An Updated Reference Time-Domain Survey and Cosmology Forecast with The Roman Space Telescope
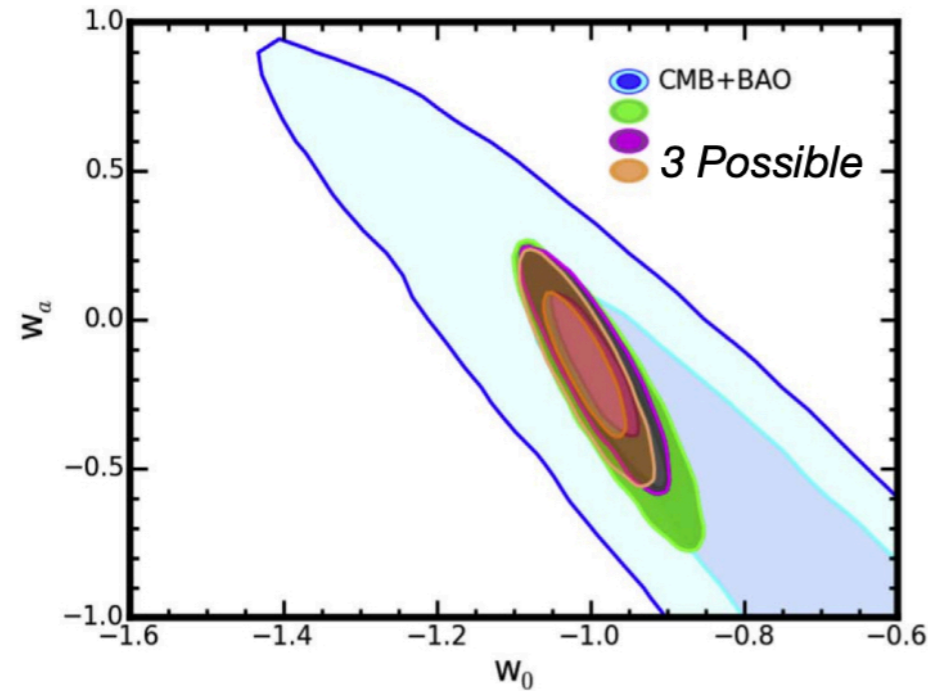
Phillip Macias (UC Santa Cruz)
+ Supernova SITs

pmacias@ucsc.edu

Roman Time Domain Conference 2/8/22

Roman Cosmology with Type Ia Supernovae
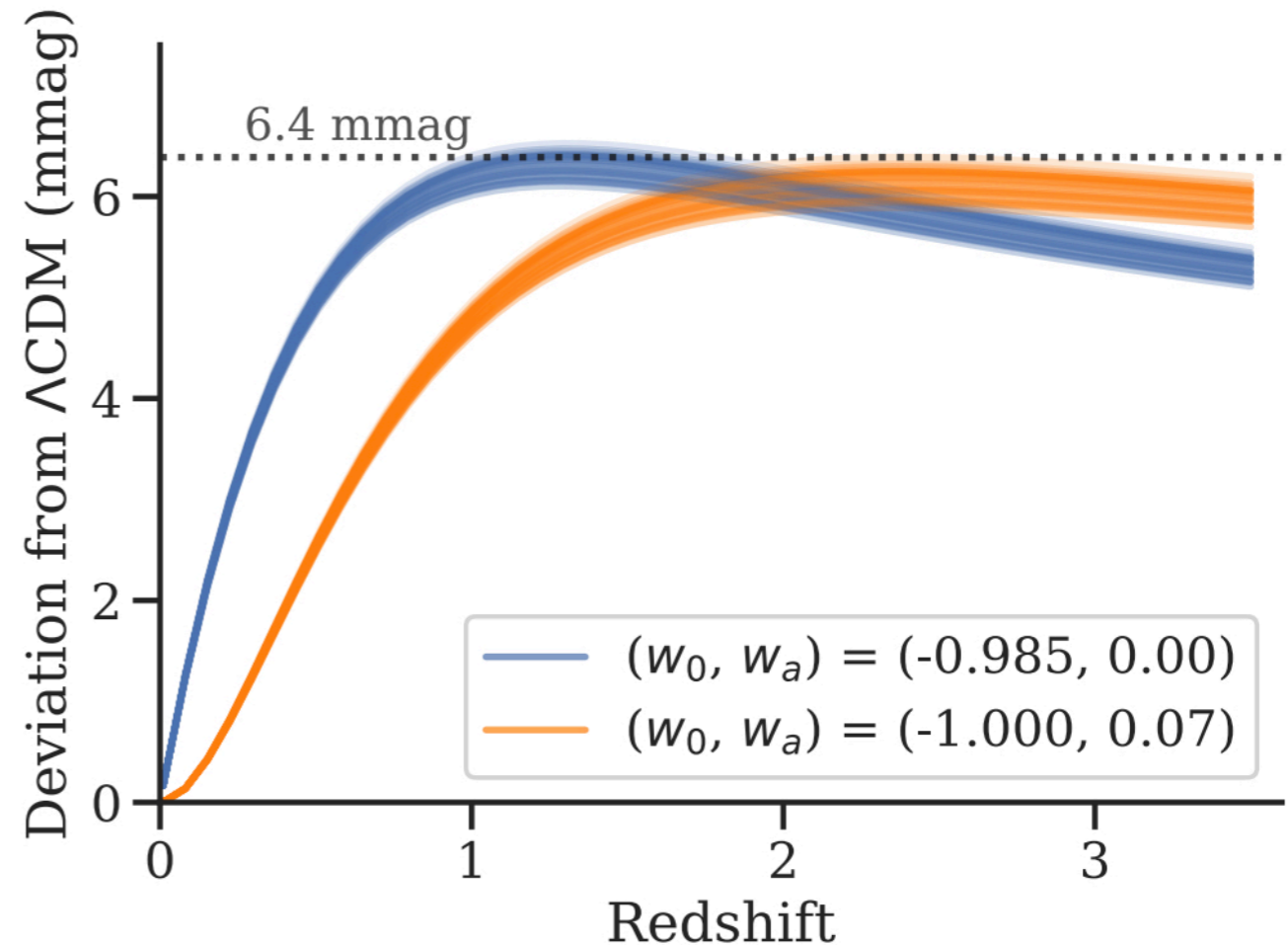

Hounsell et al. 2018

CMB+BAO

3 Possible

SN Requirement 2.0.1

FoM > 325

The Figure of Merit requirement includes data from the CMB (the Planck Collaboration 2016) and BAO (Anderson et al 2014) .
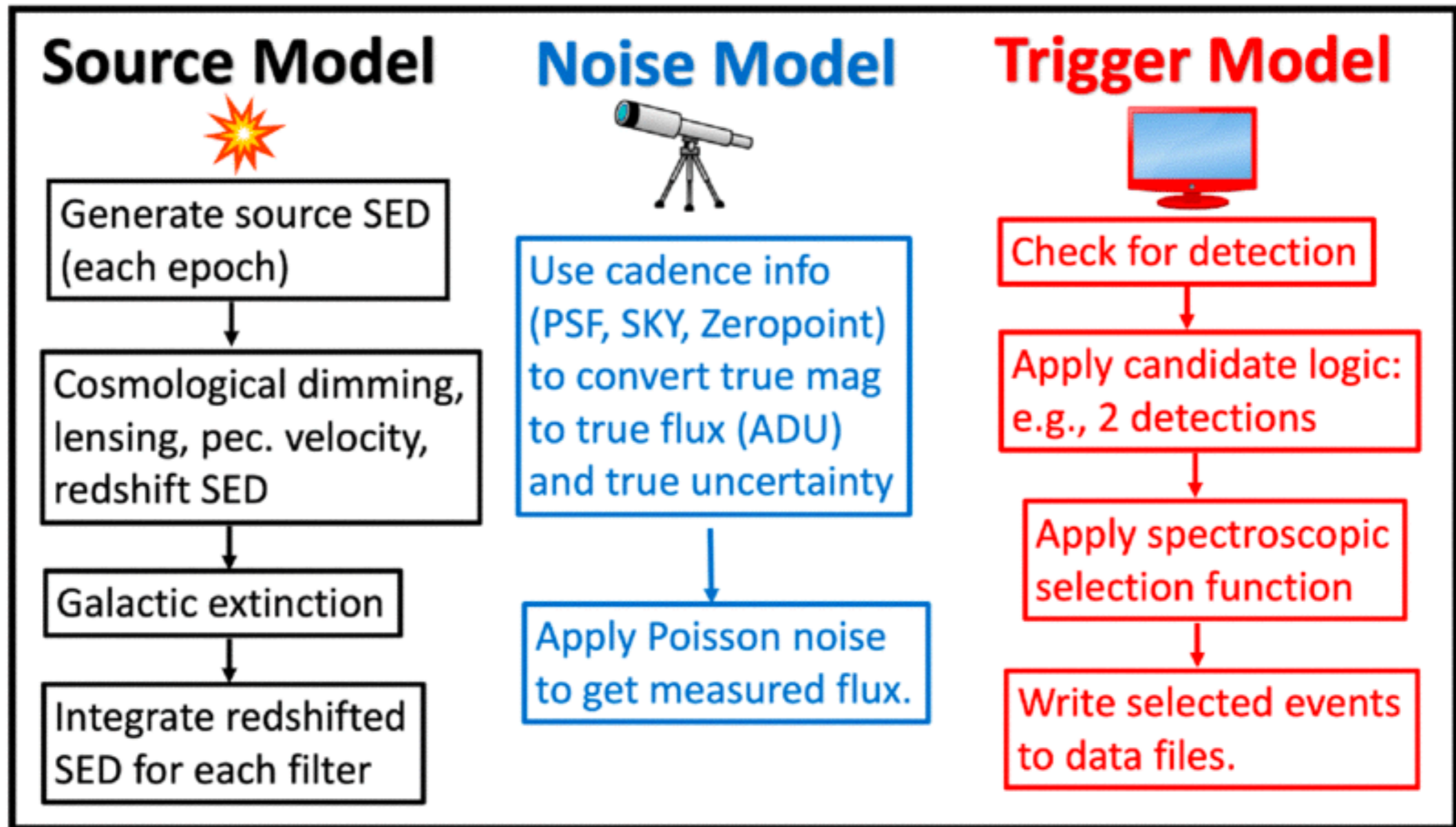
6.4 mmag

$(w_0, w_a) = (-0.985, 0.00)$
$(w_0, w_a) = (-1.000, 0.07)$

Deviation from ΛCDM (mmag)

Redshift

Shaded region shows effect of Ω_M uncertainty

survey is
6 months over 2 years

slide courtesy of Ben Rose

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The Supernova Analysis Package (SNANA)

https://github.com/RickKessler/SNANA

Image: R. Kessler

Roman Time Domain Conference 2/8/22

Pippin Pipeline for Supernova Survey Analysis

https://github.com/Samreay/Pippin

survey level choices: cadence, depth, filters, tiers, fields

```
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Task finished with wall time 0:07:23
FINISHED: AnalyseChains BANANA_OMW task (wall time 0:07:23, 1 jobs, deps ['SN_BANANA_OMW_NGRST_COV_BBC']) with 1 NUM_JOBS. NUM_JOBS now 0
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CURRENT TASK STATUS
Key: WAITING  RUNNING  DONE  FAILED  BLOCKED
SIM         NGRST_BIASCOR_G10    FOUND_BIASCOR_G10    NGRST_SIMDATA_G10    FOUND_SI
LCFIT       NGRSTfit_SIM_NGRST_SIMDATA_G10    NGRSTfit_BIAS_NGRST_BIASCOR_G10    F
            FOUNDfit_BIAS_FOUND_BIASCOR_G10
CLASSIFY    FITPROBTEST    FITPROBTEST
AGGREGATE   AGG_NGRST_BIASCOR_G10    AGG_FOUND_BIASCOR_G10    AGG_NGRST_SIMDATA_G1
MERGE       MERGE_NGRSTfit_SIM_NGRST_SIMDATA_G10    MERGE_NGRSTfit_BIAS_NGRST_BIA
            MERGE_FOUNDfit_SIM_FOUND_SIMDATA_G10    MERGE_FOUNDfit_BIAS_FOUND_BIA
BIASCOR     BBC
CREATE_COV  NGRST_COV_BBC
COSMOMC     SN_BANANA_OMW_NGRST_COV_BBC
ANALYSE     BANANA_OMW
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All tasks finished. Task summary as follows.
Successfully completed tasks:
        SNANASimulation NGRST_BIASCOR_G10 task (wall time 1:28:17, 1 jobs, deps
        SNANASimulation FOUND_BIASCOR_G10 task (wall time 0:54:49, 1 jobs, deps
        SNANASimulation NGRST_SIMDATA_G10 task (wall time 1:05:03, 1 jobs, deps
        SNANASimulation FOUND_SIMDATA_G10 task (wall time 1:02:04, 1 jobs, deps
        SNANALightCurveFit NGRSTfit_SIM_NGRST_SIMDATA_G10 task (wall time 2:46:40, 12 jobs, deps ['NGRST_SIMDATA_G10'])
        SNANALightCurveFit NGRSTfit_BIAS_NGRST_BIASCOR_G10 task (wall time 11:34:02, 36 jobs, deps ['NGRST_BIASCOR_G10'])
        SNANALightCurveFit FOUNDfit_SIM_FOUND_SIMDATA_G10 task (wall time 0:29:37, 10 jobs, deps ['FOUND_SIMDATA_G10'])
        SNANALightCurveFit FOUNDfit_BIAS_FOUND_BIASCOR_G10 task (wall time 0:44:56, 10 jobs, deps ['FOUND_BIASCOR_G10'])
        FitProbClassifier FITPROBTEST task (wall time 0:00:00, 1 jobs, deps ['NGRST_SIMDATA_G10', 'NGRSTfit_SIM_NGRST_SIMDATA_G10'])
        FitProbClassifier FITPROBTEST task (wall time 0:00:00, 1 jobs, deps ['NGRST_BIASCOR_G10', 'NGRSTfit_BIAS_NGRST_BIASCOR_G10'])
        Aggregator AGG_NGRST_BIASCOR_G10 task (wall time 0:00:23, 1 jobs, deps ['FITPROBTEST'])
        Aggregator AGG_FOUND_BIASCOR_G10 task (wall time 0:00:13, 1 jobs, deps ['FOUND_BIASCOR_G10'])
        Aggregator AGG_NGRST_SIMDATA_G10 task (wall time 0:00:18, 1 jobs, deps ['FITPROBTEST'])
        Aggregator AGG_FOUND_SIMDATA_G10 task (wall time 0:00:08, 1 jobs, deps ['FOUND_SIMDATA_G10'])
```
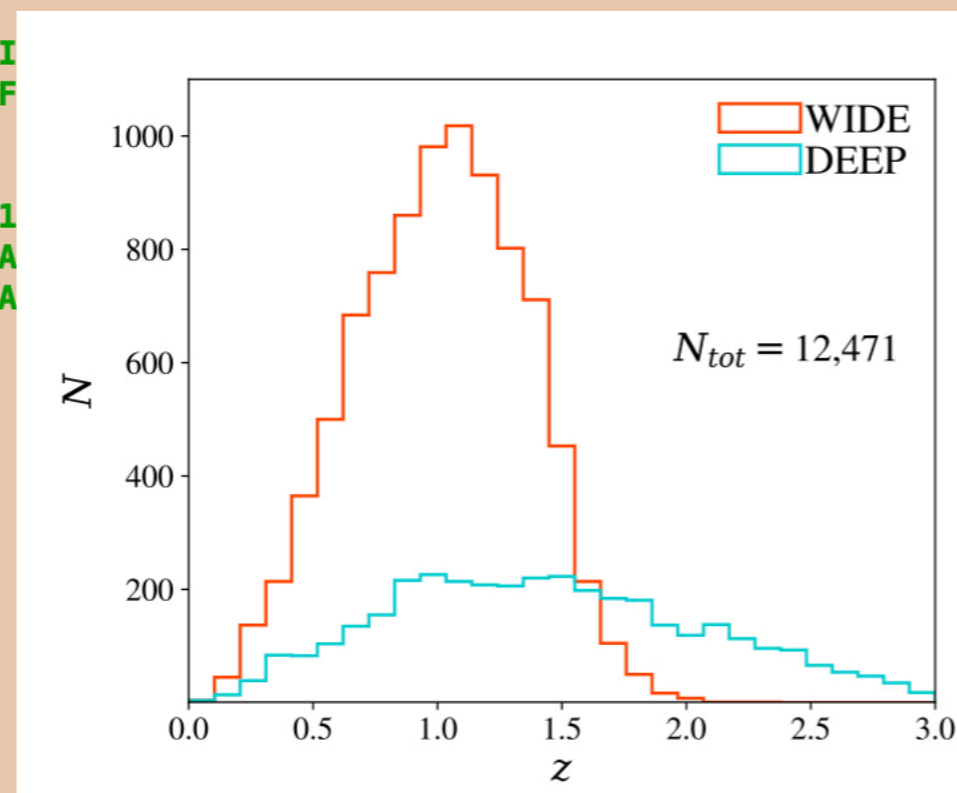
1: simulate LCs (output in catalog form)

+ …

Pippin Pipeline for Supernova Survey Analysis
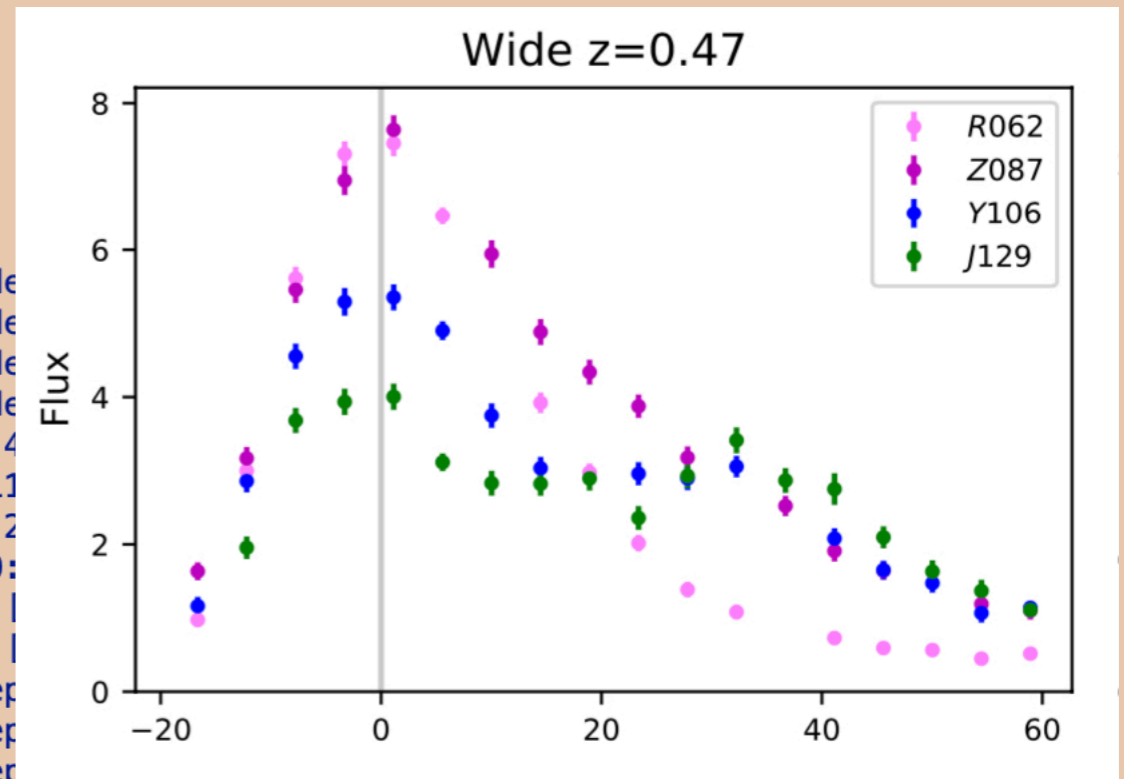
https://github.com/Samreay/Pippin

survey level choices: cadence, depth, filters, tiers, fields

```
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Task finished with wall time 0:07:23
FINISHED: AnalyseChains BANANA_OMW task (wall time 0:07:23, 1 jobs, deps ['SN_BANANA_OMW_NGRST_COV_BBC']) with 1 NUM_JOBS. NUM_JOBS now 0
--------------------
CURRENT TASK STATUS
Key: WAITING  RUNNING  DONE  FAILED  BLOCKED
SIM         NGRST_BIASCOR_G10   FOUND_BIASCOR_G10   NGRST_SIMDATA_G10   FOUND_SIMDATA_G10
LCFIT       NGRSTfit_SIM_NGRST_SIMDATA_G10   NGRSTfit_BIAS_NGRST_BIASCOR_G10   FOUNDfit_SIM_FOUND_SIMDATA_G10
            FOUNDfit_BIAS_FOUND_BIASCOR_G10
CLASSIFY    FITPROBTEST   FITPROBTEST
AGGREGATE   AGG_NGRST_BIASCOR_G10   AGG_FOUND_BIASCOR_G10   AGG_NGRST_SIMDATA_G10   AGG_FOUND_SIMDATA_G10
MERGE       MERGE_NGRSTfit_SIM_NGRST_SIMDATA_G10   MERGE_NGRSTfit_BIAS_NGRST_BIASCOR_G10
            MERGE_FOUNDfit_SIM_FOUND_SIMDATA_G10   MERGE_FOUNDfit_BIAS_FOUND_BIASCOR_G10
BIASCOR     BBC
CREATE_COV  NGRST_COV_BBC
COSMOMC     SN_BANANA_OMW_NGRST_COV_BBC
ANALYSE     BANANA_OMW
--------------------

All tasks finished. Task summary as follows.
Successfully completed tasks:
     SNANASimulation NGRST_BIASCOR_G10 task (wall time 1:28:17, 1 jobs, de
     SNANASimulation FOUND_BIASCOR_G10 task (wall time 0:54:49, 1 jobs, de
     SNANASimulation NGRST_SIMDATA_G10 task (wall time 1:05:03, 1 jobs, de
     SNANASimulation FOUND_SIMDATA_G10 task (wall time 1:02:04, 1 jobs, de
     SNANALightCurveFit NGRSTfit_SIM_NGRST_SIMDATA_G10 task (wall time 2:4
     SNANALightCurveFit NGRSTfit_BIAS_NGRST_BIASCOR_G10 task (wall time 11
     SNANALightCurveFit FOUNDfit_SIM_FOUND_SIMDATA_G10 task (wall time 0:2
     SNANALightCurveFit FOUNDfit_BIAS_FOUND_BIASCOR_G10 task (wall time 0:
     FitProbClassifier FITPROBTEST task (wall time 0:00:00, 1 jobs, deps
     FitProbClassifier FITPROBTEST task (wall time 0:00:00, 1 jobs, deps
     Aggregator AGG_NGRST_BIASCOR_G10 task (wall time 0:00:23, 1 jobs, dep
     Aggregator AGG_FOUND_BIASCOR_G10 task (wall time 0:00:13, 1 jobs, dep
     Aggregator AGG_NGRST_SIMDATA_G10 task (wall time 0:00:18, 1 jobs, dep
     Aggregator AGG_FOUND_SIMDATA_G10 task (wall time 0:00:08, 1 jobs, deps ['FOUND_SIMDATA_G10'])
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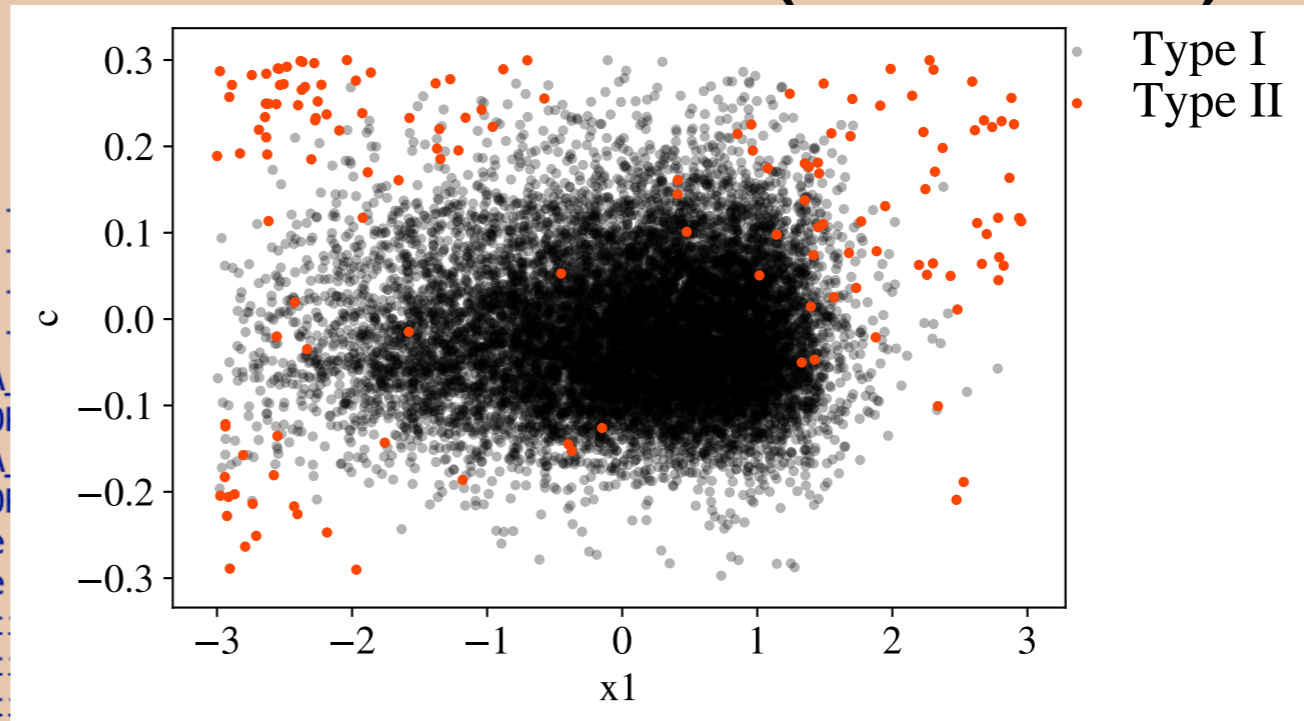
2: fit light-curves

Wide z=0.47

+ ...

Pippin Pipeline for Supernova Survey Analysis

survey level choices: cadence, depth, filters, tiers, fields

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Task finished with wall time 0:07:23
FINISHED: AnalyseChains BANANA_OMW task (wall time 0:07:23, 1 jobs, deps ['SN_BANANA_OMW_NGRST_COV_BBC']) with 1 NUM_JOBS. NUM_JOBS now 0
--------------------
CURRENT TASK STATUS
Key: WAITING  RUNNING  DONE  FAILED  BLOCKED
SIM          NGRST_BIASCOR_G10   FOUND_BIASCOR_G10   NGRST_SIMDATA_G10   FOUND_SIMDATA_G10
LCFIT        NGRSTfit_SIM_NGRST_SIMDATA_G10   NGRSTfit_BIAS_NGRST_BIASCOR_G10   FOUNDfit_SIM_FOUND_SIMDATA_G10
             FOUNDfit_BIAS_FOUND_BIASCOR_G10
CLASSIFY     FITPROBTEST   FITPROBTEST
AGGREGATE    AGG_NGRST_BIASCOR_G10   AGG_FOUND_BIASCOR_G10   AGG_NGRST_SIMDATA_G10   AGG_FOUND_SIMDATA_G10
MERGE        MERGE_NGRSTfit_SIM_NGRST_SIMDATA_G10   MERGE_NGRSTfit_BIAS_NGRST_BIASCOR_G10
             MERGE_FOUNDfit_SIM_FOUND_SIMDATA_G10   MERGE_FOUNDfit_BIAS_FOUND_BIASCOR_G10
BIASCOR      BBC
CREATE_COV   NGRST_COV_BBC
COSMOMC      SN_BANANA_OMW_NGRST_COV_BBC
ANALYSE      BANANA_OMW
--------------------

All tasks finished. Task summary as follows.
Successfully completed tasks:
        SNANASimulation NGRST_BIASCOR_G10 task (wall ...
        SNANASimulation FOUND_BIASCOR_G10 task (wall ...
        SNANASimulation NGRST_SIMDATA_G10 task (wall ...
        SNANASimulation FOUND_SIMDATA_G10 task (wall ...
        SNANALightCurveFit NGRSTfit_SIM_NGRST_SIMDATA_...
        SNANALightCurveFit NGRSTfit_BIAS_NGRST_BIASCOR_...
        SNANALightCurveFit FOUNDfit_SIM_FOUND_SIMDATA_...
        SNANALightCurveFit FOUNDfit_BIAS_FOUND_BIASCOR_...
        FitProbClassifier FITPROBTEST task (wall time ...          DATA_G10'])
        FitProbClassifier FITPROBTEST task (wall time ...          ASCOR_G10'])
        Aggregator AGG_NGRST_BIASCOR_G10 task (wall t...
        Aggregator AGG_FOUND_BIASCOR_G10 task (wall t...
        Aggregator AGG_NGRST_SIMDATA_G10 task (wall t...
        Aggregator AGG_FOUND_SIMDATA_G10 task (wall time 0:00:08, 1 jobs, deps ['FOUND_SIMDATA_G10'])
```

+ ...

3: transient classification (Helen's talk!)

Pippin Pipeline for Supernova Survey Analysis

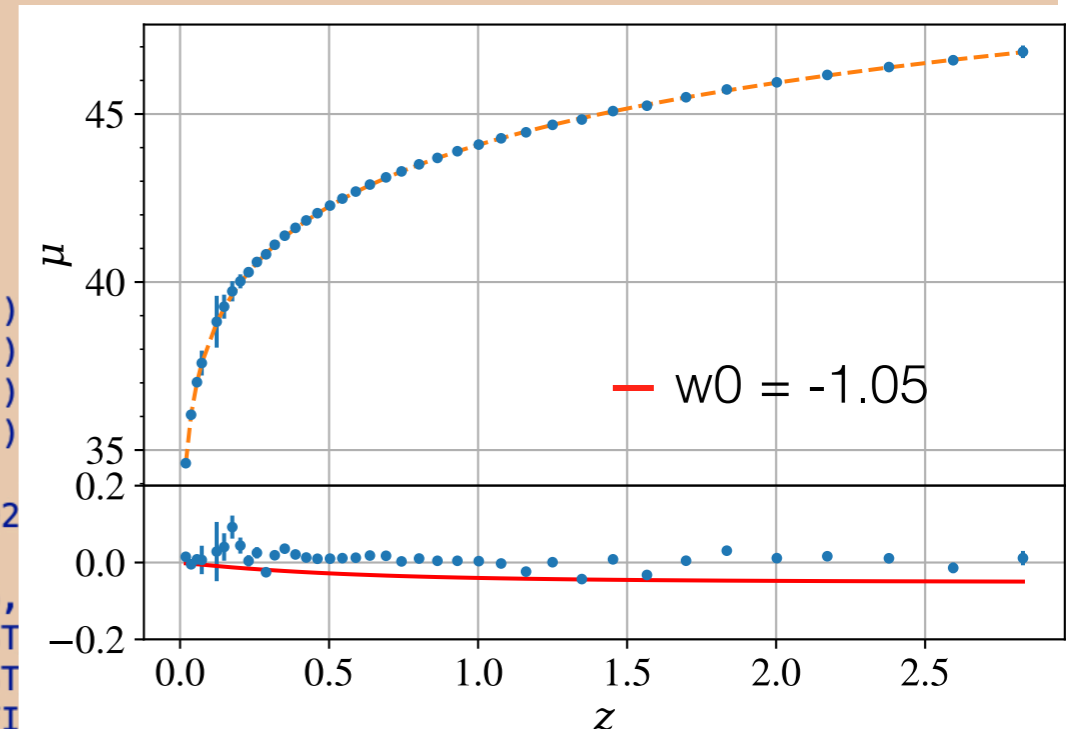## survey level choices: cadence, depth, filters, tiers, fields

```
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Task finished with wall time 0:07:23
FINISHED: AnalyseChains BANANA_OMW task (wall time 0:07:23, 1 jobs, deps ['SN_BANANA_OMW_NGRST_COV_BBC']) with 1 NUM_JOBS. NUM_JOBS now 0
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Key: WAITING  RUNNING  DONE  FAILED  BLOCKED
SIM         NGRST_BIASCOR_G10    FOUND_BIASCOR_G10    NGRST_SIMDATA_G10    FOUND_SIMDATA_G10
LCFIT       NGRSTfit_SIM_NGRST_SIMDATA_G10    NGRSTfit_BIAS_NGRST_BIASCOR_G10    FOUNDfit_SIM_FOUND_SIMDATA_G10
            FOUNDfit_BIAS_FOUND_BIASCOR_G10
CLASSIFY    FITPROBTEST    FITPROBTEST
AGGREGATE   AGG_NGRST_BIASCOR_G10    AGG_FOUND_BIASCOR_G10    AGG_NGRST_SIMDATA_G10    AGG_FOUND_SIMDATA_G10
MERGE       MERGE_NGRSTfit_SIM_NGRST_SIMDATA_G10    MERGE_NGRSTfit_BIAS_NGRST_BIASCOR_G10
            MERGE_FOUNDfit_SIM_FOUND_SIMDATA_G10    MERGE_FOUNDfit_BIAS_FOUND_BIASCOR_G10
BIASCOR     BBC
CREATE_COV  NGRST_COV_BBC
COSMOMC     SN_BANANA_OMW_NGRST_COV_BBC
ANALYSE     BANANA_OMW
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```

6: calculate distances, produce HD

BBC paper


```
All tasks finished. Task summary as follows.
Successfully completed tasks:
    SNANASimulation NGRST_BIASCOR_G10 task (wall time 1:28:17, 1 jobs, deps [])
    SNANASimulation FOUND_BIASCOR_G10 task (wall time 0:54:49, 1 jobs, deps [])
    SNANASimulation NGRST_SIMDATA_G10 task (wall time 1:05:03, 1 jobs, deps [])
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    SNANALightCurveFit NGRSTfit_BIAS_NGRST_BIASCOR_G10 task (wall time 11:34:02
    SNANALightCurveFit FOUNDfit_SIM_FOUND_SIMDATA_G10 task (wall time 0:29:37,
    SNANALightCurveFit FOUNDfit_BIAS_FOUND_BIASCOR_G10 task (wall time 0:44:56,
    FitProbClassifier FITPROBTEST task (wall time 0:00:00, 1 jobs, deps ['NGRST
    FitProbClassifier FITPROBTEST task (wall time 0:00:00, 1 jobs, deps ['NGRST
    Aggregator AGG_NGRST_BIASCOR_G10 task (wall time 0:00:23, 1 jobs, deps ['FI
    Aggregator AGG_FOUND_BIASCOR_G10 task (wall time 0:00:13, 1 jobs, deps ['FOUND_BIASCOR_G10'])
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    Aggregator AGG_FOUND_SIMDATA_G10 task (wall time 0:00:08, 1 jobs, deps ['FOUND_SIMDATA_G10'])
```

+ ...
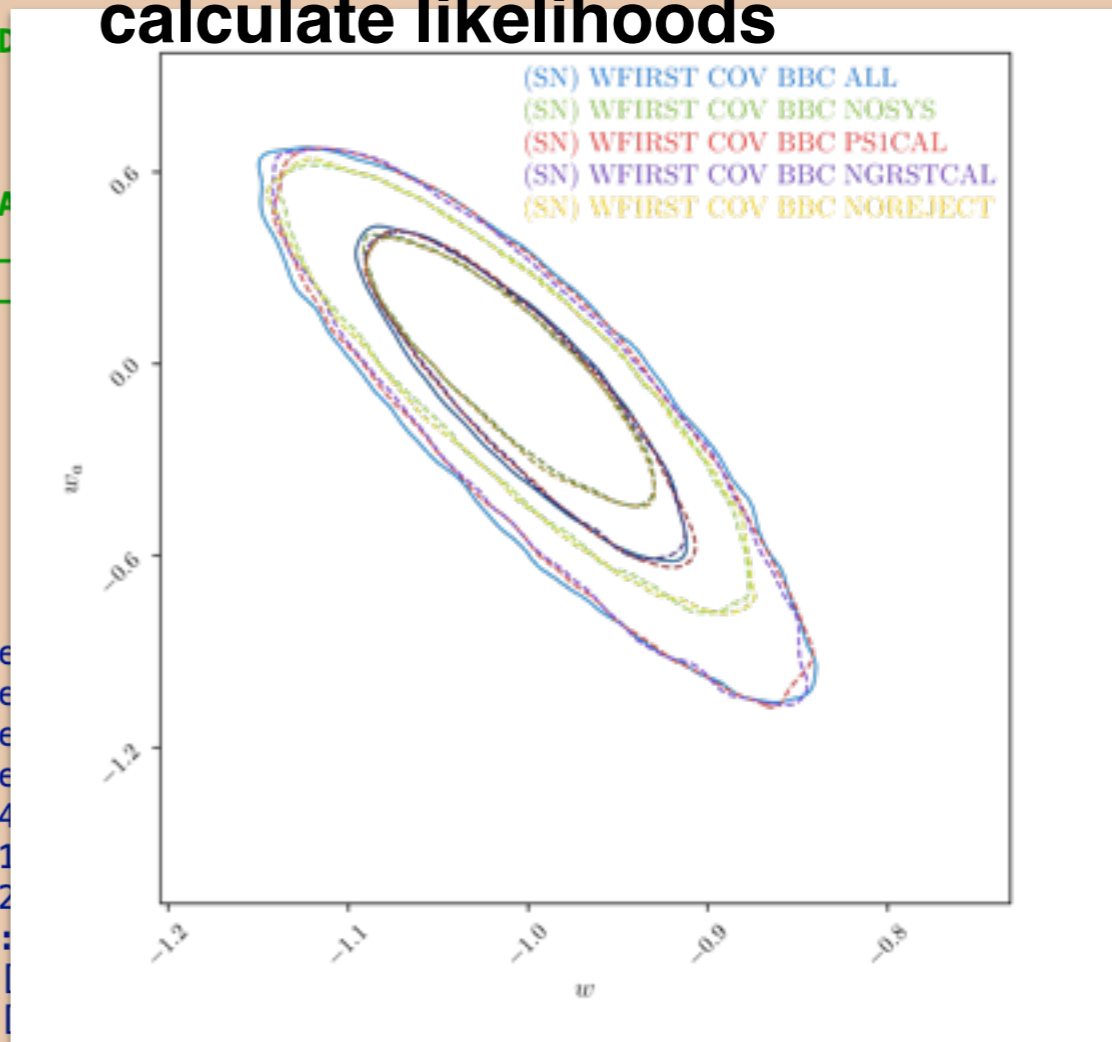
Pippin Pipeline for Supernova Survey Analysis

survey level choices: cadence, depth, filters, tiers, fields

8+9: explore cosmological-parameter space, calculate likelihoods

SIMULATIONS OF THE *WFIRST* SUPERNOVA SURVEY AND FORECASTS OF COSMOLOGICAL CONSTRAINTS

R. Hounsell,[1,2] D. Scolnic,[3] R. J. Foley,[1] R. Kessler,[3] V. Miranda,[4] A. Avelino,[5] R. C. Bohlin,[6]
A. V. Filippenko,[7,8] J. Frieman,[3,9] S. W. Jha,[10] P. L. Kelly,[11] R. P. Kirshner,[5,12] K. Mandel,[5,13,14] A. Rest,[6,15]
A. G. Riess,[6,15] S. A. Rodney,[16] and L. Strolger[6]

H18 paper
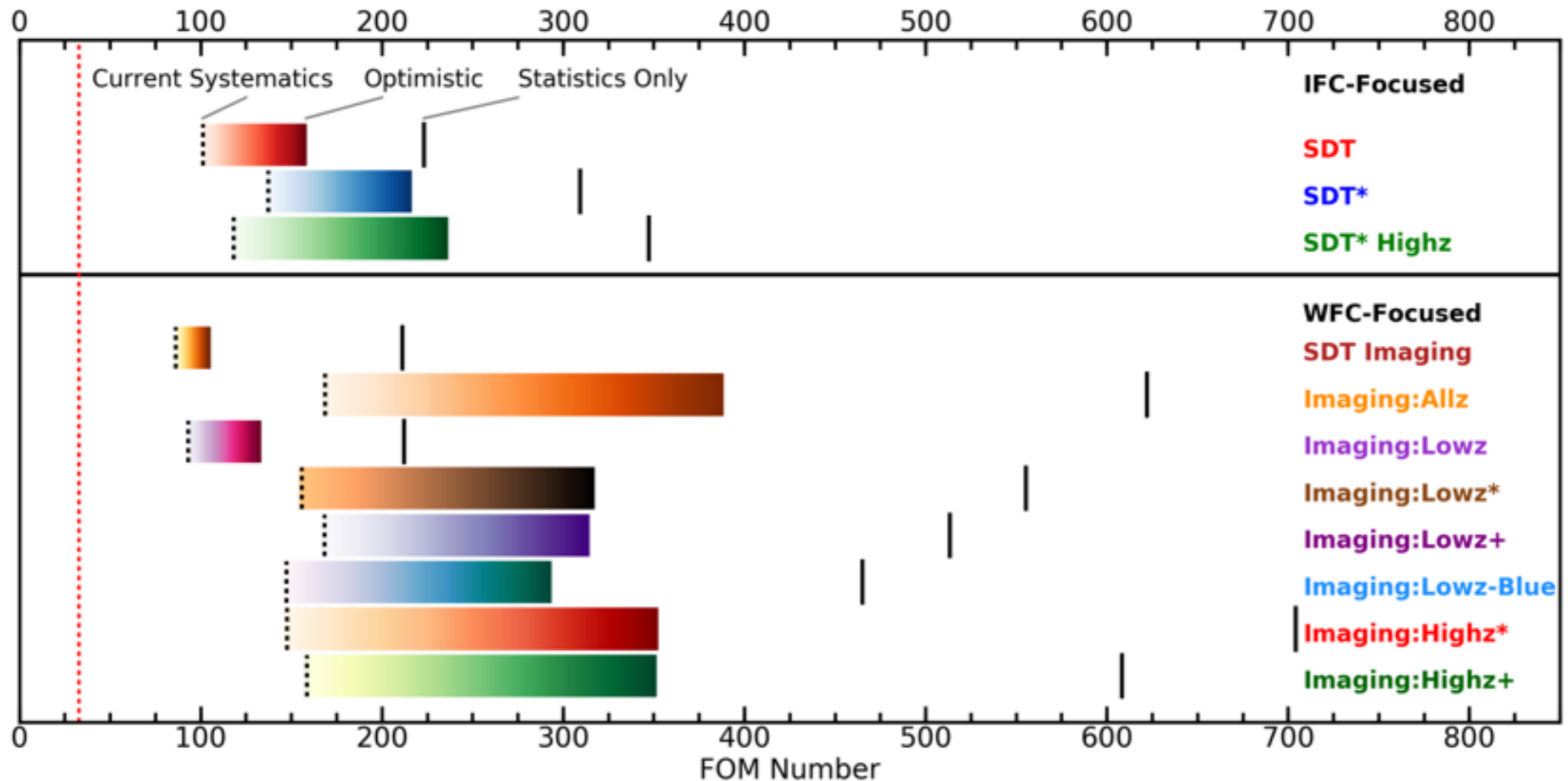
Figure 12. Predicted dark energy FoMs for the simulated *WFIRST* SN survey strategies outlined in Section 5. IFC-focused and WFC-focused strategies are presented in the top and bottom panels, respectively. The gradients for each strategy represent the range of FoMs from $FoM_{tot,curr}$ (dotted lines) to $FoM_{tot,opt}$. The thick black lines represent FoM_{stat}. The red dashed vertical line indicates the current FoM value of 32.6 (Alam et al. 2016).

Roman Time Domain Conference 2/8/22

Reference Survey

5 day cadence

5000 z >1 SNe!

| Mode	Tier	z_{targ}*	Filters	Exp.Time+Overhead (s)	No. of Pointings	Area (deg²)	Time/Visit (hours)	Total SN Ia
25% Spectroscopy Survey								
Imaging	Wide	1.0	RZYJ	160;100;100;100 + 70x4	68	19.04	14.0	8804
Imaging	Deep	1.7	YJHF	300;300;300;900 + 70x4	15	4.20	8.5	3520
Subtotal							**22.5**	**12324**
Spec	Wide	1.0	prism	900 + 70	12	3.36	3.2	831
Spec	Deep	1.5	prism	3600 + 70	4	1.12	4.1	652
Subtotal							**7.3**	**1483**

*z_{targ} denotes the redshift where the average SN Ia at peak is observed with S/N=10 per exposure.

FoM requirements met

Table 1. The 25% reference survey strategy
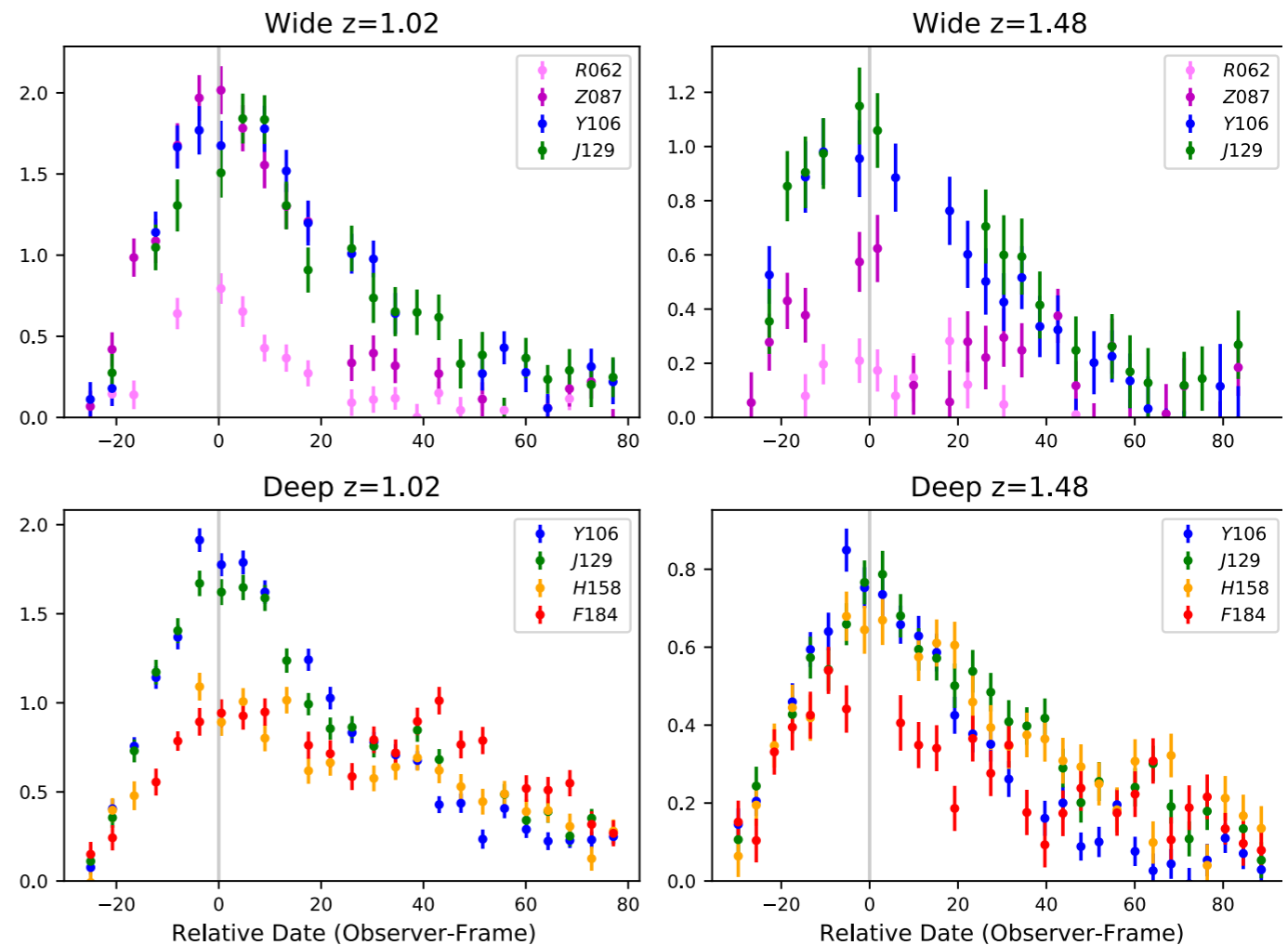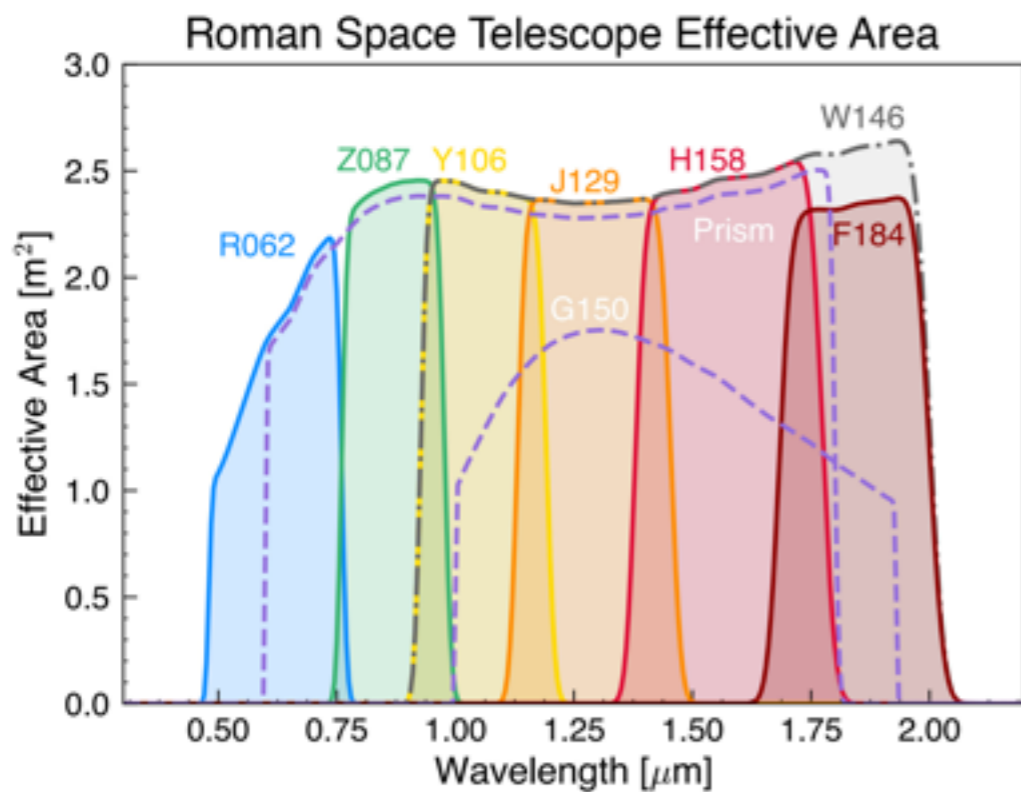
arXiv:2111.03081

|	F062/R	F087/Z	F106/Y	F129/J	F158/H	F184/F
Wide Tier						
Exposure time (sec)	160	100	100	100	—	—
Single-exposure limiting magnitude	26.4	25.6	25.5	25.4		
125-exposure co-add limiting magnitude	29.0	28.2	28.1	28.0		
Deep Tier						
Exposure time (sec)	—	—	300	300	300	900
Single-exposure limiting magnitude			26.7	26.6	26.5	26.7
125-exposure co-add limiting magnitude			29.3	29.2	29.1	29.3

Table 2. Limiting AB magnitudes for isolated point sources. Using a fill fraction of 87% and 144 epochs over the two-year survey, the co-added depths are expected to be ~2.6 mag deeper.

HUDF: ~30th mag, but 11.5 arcmins^2

redshift distributions
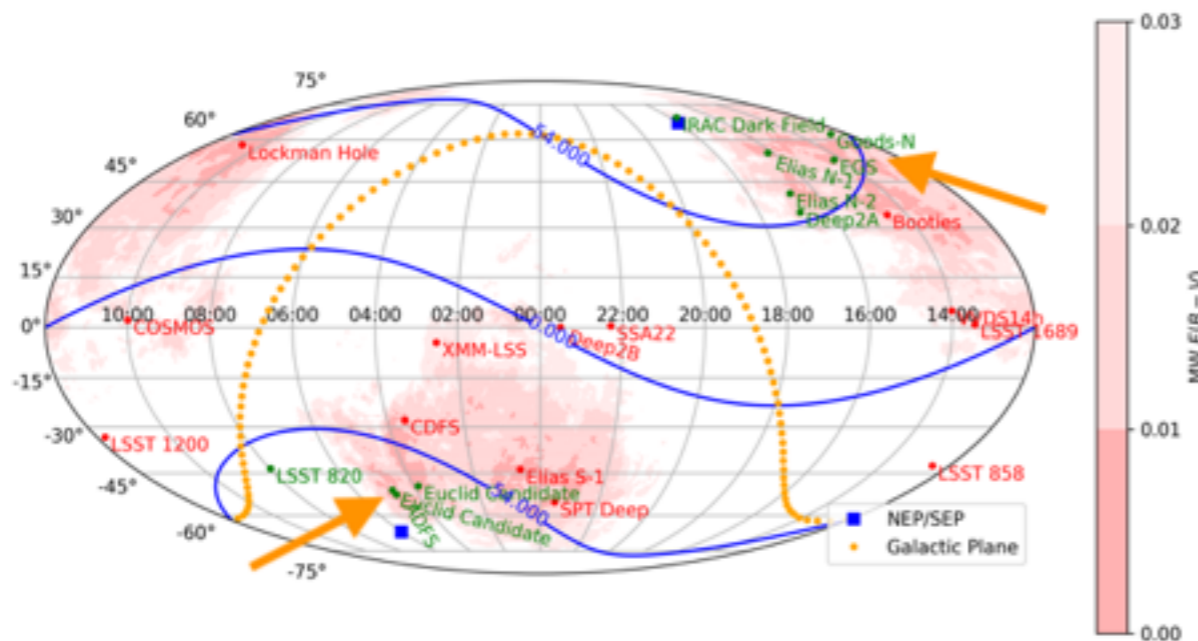
field considerations
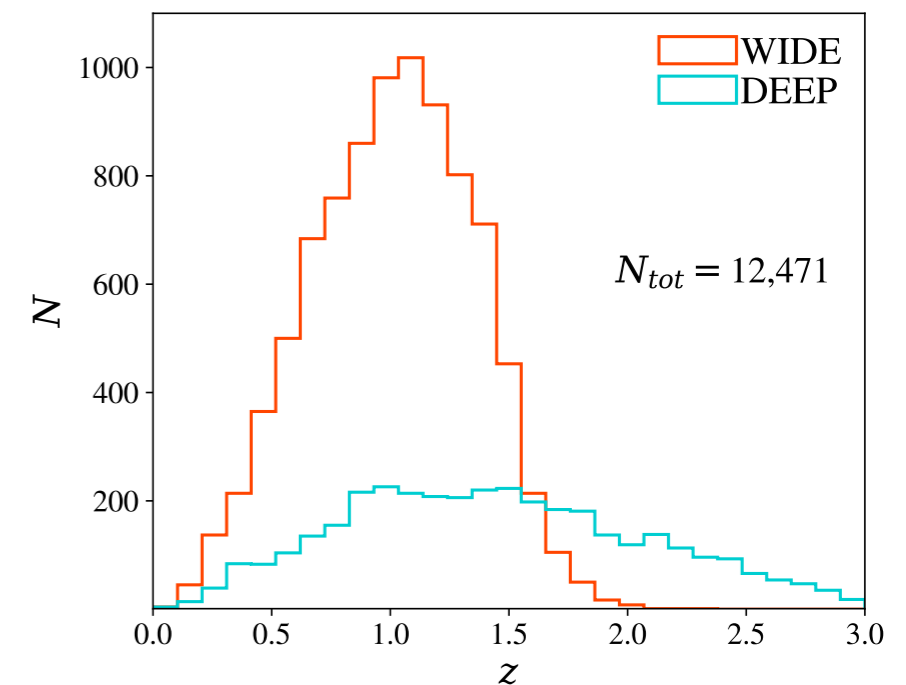
details can be found in arXiv:2111.03081

Variations

Mode	Tier	z_{targ}*	Filters	Exp.Time+Overhead (s)	No. of Pointings	Area (deg^2)	Time/Visit (hours)	Total SN Ia
10% Spectroscopy Survey								
Imaging	Wide	1.0	RZYJ	160;100;100;100 + 70x4	82	22.96	16.8	10617
Imaging	Deep	1.7	YJHF	300;300;300;900 + 70x4	18	5.04	10.2	4224
Subtotal							**27.0**	**14841**
Spec	Wide	1.0	prism	900 + 70	4	1.12	1.0	277
Spec	Deep	1.5	prism	3600 + 70	2	0.56	2.0	326
Subtotal							**3.0**	**603**
50% Spectroscopy Survey								
Imaging	Wide	1.0	RZYJ	160;100;100;100 + 70x4	45	12.60	9.3	5826
Imaging	Deep	1.7	YJHF	300;300;300;900 + 70x4	10	2.80	5.8	2347
Subtotal							**15.1**	**8173**
Spec	Wide	1.0	prism	900 + 70	25	7.00	6.7	1731
Spec	Deep	1.5	prism	3600 + 70	8	2.24	8.2	1302
Subtotal							**14.9**	**3032**
75% Spectroscopy Survey								
Imaging	Wide	1.0	RZYJ	160;100;100;100 + 70x4	19	5.32	3.9	2460
Imaging	Deep	1.7	YJHF	300;300;300;900 + 70x4	6	1.68	3.5	1408
Subtotal							**7.4**	**3868**
Spec	Wide	1.0	prism	900 + 70	19	5.32	5.1	2460
Spec	Deep	1.7	prism	10400 + 70	6	1.68	17.5	1408
Subtotal							**22.6**	**3868**

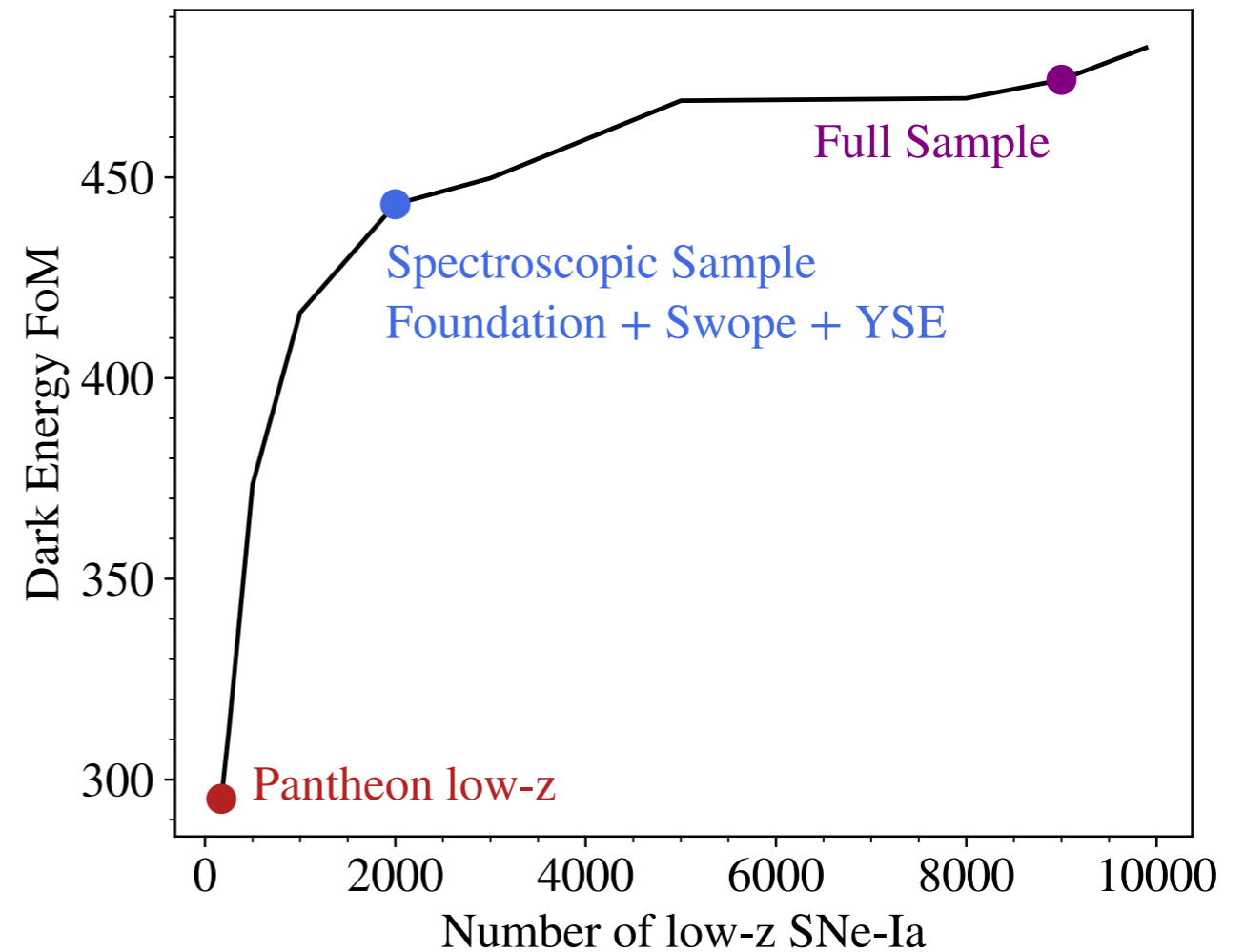*z_{targ} denotes the redshift where the average SN Ia is observed with S/N=10 per exposure.

FoM requirements met across variants

details can be found in arXiv:2111.03081

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Preparatory Work / Low-z Sample

- low-z sample is necessary to "anchor" Hubble Diagram

- at ~5k SNe this sample saturates in its cosmological utility (systematics limited)

Macias et al., in-prep

Summary

- SNANA + Pippin as a tool for forecasting cosmological constraints with *Roman*

- Cosmology FoM requirements met for reference survey and variants, with lots of work/optimization to be done in an evolving landscape

pmacias@ucsc.edu