_from_am(np.exp(lam_test), mass_bins)
        x = X_pred / X_test
```

```
        v_true = latex_var + r"^{\rm true}"
        v_pred = latex_var + r"^{\rm pred}"

        ax1.scatter(X_test, x, alpha=alpha, color=colors[i], label=name)
        ax1.set_xlabel(f"${v_true}$")
        ax1.set_ylabel(f"${v_pred}/ {v_true}$")


        ax2.scatter(X_pred, x, alpha=alpha, color=colors[i], label=name)
        ax2.set_xlabel(f"${v_pred}$")
        ax2.set_ylabel(f"${v_pred}/ {v_true}$")

        ax3.scatter(a_2_test, x, alpha=alpha, color=colors[i], label=name)
        ax3.set_xlabel(r"$a_{1/2}^{\rm true}$")
        ax3.set_ylabel(f"${v_pred}/ {v_true}$")

        # add median line
        print(f'median {name}: ', np.median(x))
        ax1.axhline(1, ls='--', color='k')
        ax2.axhline(1, ls='--', color='k')
        ax3.axhline(1, ls='--', color='k')

        # set scales.
        ax1.set_xscale('log')
        ax2.set_xscale('log')

        ax1.set_yscale('log')
        ax2.set_yscale('log')
        ax3.set_yscale('log')

        ax1.legend()
    plt.tight_layout()
```

[49]:
```
names = ['MV-LLR', 'LN-RS', 'CAM', 'MG-TFC']
colors = ['r', 'b', 'g', 'y']
scatter_plots(lam_test, cvir_test, cvir_models, names=names, colors=colors,␣
 ↪alpha=0.2, latex_var=r'c_{\rm vir}')
```

```
median MV-LLR:  0.9968353249568148
median LN-RS:  0.9734207208635646
median CAM:  1.0172717888014475
median MG-TFC:  1.008432919808826
```



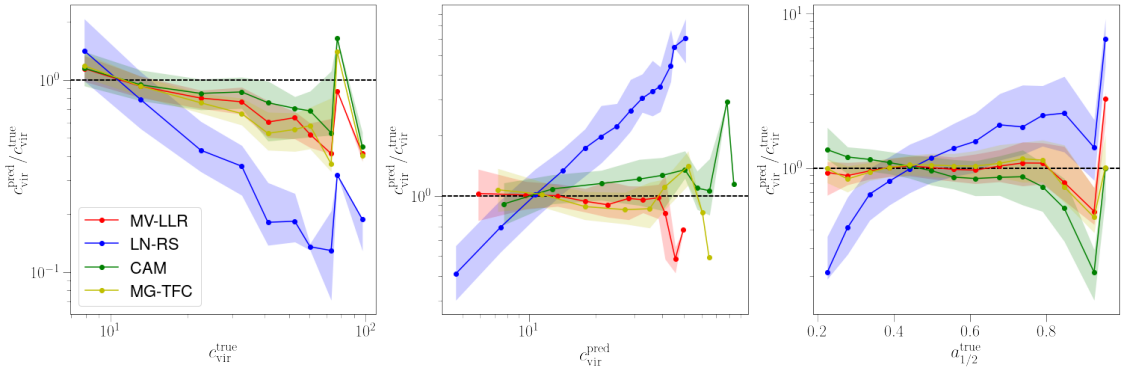
4.3 Median bin statistic

[50]:
```
def make_scatter_binning(ax, x, y, n_xbins=15, bin_bds=None, show_bands=True,␣
↪color='r', label=''):

    if bin_bds is not None:
        # ignore n_xbins
        size = len(bin_bds) - 1
        x_bds = np.array([(bin_bds[i], bin_bds[i + 1]) for i in range(size)])
    else:
        # divide uniformly.
        xs = np.linspace(np.min(x), np.max(x), n_xbins)
        x_bds = np.array([(xs[i], xs[i + 1]) for i in range(len(xs) - 1)])

    masks = [((x_bd[0] < x) & (x < x_bd[1])) for x_bd in x_bds]

    xbins = [x[mask] for mask in masks if len(x[mask]) > 0 and len(y[mask])>0] ␣
↪# remove empty ones.
    ybins = [y[mask] for mask in masks if len(x[mask]) > 0 and len(y[mask])>0]

    xmeds = np.array([np.median(xbin) for xbin in xbins])
    ymeds = np.array([np.median(ybin) for ybin in ybins])

    ax.errorbar(
        xmeds,
        ymeds,
        fmt="o-",
        color=color,
        label=label,
        capsize=10,
    )

    y1 = np.array([np.quantile(ybin, 0.25) for ybin in ybins])
```

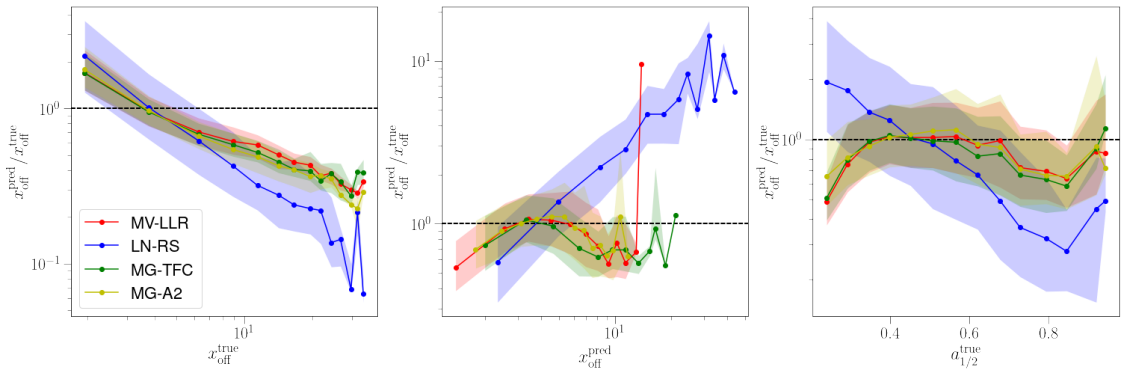
```
    y2 = np.array([np.quantile(ybin, 0.75) for ybin in ybins])

