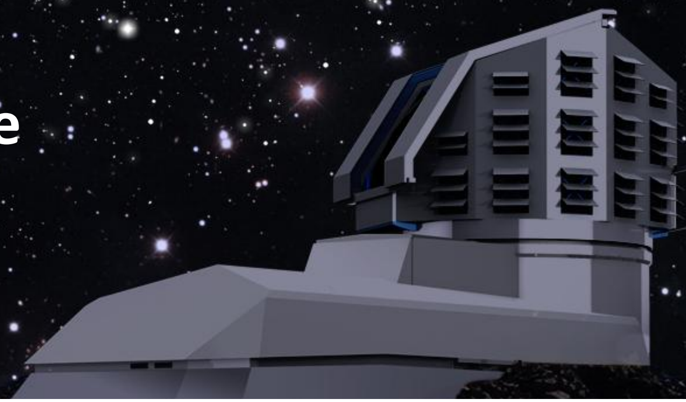
« Nearby « ($z<0.35$) SN in LSST era
a few questions / remarks / proposition on
- Science cases
- Spectral follow-up

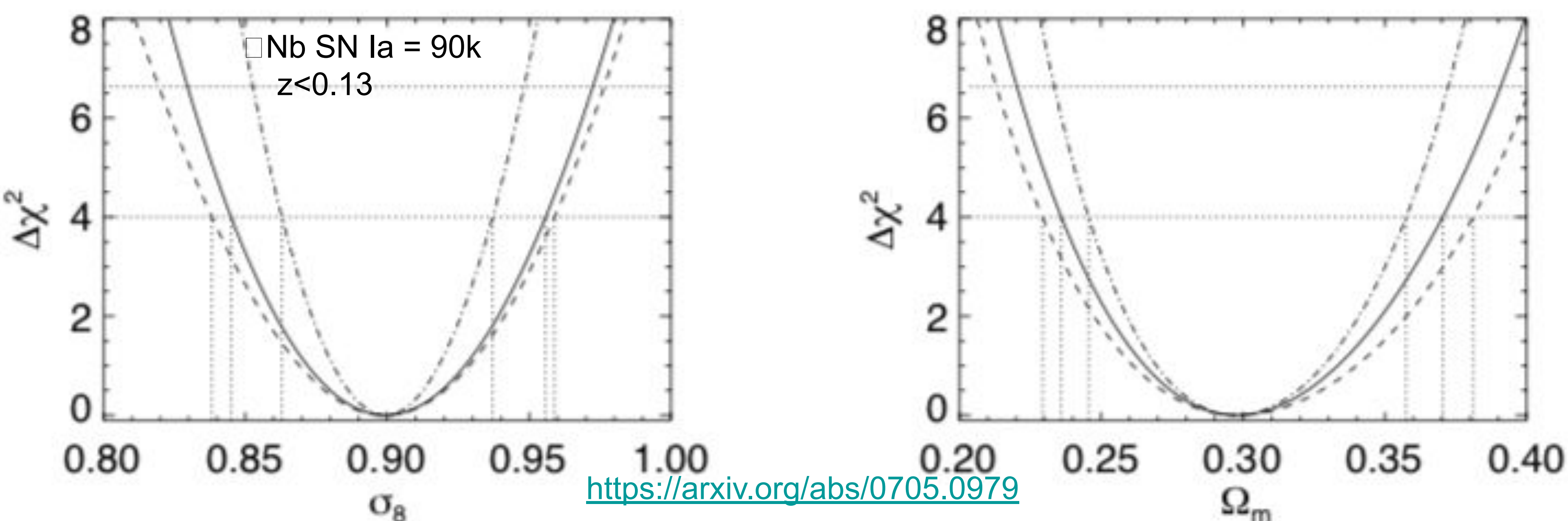
Seeds of the google slide :

Pierre Antilogus talk,

LPNHE Wednesday 3rd July 2019

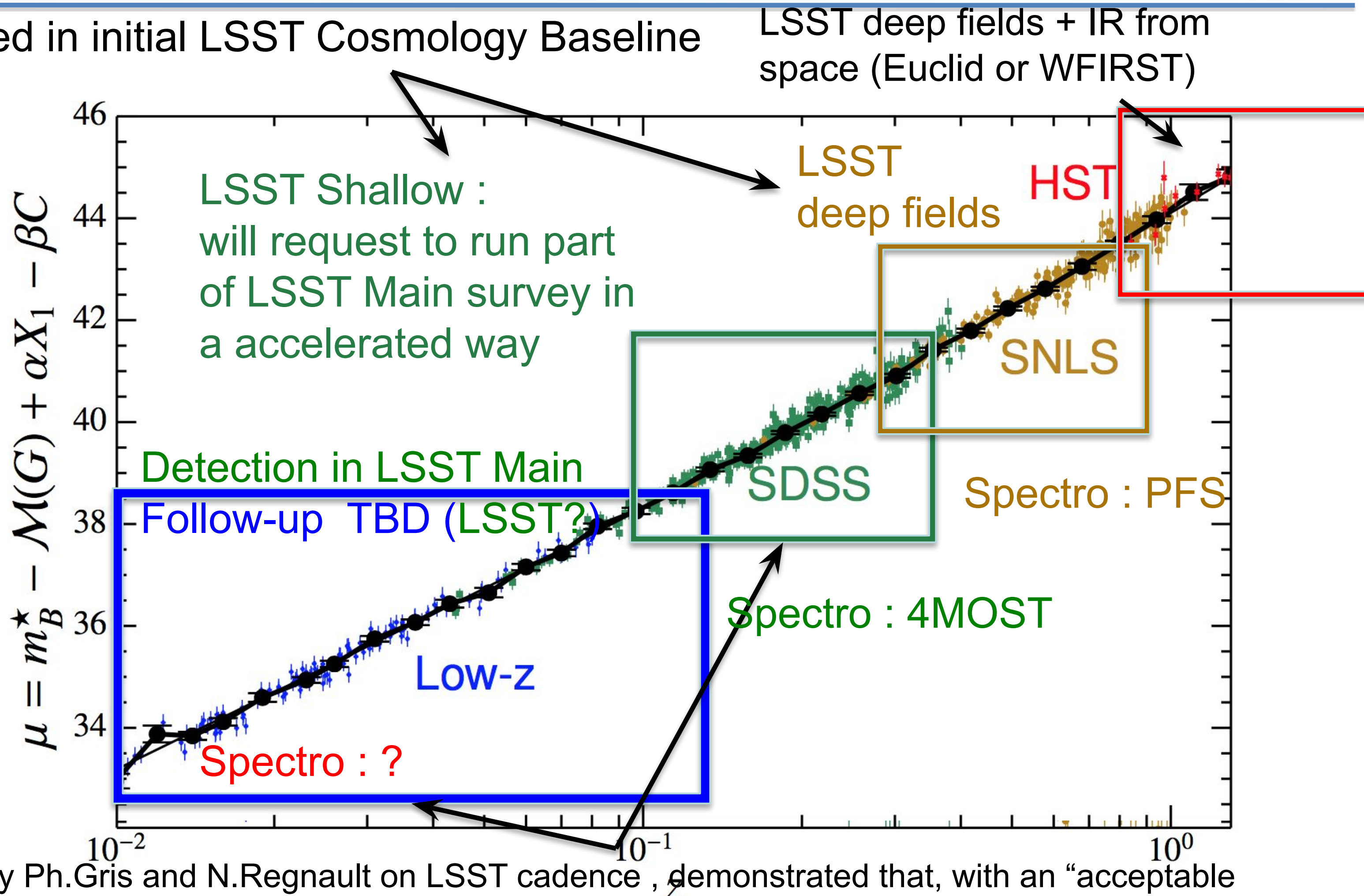
SN in LSST : Science case





https://arxiv.org/abs/0705.0979

SN Ia redshift domain & LSST



A recent work done by Ph.Gris and N.Regnault on LSST cadence , demonstrated that, with an "acceptable cadence", LSST could collect ~ 30 k good/un-biased SN Ia light curves up to a redshift of 0.35 per year .
The base line cadence produces 5-10 time less good light curve, and will have a hard time to do usefull trigger (how many spectra/ independent photo-metric followup have to be done on early detection to grant a nice light curve / early follow-up ? : impossible to get to large number that way.)
This puts back SN Ia in the game of cosmology in LSST, and in particular the SN Ia z < 0.2 .

SN Ia redshift domain & LSST

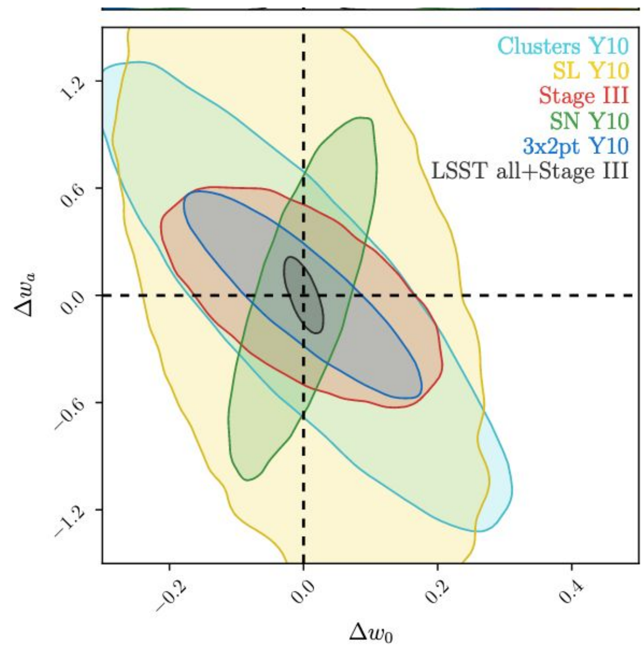
Extra remarks :

- Photometry :
  - current work on photometric calibration in LSST has a goal of .1% photometric precision full sky (project requirement : 1%) . This is lots of work , but it seems achievable and will bring an incredibly good SN Ia sample.
- Saturation :
  - First study by Ph.Gris indicate that SN Ia up to z ~ 0.05 may have part of their light curve saturated with 15s exposure. This concern ~ 100 SN Ia / year .
  - If no extra follow-up at low redshift is implemented , this will make the interesting volume z<0.05 not usable for cosmology (biased toward faint object) .
  - For such low number and for these bright objects , a specific photometric follow-up could be considered by a pointing instrument :
    - even if it means to follow 2-3 times more objects at early stage , prior the confirmation of the type from light curve (or prior to a follow-up spectra)
    - The only constrain is the quality of the associated instrument/photometry (but a 40-60 cm primary should do it ?), photometry that should be put back in the LSST photometric frame with a minimal effort.

SN Ia Science case : Sure Hubble diagram

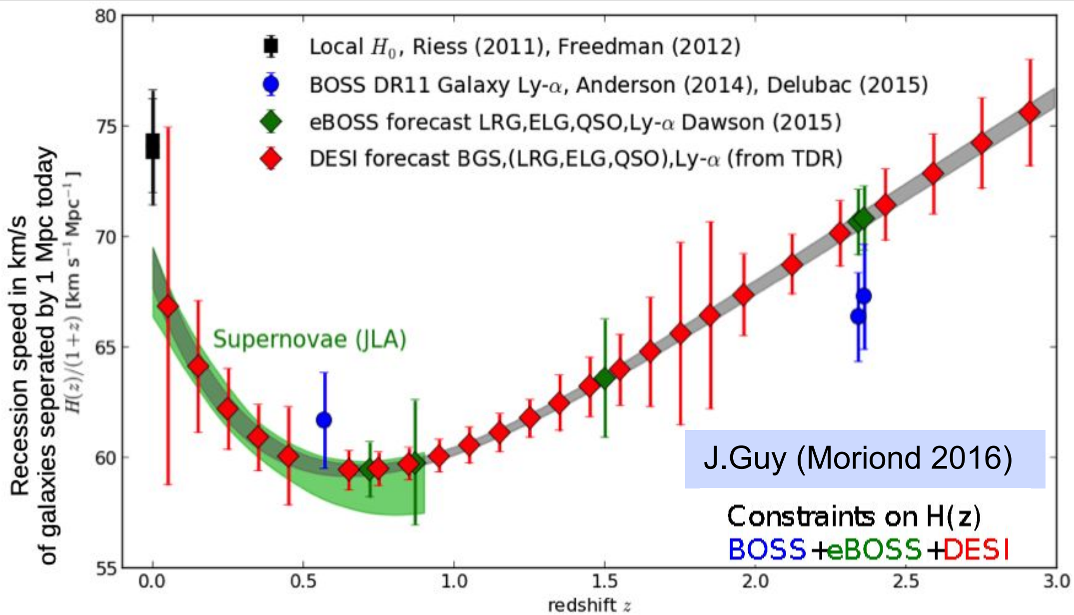
Hubble diagram interest for z<~0.35 ?

- **SN Ia are mandatory to reach the targeted Phase IV FOM once combined with the other probes**
- **it also implies a good (.1%) photometric precision .**
- **Still there is some doubt in the corresponding DESC plot ?**
- **DESC consider that it can only get 100 k redshift. (4MOST , PSF) ,with the usual 80% efficiency for SN Ia host, on 10 years . (including the deep field that I didn't comment here)**
- **At this stage, , on the Hubble diagram side , the argument on the needed number of SN and the associated photometric precision is not that "gold plated" to me … In the DESC SRD the unbiased SN sample is indicated at 0.4 … and the mean red shift at 0.4 … (for 100k SN Ia , including the deep field …)**



So the optimization of the SN Ia contribution to the Hubble diagram / combined fit , is I think still a subject … but this is not my topic today , I'll like to focus on the unique low z (<.4) sample and on velocity field study.

SN Ia « nearby » to do what ?



SN Ia for z <~0.35 are unique :

- **Cosmic variance limit the interest of BAO & weak lensing at low redshift : example JLA SN Ia sample does today , through their Hubble diagram a better work in this redshift range than what DESI will do : BAO is cosmic variance limited for z ~ 0.5 .**
- **The LSST « nearby « SN (z <.35) can directly probe the information in the "recent" universe , after re-acceleration of the expansion .**
- **But they can also be used in a new way and measure σ_8 , probe the "nearby" universe content/structure/uniformity through the galaxy velocity field / distance study . It will give an unique precision on such measurement :**
  - **~4 time more precise than Tully-Fisher**
  - **~5k SN Ia z<0.15 /year**

SN Science case beyond Hubble Diagram (1/2)

- Ok , Romain is looking to velocity filed / sigma 8 key to answer to all 0 level questions
- But there is other topics that we may consider with 300 k SN Ia z<0.35 in 10 years :
  - universe uniformity
  - X-correlation with the galaxy distribution
  - X-correlation with magnification ? Lensing ?
  - SN Ia astrophysics / cosmic distance ladder / systematics
  - SN II astrophysics / cosmic distance ladder / systematics …at least give it a real try !
  - ????

- Remark : As I was looking around , found a bunch of Danish interested by SN & LSST & velocity field :
  - Precision measurements of large scale structure with future type Ia supernova surveys, Steen Hannestad ,2007, https://arxiv.org/abs/0705.0979
  - The cosmic velocity field – local variations in the Hubble constant and the power spectrum from future sky surveys , PhD Thesis , 2016 , Io Sandberg Hess Odderskov
  -

SN Science case beyond Hubble Diagram (2/2)

For all these topics , and the velocity field in particular , there is a bunch of key questions, to further define our requirements :

- **Dependency with :**
  - The red-shift domain :
    - 0.2 is much better than 0.15 ? … if we do a life spectro up to z=.2 has a cost ! … So the first question will be up to where we want/ need our SN spectred life :
      - For SN II spectra are mandatory … no spectra … no SN II
      - For SN Ia, with spectra better distance (Twins?) & spectra will grant galaxy association for most of the sample (no spectra , on ~ 80% will be granted)
    - We can still do a few life spectra above ".2" …so is there an interest above .2 (up to ~ 0.35 , limit of the un-biased sample)
  - The SN statistic : at which point / which SN density , saturate the useful information ? (Pk …)…and the dependency of this with the photometric/light curve quality , red-shift precision ?
  - Red-shift precision ? Any possible bias in redshift ? (mix velocity & rotation ?)
  - What precision on sigma 8 ? Why ? (interest/possibility to probe # volume with equivalent precision ?
- **The interest to add a SN II sample up to z <=0.07 (5-10 time more important than the SN Ia , but a precision 2-4 time worse in distance)**
- **???**

Nearby SN in LSST : Spectral follow-up & redshift

Why spectroscopy ?

- **Why do we want spectra of the galaxy and how do we want them :**
  - **photometric redshift using SN light curve is too bad ⇒ z from galaxy spectra**
  - **SN environment is a key parameter ⇒ integral field spectrograph for environment study (but life SN is not the optimum …)**
  - **What precision on z / what spectra precision ?**
    - Q?: We really want the usual R ~ 1 000 1 line Sigma z ~ 0.001 ~ 300 km/s. Looks a bit loose in respect of what we want to measure (velocity differences in the ~100 – 1000 kms-1)
    - Q? Does a fiber is ok , or we want an integral field : radial velocity of the galaxy may offset the result … by 50-100 kms-1 ? More ?
- **Why do we want a life spectra of the SN ? :**
  - **For a precise study of the SN / next step in systematic study (imagin 50 k spectra + light curve) + twin (leave open the possibility to further improve the distance indicator) : a survey of this type (LSST) will be done once , lets DO IT FULLY / CORRECTLY .**
    - Q? : How many SN Ia with a given precision in distance , for a given precision in Sig8,OmegaM…
  - **For once give a chance to the SN II : for the first time (LSST mag limit) we have a change to have a large sample of SN II , and use them as standard candle … there is a hope that we can reach a distance indicator a factor 2 worse than SN Ia … factor 2 better than Tully-Fisher … up to z ~ 0.08 , this could be a huge sample spectra mandatory for SN II distance**
    - Q?: The optimization of the cut is open : doing a spectra of a SN II cost ~2 more than a I a and is at best ½ as precise in distance unclear if observing these SN II is usefull
    - Q?: the question is for SN Ia and SN II : should we target more surface or higher density ? at all z ?
  - **Avoid contamination : SN Ia , SN Ib/c , SN II P-L , WTF …**
    - Q?: a sampling will probably do the job … and anyway above a given z , it's what we will do : can we precise ?
  - **SN – Galaxy association : for 20% of the SN this is not straight forward … spectra in real time avoid this issue : we can grant that the SN belong to a given galaxy .**
    - Q? : there is a specific bias with SN in high density environment : association mistake can be performed … is this an important issue ?
    - Q? : not doing this association , rejecting SN for which we have a doubt , could it bias the result ?
- **The object density is low , 4 MOST with 4 square degrees / ~10 pointing per night (at max) can at best get 1-2 life (with in 30 days in the light curve) SN / day … as we would like to be able to do up to ~ 30 .**
- **But the issue is the same for getting the galaxy spectra : except if we do a full sky spectroscopy survey after the end of LSST , the fraction of galaxy granted by 4MOST is small at low redshift. (Q? : should do some math there)**

LSST : Starting point numbers for life spectro

- So we have SN Ia un biased up to z~0.35 … what's up about spectro
- SN Ia at z <~ 0.2-0.15 : ~ 5500 SN Ia / an , 55 k SN Ia total
  - 5500/340 ~ 15 new SN Ia per day
  - □ to keep up the cadence = 15 SN Ia spectra / night , 15 galaxy spectra per night
  - Why z=0.2 □ this is the best we can dream with a 2.6 m (no real estimation/simulation done … pure guess)
  - Why z=.15 □ // with a 2m (no real estimation/simulation done …)

- SN II at z <~ 0.08(~ 3500 SN II-P-L / an)
  - 3500/340 ~ 10 new SN II per day
  - □ to keep up the cadence = 10 SN II spectra / night , 10 galaxy spectra per night
  - Why z=0.08 □ this is the best we can dream with a 2.6 m (no real estimation/simulation done …)
    - Q? : sample bias has to be studied … hopefully like the SN Ia this cut is far bellow the z biased sample .

- Q? : what S/N we want on the SN/galaxy spectra ? What lambda coverage ? What resolution ?

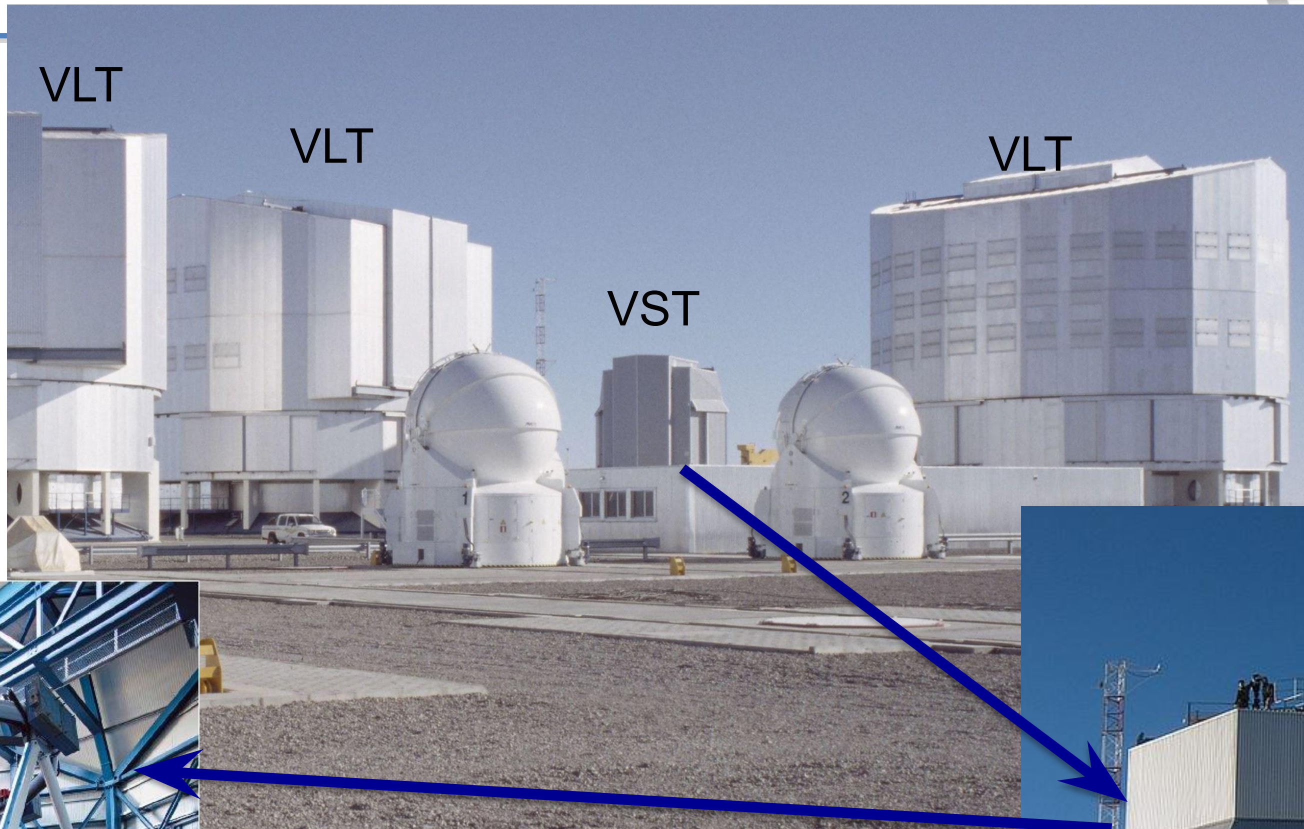
Which mirror ? (1/2)

- **LSST will start its scientific program in 2023 …**
- **which in practice could be the year of the commissioning of the spectro …So the follow-up instrument should be ready for this date … 2025 looks the ultimate limit.**
- **This is really short (~ SNIFS delay like) , just the time to build a spectro not telescope … just the time to find ~ 2-3 M€ (optimistic the guy) …not 7-10 M€**
- **So we are in pre-study , our goal should be to answer to all the questions we may have to define a good desing , write a proposal and advertise it :**
  - **ESO has a strong interest to recyle existing telescope, they are ready to support the running .**
  - **Australia , is looking for interesting program … and money to run its telescope … are interested too**
  - **There is a larger and larger community interested by the science case community …in LSST and beyond**

Which mirror ? (1/2)

- **At ESO the prefered/best solution(=largest mirror "available") : the VST (2.6m). VST will be great … still challenging .**
- **With a standard method for a classical way of doing the observation , + callibration , we are targetting 35-40 spectra per night , for a SN at max up to 20 mag … : this is more a the requirement for a fast moving 4 m**
- **So with a 2.6 m , we need to win a factor ~ 2.5 by designing :**
  - **an ultra-efficient instrument (~35-40%) / fast readout**
  - **A low cost (in time) , good quality calibration metod .**
  - **A fast telescope (1 min target acquistion will be great, 2 min ok …)**

VST at Paranal , ESO , Chili



Alt-azimutal , telescope wide field (1 deg^{2})
2.6 m primary (~0.93 m secondary)
OmegaCam : 268 10^{6}pixels

But once LSST is on sky (~ x100) □
End of ESO program in 2021

THE spectro

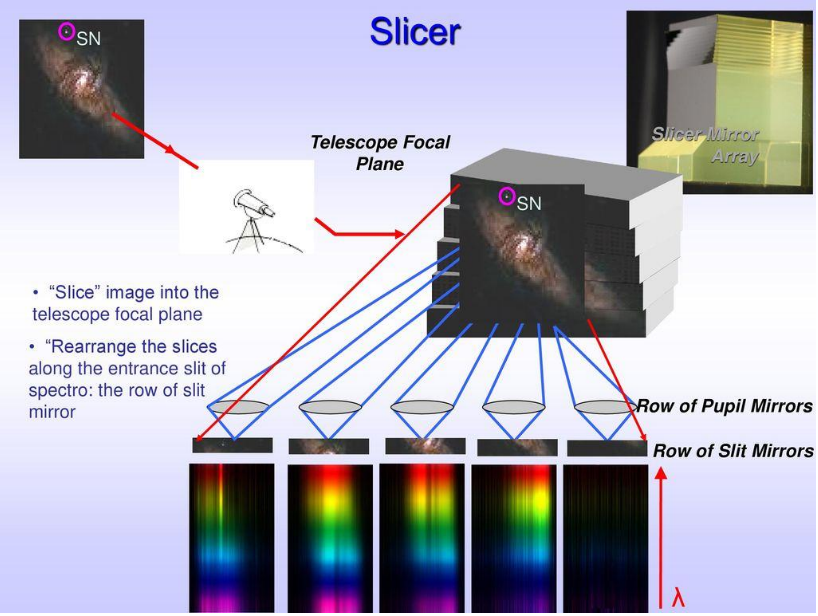
- Resolution 1000 – 1500 (delta lambda = 0.4 nm at 500 nm) ? 2000 ? More is complex/hard
- Spectral Domain : 1 octave will make the instrument simpler and efficient
  - First proposal for SN Ia : 370 nm – 740 nm (~ visible ! For human eye …)
  - relaxing efficiency constrain bellow 390-400 (realy bright SN Ia) …
- All spectro should be slicer ! More flux from the object collect , SN + galaxy core :
  - 15’’ x 15’’ seems the minimum …
  - With the possibility to rotate the filed we could also do a non-square slicer 15’’x20’’ (wide slice to grant galaxy core – SN association)

□

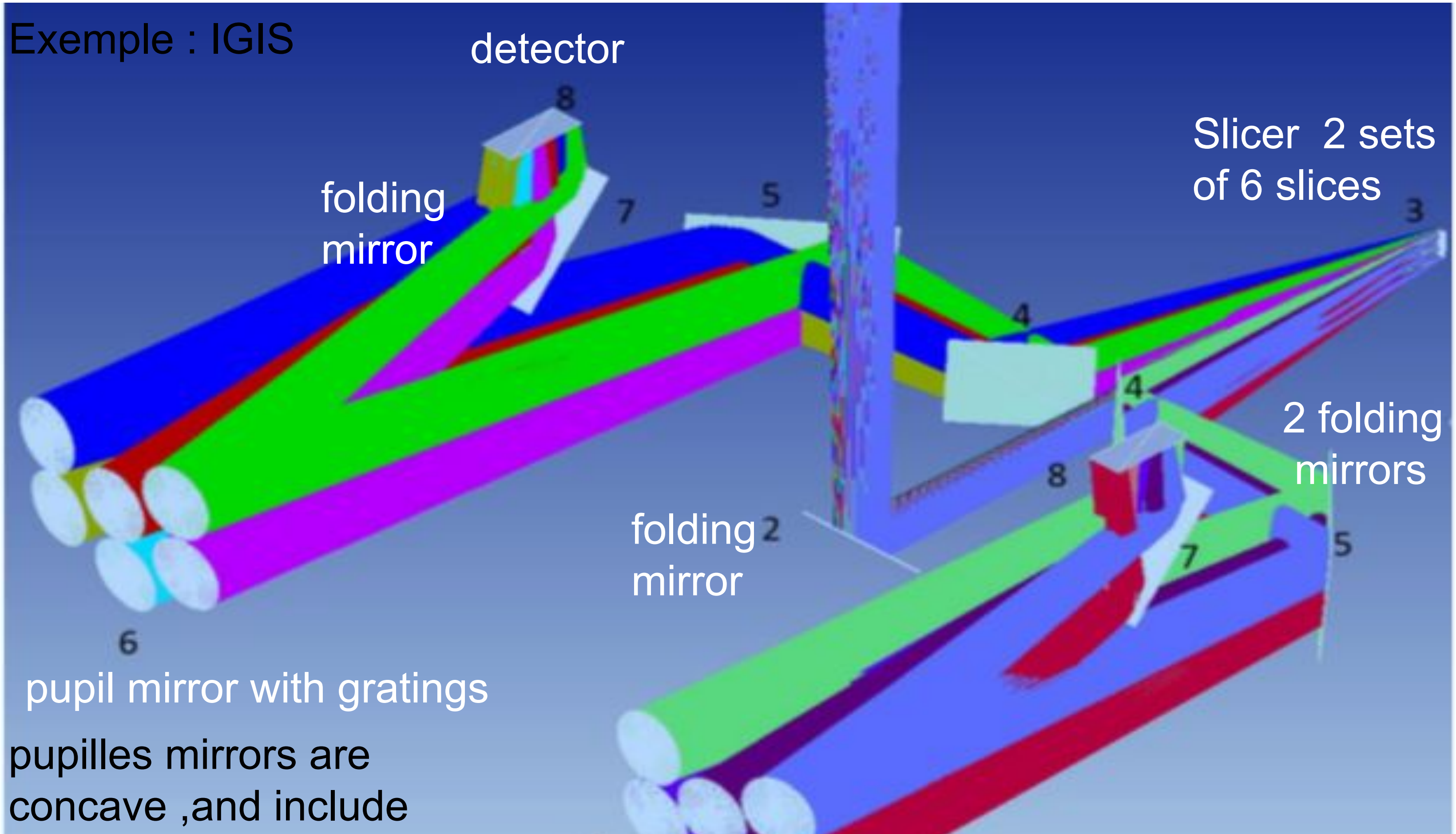
~ 50 slices de .3 ‘’ ? Hum

~ 38 slices de .4 ’’ ? more reasonnable

(median seeing ~ 0.7 ‘’)



A spectro without lenses ? □ Highly efficient



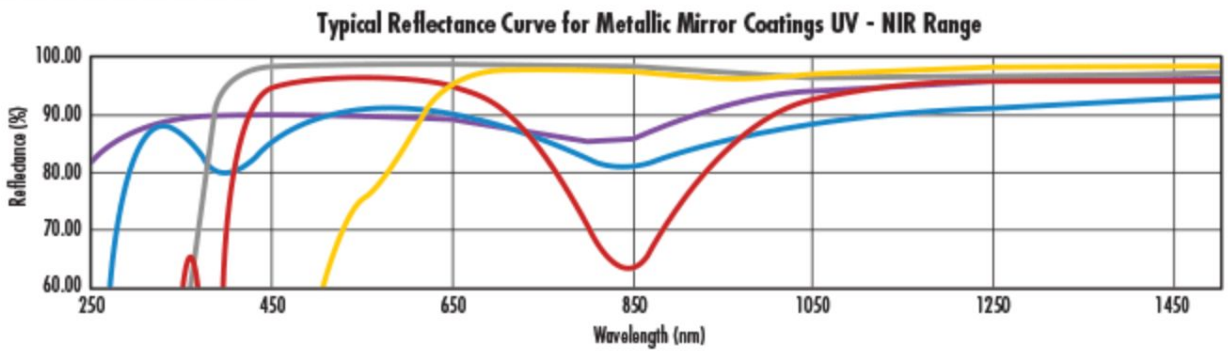
pupilles mirrors are concave ,and include the grating « free form optic » = highly compact instrument : good for stability / lambda calib

- Only mirror : 6x.97 ~ optics 80% (90%) eff
- Compact = smal flection , good for calib.
- “grism” small surface ~ 70 % (80%) eff
  (# in a slicer classical or fiber spectro : large grism)
- Detector ~ 80% (90%) eff

Efficiency Total
~ 45% (65% max)

Telescope

- **Pointing / target acquisition / guiding :**
  - Guiding – Acquisition by CMOS , in-front of shutter spectro (always on sky)
- **1 -3 minutes for target acquisition (=hard point)**
  - if 3 minutes : 3 x 40 target (SN + standard) = 2h = 80% d’efficacité (2h/10h)
- **télescope mirror : silver coating ?**



Protected Aluminum		Enhanced Aluminum		UV Ehanced Aluminum		Protected Gold		Protected Silver	
Range (µm)	% Reflection	Range (µm)	% Reflection	Range (µm)	% Reflection	Range (µm)	% Reflection	Range (µm)	% Reflection
0.4 - 0.7	85	0.45 - 0.65	95	0.25 - 0.45	89	0.7 - 2.0	96	0.45 - 2.0	98
0.4 - 2.0	90	–	–	0.25 - 0.70	85	2.0 - 10.0	96	2.0 - 10.0	98

Figure 4: *Typical Reflectance Curves for Metallic Mirror*

Silver coating +~10% / mirror compared Alu. Except below 400 nm :
But nearby SN are bright … so not necesserly a killer if eff 1/2
(370 nm silver ~ .6^2~ 35% alu ~ .9^2 ~ 80%) …and can do 1 Mirror Alu & 1 silver
or if we are full of time and money : Primary silver , secondary multi-layer at LMA ? ;-)

“operation time” improvement (1/2)

- **Minimize the time spend on lambda calibration :**
  - **Do not do an extra lambda calibration exposure for each science exposure :**
    - Small instrument + Mechanical optimization to avoid flection (gravity is our enemy)
    - Instrument thermalized to avoid dilatation (temperature variation is our enemy)
- **Reduce the time spend on flux calibration (standard observation)**
  - **The goal is to have the spectra color right … the absolute flux will come from the photometry**
    - Monitoring à la Sndice – aux-tel ? (VST has an extra harm that can catch a star in the field)
  - **Correct the sky line**
    - With a “wide” field IFU , there is enough sky to correct the sky line … this can also be used for some lambda calibration/control on the fly.
- **Work on the telescope + instrument + data taking : key of the success … lots of work ! …but pay back on efficiency !**

“operation time” improvement (2/2)

- **CCD readout time in spectroscopy :**
  - **The usual goal is a readout noise ~< 2 e- long readout time …this is an issue. Clasical Solution : frame transfert to absorb the readout time in the next exposure :**
    - 4 minutes max per objet readout at 10 KHz possible…seems the good idea
    - Issue : you cannot add a calibration exposure between science exposure
    - The need of an optimal readout may be addapted in function of the needs / may depend of the signal size / lambda resolution goal …: so we may want to addapt the noise requirement in fucntion of the available LSST data (light curve , galaxy …) so a good flexibility (à la LSST) in the CCD acquistion could be a + : re-bin , readout rate change …
  - **Optimal solution may request more than one CCD (due to the lambda domain/resolution , number of slice , frame transfet (=lost ½ lines))**
  - **example of a good candidate : e2v CCD 4290 (=megacam +++)… :**
    - 2 amps
    - 2048x4096 frame transfer (2048x2048 usefull)
    - Efficience > 90% for 400-700nm
- **+ the data reduction software has to be written … in particular to benefit of the ~x 2 in flux collected by a slicer (Spectro 2D , not slit) lots of work .**

Plan / Conclusion

- **I think that for efficiency/timing reason , the overall design , and the construction should be sub-contracted to an optical company.**
- **The DESI spectrograph is a good example of what can be done (there is contribution on the CCD , electronic , mechanics from the labs … but the optic and the overall optical /mechanical integration is done at the optical company :**
  - **WinLight (Aix en Provence) □**
    - Slicer specialist (patent with LAM … Muse …)
    - Specialist spectro (desi)
    - I don't think they have "free form optic " (grims concave) expertise …but the LAM is working on this …
- **There is lots of work on top :**
  - **Mechanic**
  - **Electronic**
  - **Slow control / telescope & instrument optimization**
  - **reconstruction software**
- **Hard point , before the money : the telescope !**
  - **Discussion on VST with Napoli : for the moment it's a dead end , and we still don't know if the telescope can hold the foreseen cadence**
  - **Australia : big telescope … bad weather & observing condition … and running cost high (VST , if we make the data public in real time , could be supported by ESO …)**
  - **WE SHOULD PROVIDE DOCUMENT TO ESO NOW !**
- **Funding (my guess 2-3 M€) :**
  - **This is to work on a new probe . Indeed we should precise the science case … but it sounds great ! Lots of people start to look in this direction today .**
  - **A high efficiency IFU , is on the air … what I presented here is , I think, the natural design that many can come to . This is maybe the only follow-up « in kind » that could be propose by Europe and could be payed back by some LSST ticket. Ariel already contacted me for this …**
  - **IN2P3 will not give 0… so we should try an European grant .**
  - **Beyond the money there is the work. We need lots of friends to implement AND run such program (…. 10 years follow-up each night its a huge effort).**


Fin