



Centro Brasileiro de Pesquisas Físicas

Ministério da  
Ciência, Tecnologia  
e Inovação



UFRJ



Universidade Federal  
do Rio de Janeiro



**II JAYME TIOMNO SCHOOL OF COSMOLOGY**  
CBPF • CENTRO BRASILEIRO DE PESQUISAS FÍSICAS

**Rio de Janeiro, 6-10 August, 2012**

The II Jayme Tiomno School of Cosmology will be held at Brazilian Center for Research in Physics in Rio de Janeiro from 6 - 10 August, 2012. It aims at preparing the Brazilian community to the ongoing and also to the next generation of experiments in Cosmology, by providing Ph.D. students and researchers with basic and more advanced selected courses in Cosmology. The topics, and lecturers, covered in the second edition of the School are:


HOME
ORGANIZERS
REGISTRATION
PRELIMINARY SCHEDULE
VENUE & ACCOMMODATION
PARTICIPANTS
LECTURES
SPONSORS

**Baryonic Acoustic Oscillations**  
Yun Wang  
University of Michigan - USA

**Cosmology with Type Ia Supernovae**  
Richard Kessler  
University of Chicago - USA

**The Physics of Cosmic Acceleration**  
Eric V. Linder  
University of California, Berkeley - USA

**Primordial non-Gaussianity in the cosmological perturbations**  
Antonio Riotto  
University of Geneva - SWITZERLAND



# Lectures on Cosmology with Type Ia Supernovae: **SALT-II Spectral Training**

R.Kessler (U.Chicago)

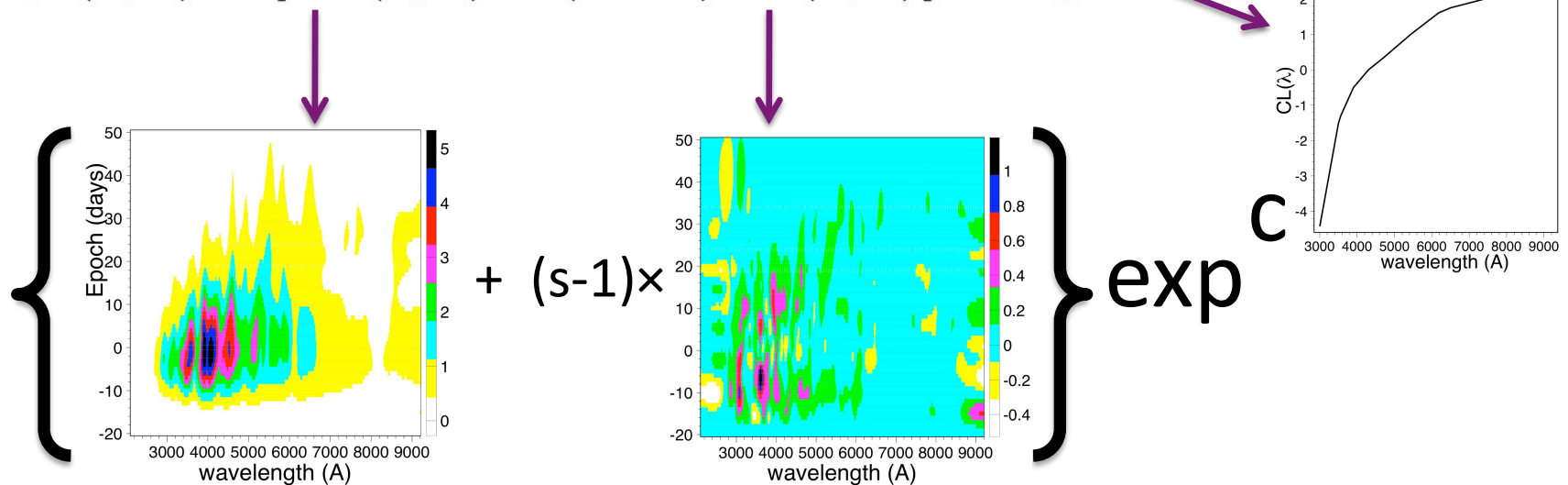
**II Jayme Tiomno School of Cosmology**  
**Rio de Janeiro, Brazil**  
**Aug 6-10, 2012**

# Review SALT-II Model

$$F_{e,f} = x_0(1+z) \int d\lambda [\lambda f_\lambda(e, \lambda) T_f(\lambda(1+z))] .$$

The SALT-II model (Guy 2007, 2010) is described by a spectral time-series,

$$f_\lambda(e, \lambda) = [M_0(e, \lambda) + (s-1)M_1(e, \lambda)] \times \exp^{c\text{CL}(\lambda)}$$

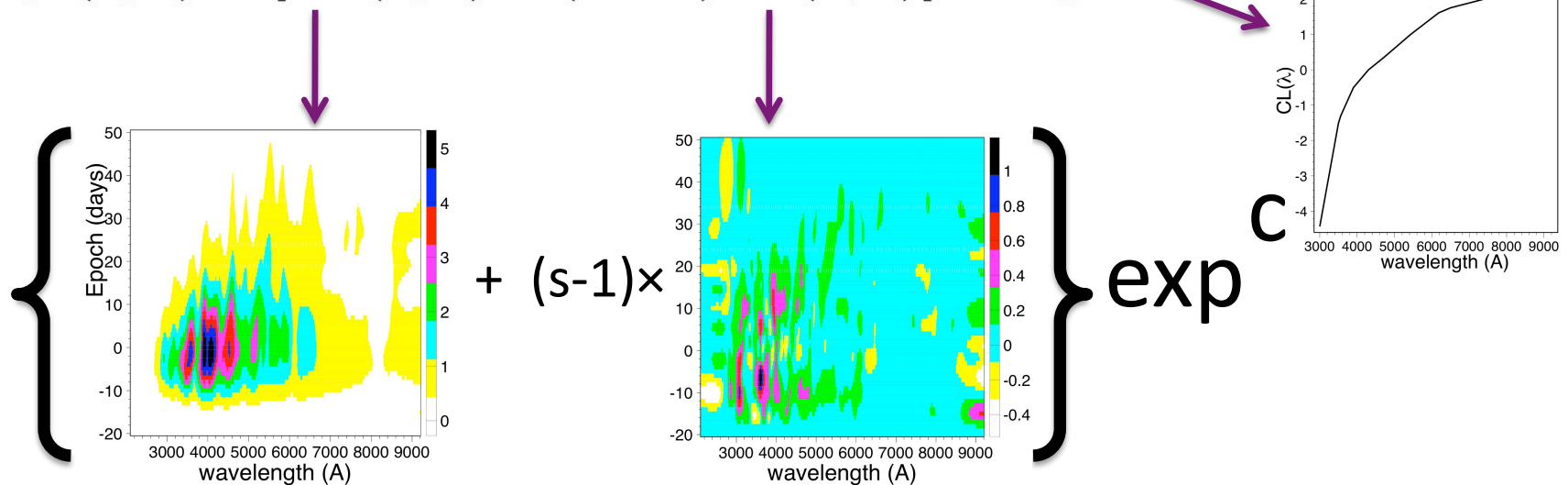


# Review SALT-II Model

$$F_{e,f} = x_0(1+z) \int d\lambda [\lambda f_\lambda(e, \lambda) T_f(\lambda(1+z))] .$$

The SALT-II model (Guy 2007, 2010) is described by a spectral time-series,

$$f_\lambda(e, \lambda) = [M_0(e, \lambda) + (s-1)M_1(e, \lambda)] \times \exp^{cCL(\lambda)}$$



**“Training”** determines the fixed parameters for  $M_0$ ,  $M_1$  and  $CL(\lambda)$ .  
Used in LCFIT to get shape ( $s$ ) and color ( $c$ ) for each SN.

# Training the SALT2-II Model

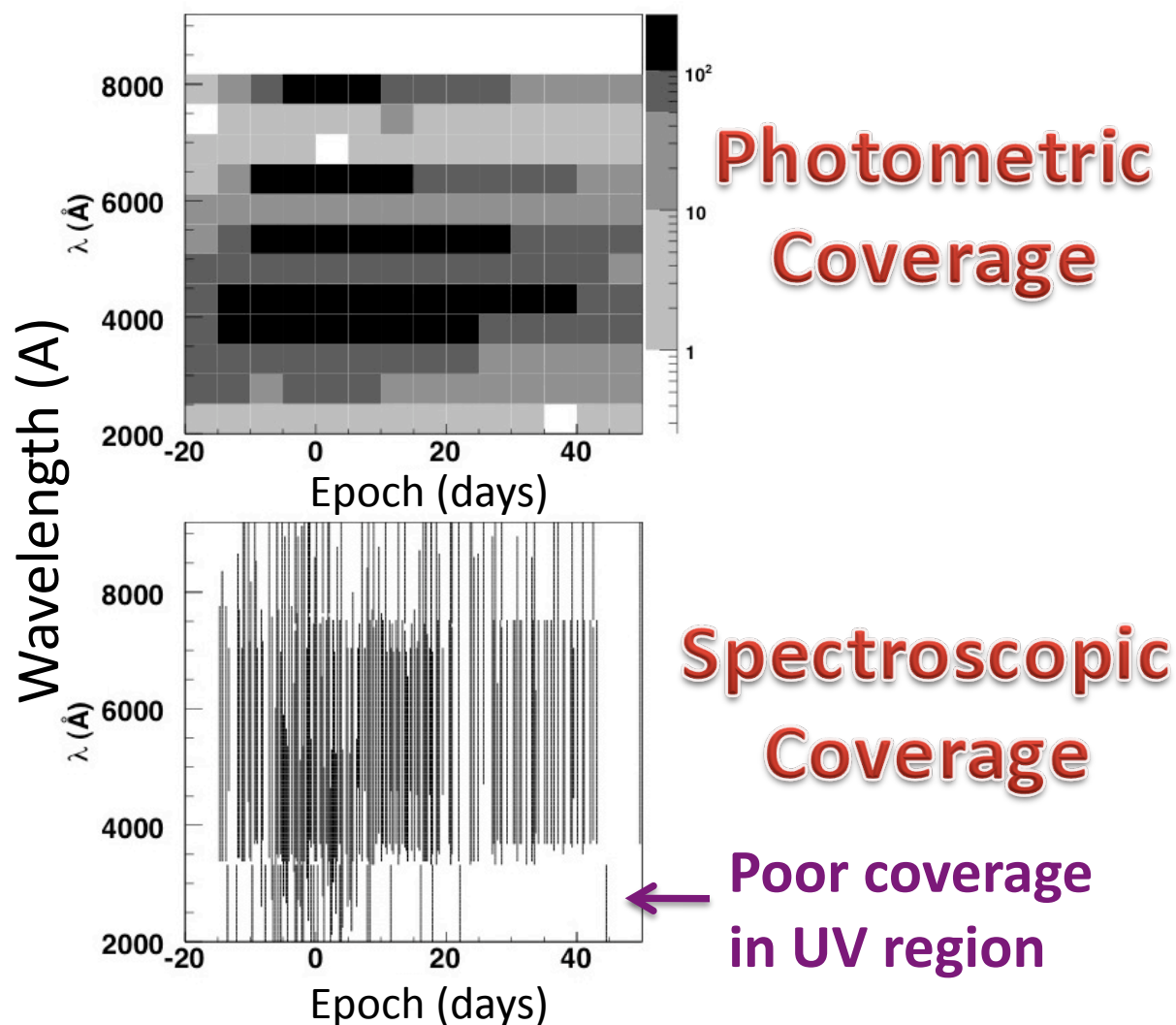
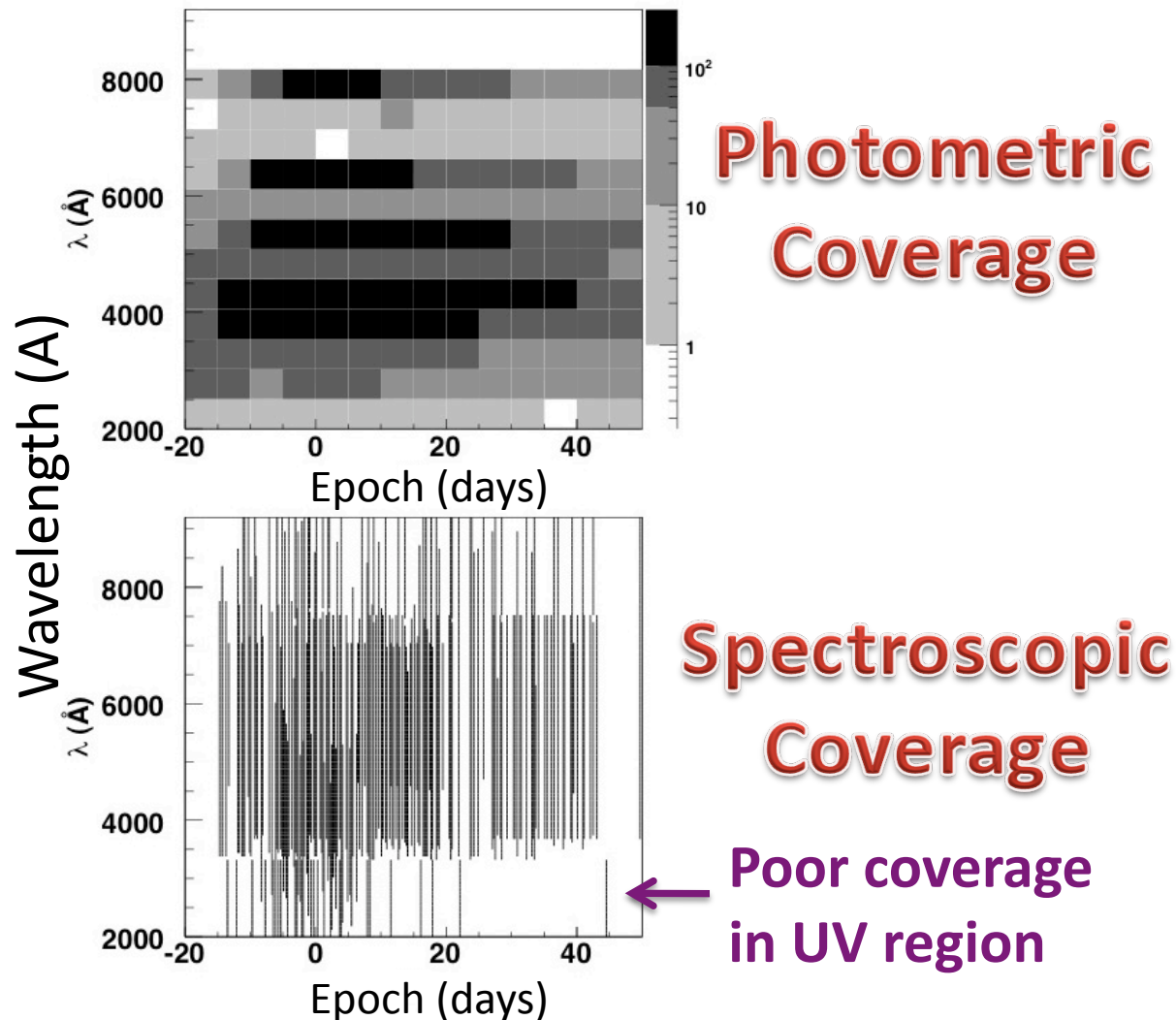


Fig. 1 Phase-space mapping by photometric data (top) and spectra (bottom). For photometric observations, the rest-frame central wavelength of the filter is considered.

# Training the SALT2-II Model



Training: fit data with splines to create spectral sequences  $M_0(e, \lambda)$  and  $M_1(e, \lambda)$

Challenges:

- Gaps in data, mainly in UV
- Distinguishing spectral noise from real features
- Poor spectral calibration (~10%)

Fig. 1 Phase-space mapping by photometric data (top) and spectra (bottom). For photometric observations, the rest-frame central wavelength of the filter is considered.

# Training the SALT2-II Model

Interpolate with splines  
(ideal: add more data !!!)

“Regularization” to avoid  
high frequency noise:  
major issues under study  
by SDSS+SNLS collab.

Warp spectra so that synthetic  
mags match photometry.

Training: fit data with  
splines to create  
spectral sequences  
 $M_0(e,\lambda)$  and  $M_1(e,\lambda)$

Challenges:

- Gaps in data,  
mainly in UV
- Distinguishing  
spectral noise  
from real features
- Poor spectral  
calibration (~10%)

# Training the SALT2-II Model: Regularization

$$\chi^2 = \sum_{e,\lambda} [F_{\text{data}(t,\lambda)} - F_{\text{model}(t,\lambda)}]^t C_D^{-1} [F_{\text{data}(t,\lambda)} - F_{\text{model}(t,\lambda)}]$$

$$+ \chi_{\text{reg}}^2$$



**Penalty for spectral changes  
that are too rapid**

# Training the SALT2-II Model: Regularization

$$\chi^2 = \sum_{e,\lambda} [F_{\text{data}(t,\lambda)} - F_{\text{model}(t,\lambda)}]^t C_D^{-1} [F_{\text{data}(t,\lambda)} - F_{\text{model}(t,\lambda)}] \\ + \chi_{\text{reg}}^2 \longrightarrow \text{Penalty for spectral changes that are too rapid}$$

$$\chi_{\text{reg}}^2 = (W_{\text{reg}}/N_{\text{bin}}) \sum_{e,\lambda} (\Delta F_{\text{model}(t,\lambda)} / \Delta \lambda)^2$$

or

$$\chi_{\text{reg}}^2 = (W_{\text{reg}}/N_{\text{bin}}) \sum_{e,\lambda} (\Delta F_{\text{model}(t,\lambda)} / \Delta t)^2$$



# Training the SALT2-II Model: Regularization

$$\chi^2 = \sum_{e,\lambda} [F_{\text{data}(t,\lambda)} - F_{\text{model}(t,\lambda)}]^t C_D^{-1} [F_{\text{data}(t,\lambda)} - F_{\text{model}(t,\lambda)}]$$

+  $\chi_{\text{reg}}^2$  →

Penalty for spectral changes  
that are too rapid

$$\chi_{\text{reg}}^2 = (W_{\text{reg}}/N_{\text{bin}}) \sum_{e,\lambda} (\Delta F_{\text{model}(t,\lambda)} / \Delta \lambda)^2$$

or

$$\chi_{\text{reg}}^2 = (W_{\text{reg}}/N_{\text{bin}}) \sum_{e,\lambda} (\Delta F_{\text{model}(t,\lambda)} / \Delta t)^2$$

or

$$\chi_{\text{reg}}^2 = (W_{\text{reg}}/N_{\text{bin}}) \sum_{e,\lambda} (\Delta F_{\text{model}(t,\lambda)} / \Delta \lambda \Delta t)^2$$

or

$$\chi_{\text{reg}}^2 = (W_{\text{reg}}/N_{\text{bin}}) \sum_{e,\lambda} \sum_{l,k} (\Delta_{l,k} F_{\text{model}(t,\lambda)} / \Delta_l \lambda \Delta_k t)^2$$

↑  
 $W_{\text{reg}}$  weight is arbitrary:  
no clear optimization algorithm

Multiple scales  
for  $\lambda$  and  $t$

# SALT-II Trainings Tests on **Simulations**

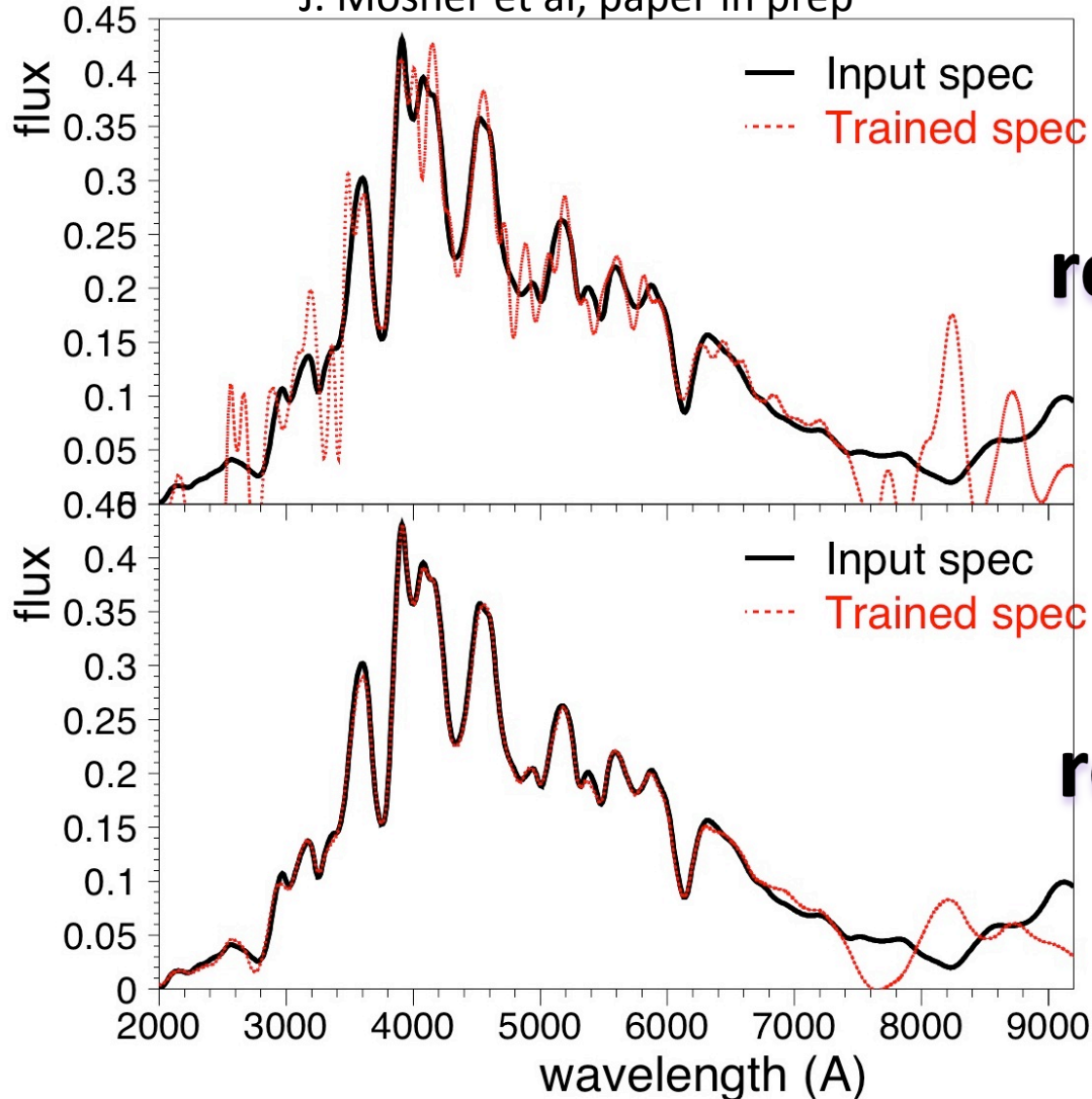
(part of SDSS+SNLS collaboration)

Train on **REALISTIC** data-like  
samples (photometry + spectra)  
including nearby, SDSS, SNLS

Evaluate biases from training.

# SALT-II Training Test on **Simulations**: No spectra within $\pm 3$ days

J. Mosher et al, paper in prep



**no  
regularization**

**with  
regularization**

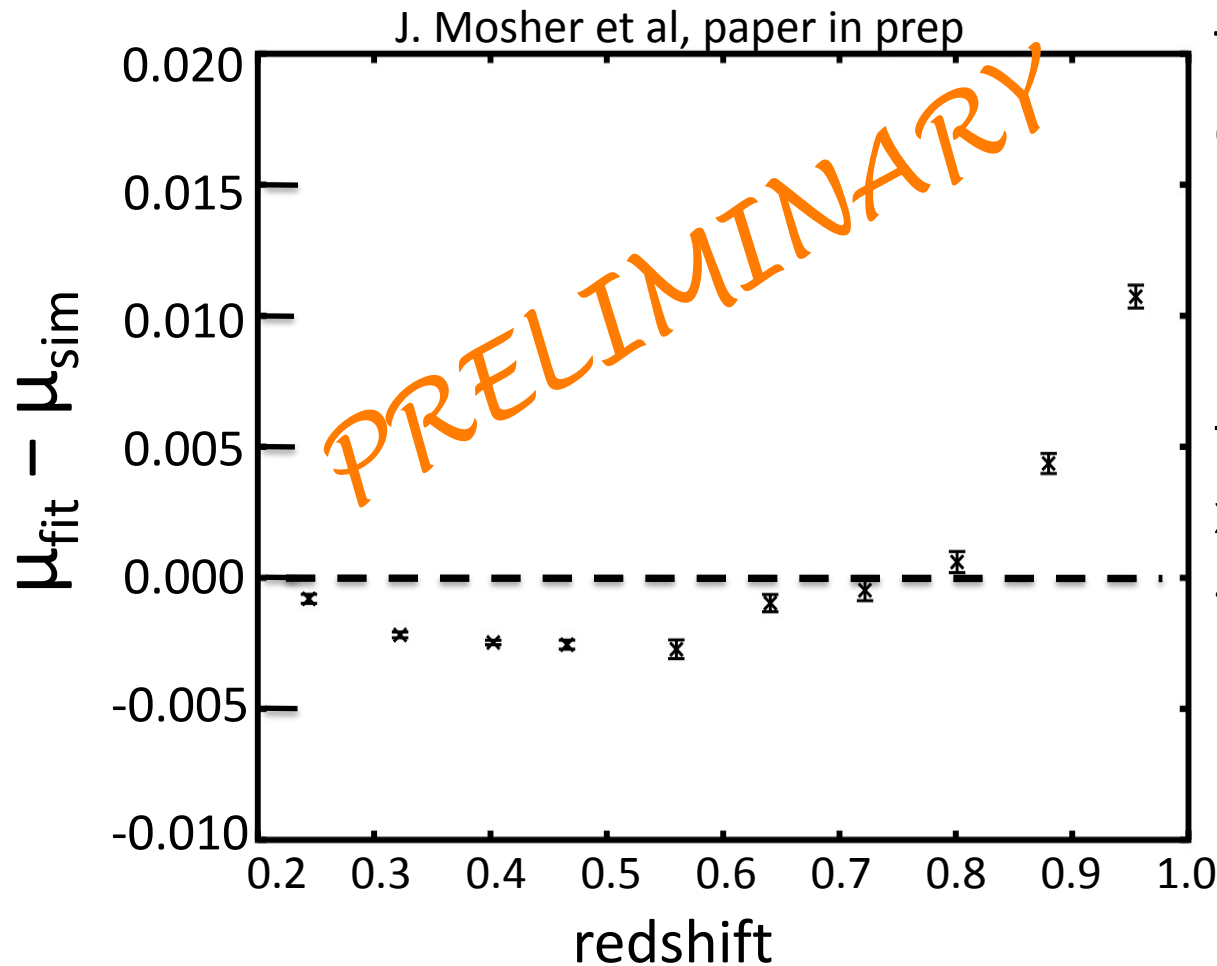
# SALT-II Trainings Tests on **Simulations:** Hubble Bias

Train on **REALISTIC**  
data-like sample  
(photometry + spectra)

Use trained model to  
fit **IDEAL** SNLS3 sample:  
x10,000 exposure time  
--> no Malmquist bias

➔ Hubble bias from  
training only.

# SALT-II Trainings Tests on **Simulations:** Hubble Bias



Train on **REALISTIC**  
data-like sample  
(photometry + spectra)

Use trained model to  
fit **IDEAL** SNLS3 sample:  
x10,000 exposure time  
--> no Malmquist bias

➔ Hubble bias from  
training only.