    if show_bands:
        ax.fill_between(xmeds, y1, y2, alpha=0.2, linewidth=0.001, color=color)
```

[58]:
```
def median_bin_statistic(lam_test, X_test, trained_models, colors=('r', 'b','g'), names=("CAM",), latex_var="", log_scale=True):
    fig, axes = plt.subplots(1, 3, figsize=(21, 7))
    ax1, ax2, ax3 = axes.flatten()
    for i, name in enumerate(names):
        model = trained_models[name]
        X_pred = model(lam_test)
        a_2_test = get_a2_from_am(np.exp(lam_test), mass_bins)
        x = X_pred / X_test

        v_true = latex_var + r"^{\rm true}"
        v_pred = latex_var + r"^{\rm pred}"

        make_scatter_binning(ax1, X_test, x, color=colors[i], label=names[i])
        ax1.set_xlabel(f"${v_true}$")
        ax1.set_ylabel(f"${v_pred}/ {v_true}$")


        make_scatter_binning(ax2, X_pred, x, color=colors[i], label=names[i])
        ax2.set_xlabel(f"${v_pred}$")
        ax2.set_ylabel(f"${v_pred}/ {v_true}$")

        make_scatter_binning(ax3, a_2_test, x, color=colors[i], label=names[i])
        ax3.set_xlabel(r"$a_{1/2}^{\rm true}$")
        ax3.set_ylabel(f"${v_pred}/ {v_true}$")

        # visual guides.
        ax1.axhline(1, ls='--', color='k')
        ax2.axhline(1, ls='--', color='k')
        ax3.axhline(1, ls='--', color='k')

        if log_scale:
            # set scales.
            ax1.set_xscale('log')
            ax2.set_xscale('log')

            ax1.set_yscale('log')
            ax2.set_yscale('log')
            ax3.set_yscale('log')

        ax1.legend()
    plt.tight_layout()
```

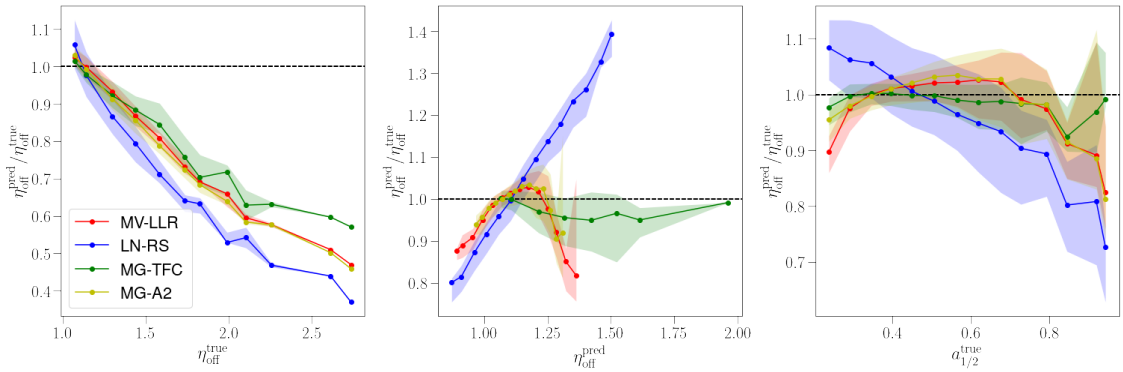
[35]:
```
names = ['MV-LLR', 'LN-RS', 'CAM', 'MG-TFC']
colors = ['r', 'b', 'g', 'y']
median_bin_statistic(lam_test, cvir_test, cvir_models, names=names,␣
↪colors=colors, latex_var=r'c_{\rm vir}')
```



[56]:
```
names = ['MV-LLR', 'LN-RS', 'MG-TFC', "MG-A2"]
colors = ['r', 'b', 'g', 'y']
median_bin_statistic(lam_test, xoff_test, xoff_models, names=names,␣
↪colors=colors, latex_var=r'x_{\rm off}')
```



[59]:
```
names = ['MV-LLR', 'LN-RS', 'MG-TFC', "MG-A2"]
colors = ['r', 'b', 'g', 'y']
median_bin_statistic(lam_test, eta_test, eta_models, names=names,␣
↪colors=colors, latex_var=r'\eta_{\rm off}', log_scale=False)
```


MV-LLR
LN-RS
MG-TFC
MG-A2
$\eta_{\text{off}}^{\text{pred}} / \eta_{\text{off}}^{\text{true}}$
$\eta_{\text{off}}^{\text{true}}$
$\eta_{\text{off}}^{\text{pred}}$
$a_{1/2}^{\text{true}}$

[ ]: