Magic Lantern

Canon EOS Camera Tool

www.magiclantern.fm

Libre Graphics Meeting 2014

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What is Magic Lantern?

- Free Open Source (GPL) firmware addon for Canon EOS cameras.
- Developed by hobbyists but used by professionals.

- Magic Lantern adds advanced photo and film functionality.
- Runs from the SD/CF card and adds a host of new features to Canon EOS cameras that weren't included from the factory by Canon.

Supported Models, Statistics

13 active ports:

1100D (T3), 500D (T1i), 550D (T2i), 600D (T3i), 650D (T4i), 700D (T5i), EOS M, 50D, 60D, 6D, 7D, 5D2, 5D3

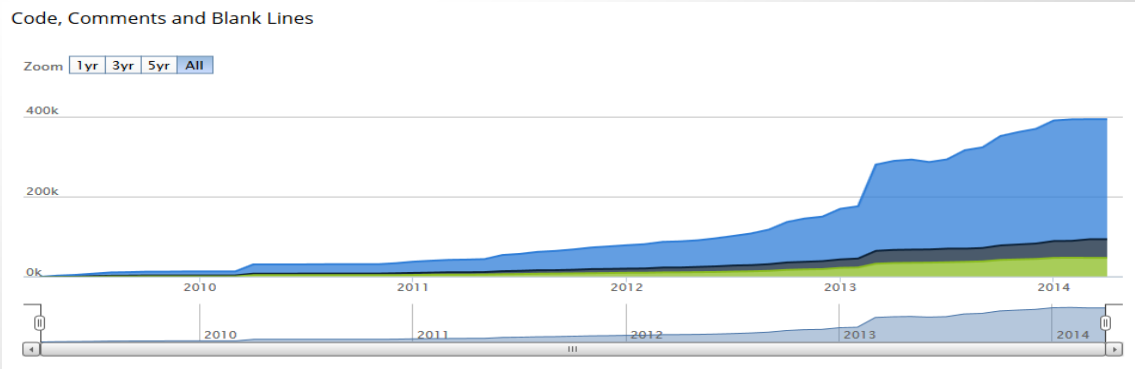
Community:

300k+ downloads and 28k+ *registered* users

Source Code:

- **10k+ commits** made by **106 contributors**, **76** in the last year
- **~300k lines of code** mostly **written in C**

Ohloh: "This is one of the largest open-source teams in the world, and is in the top 2% of all project teams on Ohloh."



How does Magic Lantern work?

- Runs in RAM only
  - No need to flash anything
  - We either...
    - Forge firmware update (with payload)
    - Use autoexec.bin functionality by setting a boot flag
- Hooks into original firmware startup
  - Shrinks memory pools
  - Hooks original firmware tasks
- Starts its own tasks under DryOS operating system
- Implements its own menu
  - Full control over visual appearance
  - More flexibility
- Accesses image buffers, hardware registers, and more

Legal issues

Similar to smartphone jailbreaking, but Cameras have no software ecosystems.

- Copyright
  - We do not copy verbatim Canon code in Magic Lantern.
- Reverse engineering
  - Both US and EU laws allow reverse engineering for interoperability, without requiring the permission from the copyright holder (Canon).
  - We examine Canon firmware by disassembling, decompiling and experimentation (trial and error).
- Encryption and Digital signatures
  - We do not publish crypto keys neither algorithms. Signing and encryption tool is kept internal to the team.
- "Ethical decisions"
  - We do not touch high-end cameras like the 1D series.

History and Community

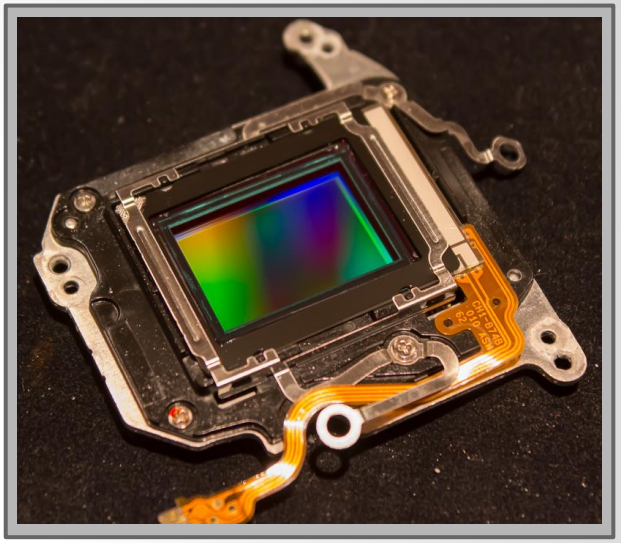
- **2009-2010**: mostly one-man show (Trammell Hudson)
  - Inspired by CHDK (boot method), but new code
  - First camera: EOS 5D Mark II
  - First code on Bitbucket: April 2009
  - Community mainly collaborated on mailing list, wiki and Vimeo group
- Since **2010**: Alex is the main dev and coordinator
- Xmas **2011**: HDR video
- **2012**: new website: www.magiclantern.fm
  - Post on mailing list, suggested setting up community website, people got together: Forums, twitter, etc..
  - EOS 7D finally working

History and Community

- **2013**:
  - Modules (move advanced functions from the core)
  - 14-bit RAW Video (this made lots of forum traffic!)
  - Auto ETTR, Dual ISO
  - Arkanoid :-)
- **2014 (works in progress):**
  - Lots of refactoring and backend improvements
  - RAW format v2.0 (MLV) getting ready (with sound!)
  - RSA Image Encryption
  - Unified Audio Framework
  - Scripting (TCC - http://bellard.org/tcc/)
  - “Sensor upgrade” (ISO research)

14-bit RAW Video

- Recording 1920x1080 @ 24 fps
- ~85 MiB/s video stream
- Saving raw bayer pattern bitstream
- 14 bits per pixel
- Needs post-processing
- Astounding results
- 60 fps possible

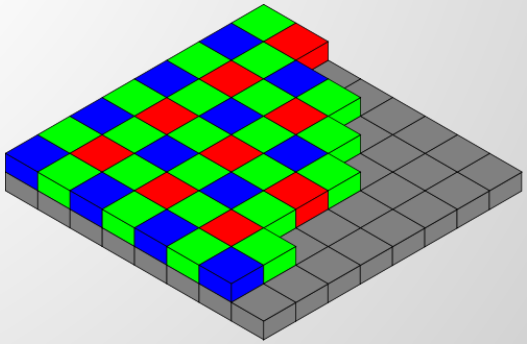


Quotes:

EOSHD: *"I have no other words to describe it – this is huge news (...) The world just exploded."*

Cinema5D: *"It's a revolutionary time for indie filmmakers"*

Neumann Films: *"We are impressed, to say the least!"*



source: Wikipedia

Standard H.264

RAW Video

Source: www.eoshd.com

What was just before RAW Video?

April 17, 2013

- Found the photo RAW buffers (what goes into CR2)
- RAW zebras and histogram ⇒ **correct overexposure warnings!**

April 26, 2013

- Found the LiveView RAW buffers (14-bit silent pictures)

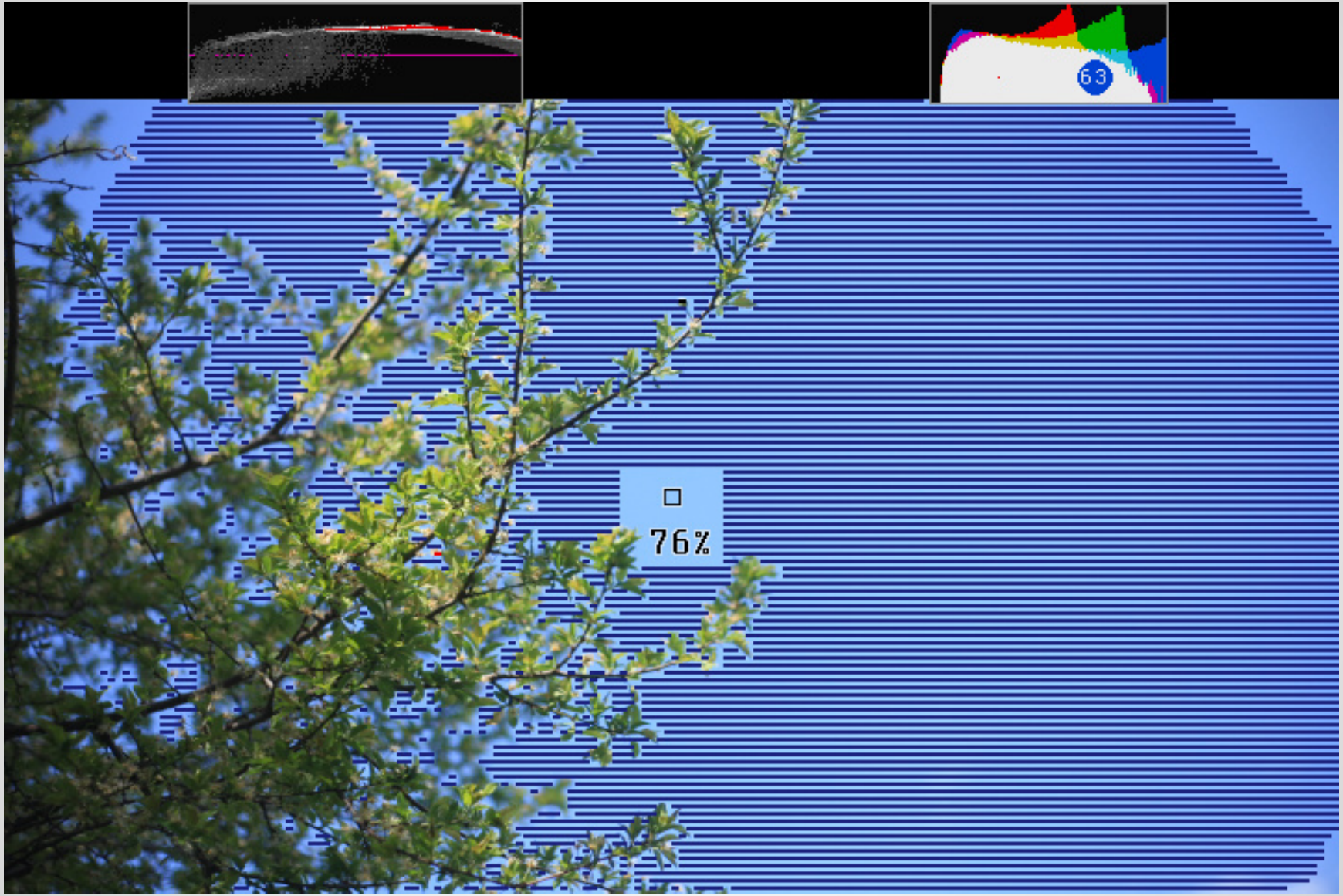
May 12, 2013

- 1000x cards fast enough for RAW video (1920x1080 24fps)
- **RAW video madness begins**

Not many people know that…

- RAW video started from a still-photo breakthrough!

What's wrong with JPEG zebras/histogram?



JPEG-based RGB zebras say this image is grossly overexposed. Really?

What's wrong with JPEG zebras/histogram?

RAW zebras: this image is actually **underexposed by at least 1 stop!**

ETTR - Expose To The Right

How to expose for minimal noise?

- Capture more photons
  - Slower shutter speed or wider aperture
  - 1 stop to the right ⇒ noise gets cut in half
- Increase ISO (once you've ran out of photons)
  - This reduces electronic noise (read noise)
  - It doesn't help with photon noise (in low light)
  - Little or no benefits above ISO 1600
- Make sure you don't clip important highlights
  - More highlights captured == more noise in shadows
  - You may want to clip spec(tac)ular highlights

Auto ETTR - Automate this Process

Settings:

- How many highlights you can clip?
  - (Highlight ignore, maybe also clip the green channel)
- How much noise you are OK with?
  - SNR limits for midtones and shadows
- Slowest shutter speed, maximum ISO…

⇒ Constrained optimization

(minimize noise without clipping important highlights)

Canon Exposure Metering

Canon metering (Av mode, LiveView metering): underexposed by about 1.5 EV

Canon Exposure Metering

Canon metering: overexposed by 0.5 EV just by changing the framing

Auto ETTR

ETTR metering - raw exposure is just right (with a small safety margin)

Auto ETTR

ETTR metering is consistent - exposure does not change with framing

Dual ISO - Extending Dynamic Range

As you know, on Canon cameras:

- ISO 100 is the noisiest* ISO available (weak signal, noisy electronics)
- Higher ISOs are cleaner, but they clip highlight details, forcing you to underexpose

* all other exposure variables being equal

Why not combine both?

5D3, ISO 100, +7.5 EV in post

Noisy shadows, great highlight detail

5D3, ISO 1600, +3.5 EV in post

Clean shadows, but highlights are clipped

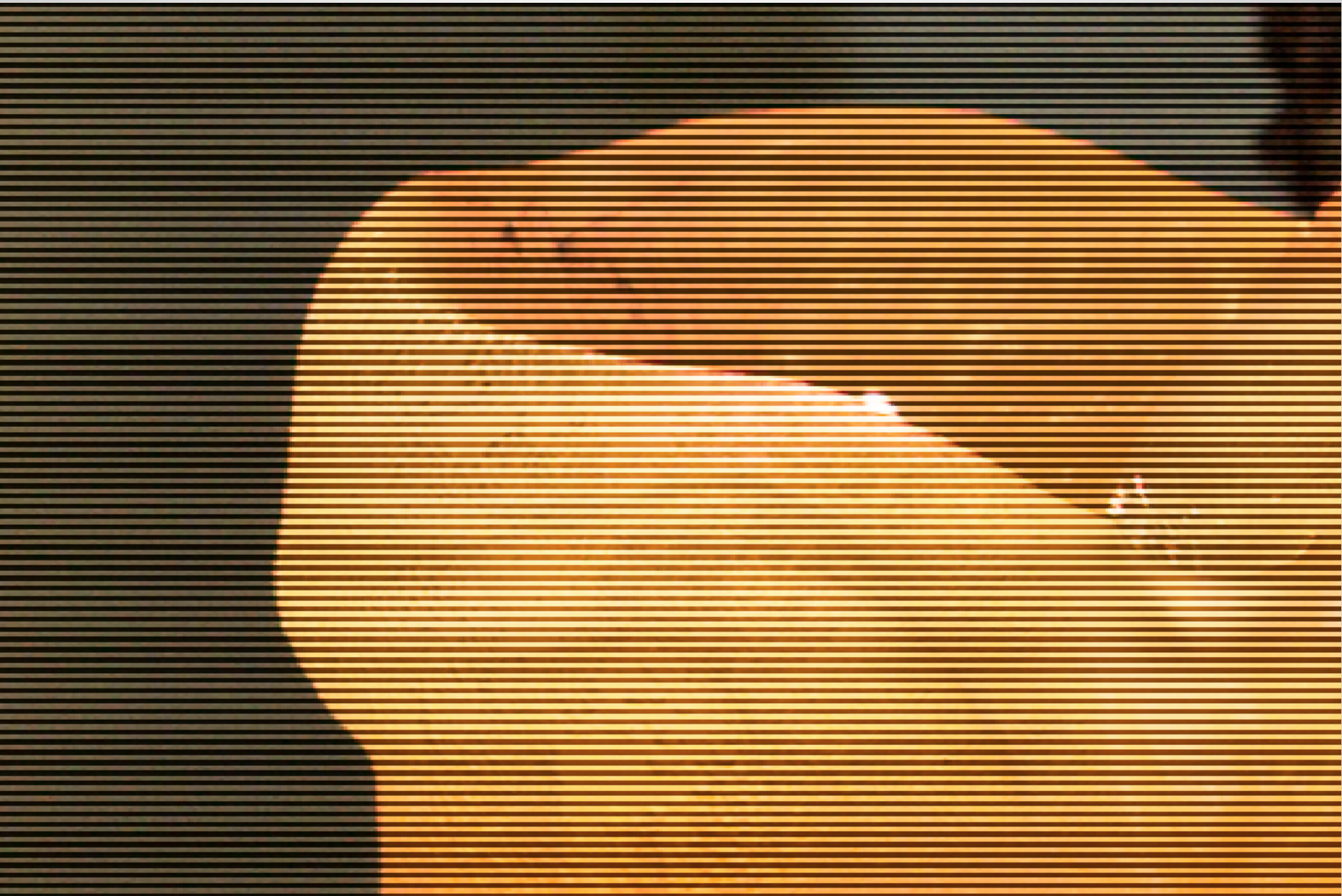
5D3, Dual ISO 100/1600, +7.5EV in post

Clean shadows **and** good highlight detail!

Back to ISO 100, +7.5 EV in post

Noisy shadows, great highlight detail

Dual ISO - alternate ISO every two lines



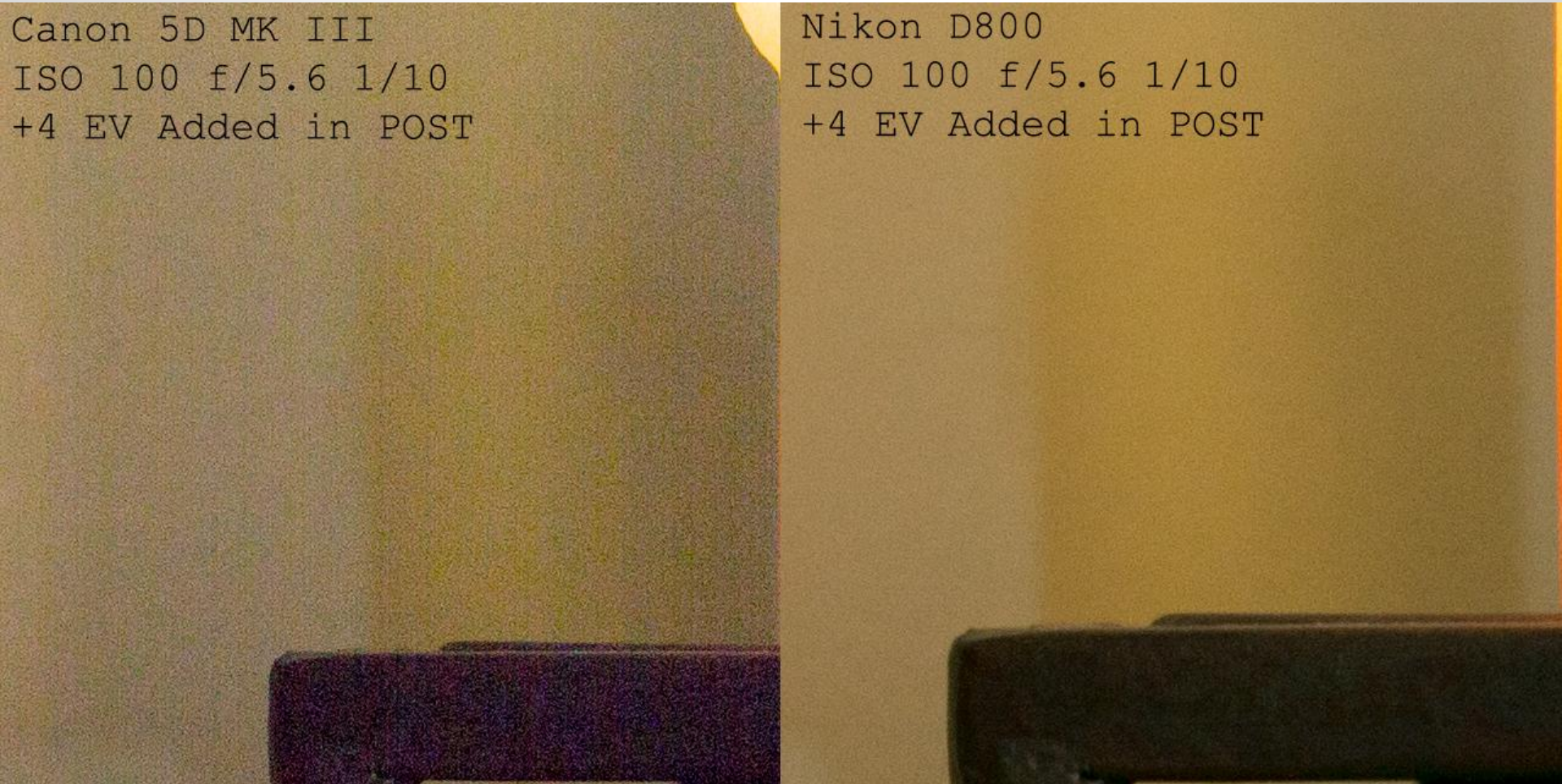
Dual ISO - dark image (as with ISO 100)

Dual ISO - you can raise the shadows!

Try doing this with a stock Canon!

No problems with Nikon D800.

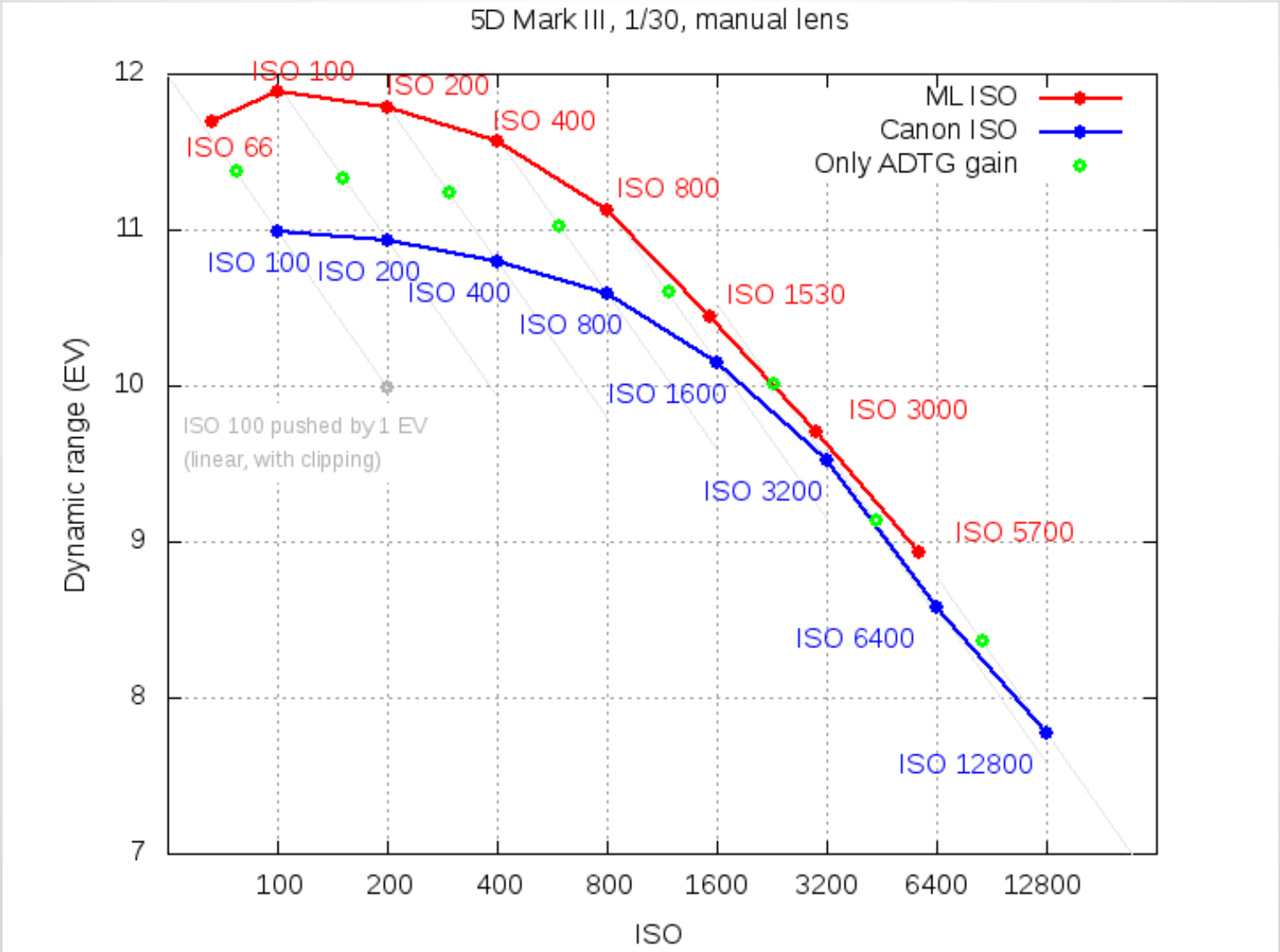
Sample from Jonathan Zdziarski, http://www.zdziarski.com/blog/?p=2792
Open Source Brings High-End Canon 5D MK III Dynamic Range Closer to Nikon D800



Work in progress: “sensor upgrade”

We will re-implement ISO settings for even lower noise

(almost 1 stop more dynamic range on 5D Mark II and III)



Work in progress: TCC scripting

Proof of concept working: run a C compiler on your camera!

TCC - Tiny C Compiler, http://bellard.org/tcc/

Future Outlook

It is very difficult to make any reasonable predictions (who knew HDR or RAW video would be possible?)

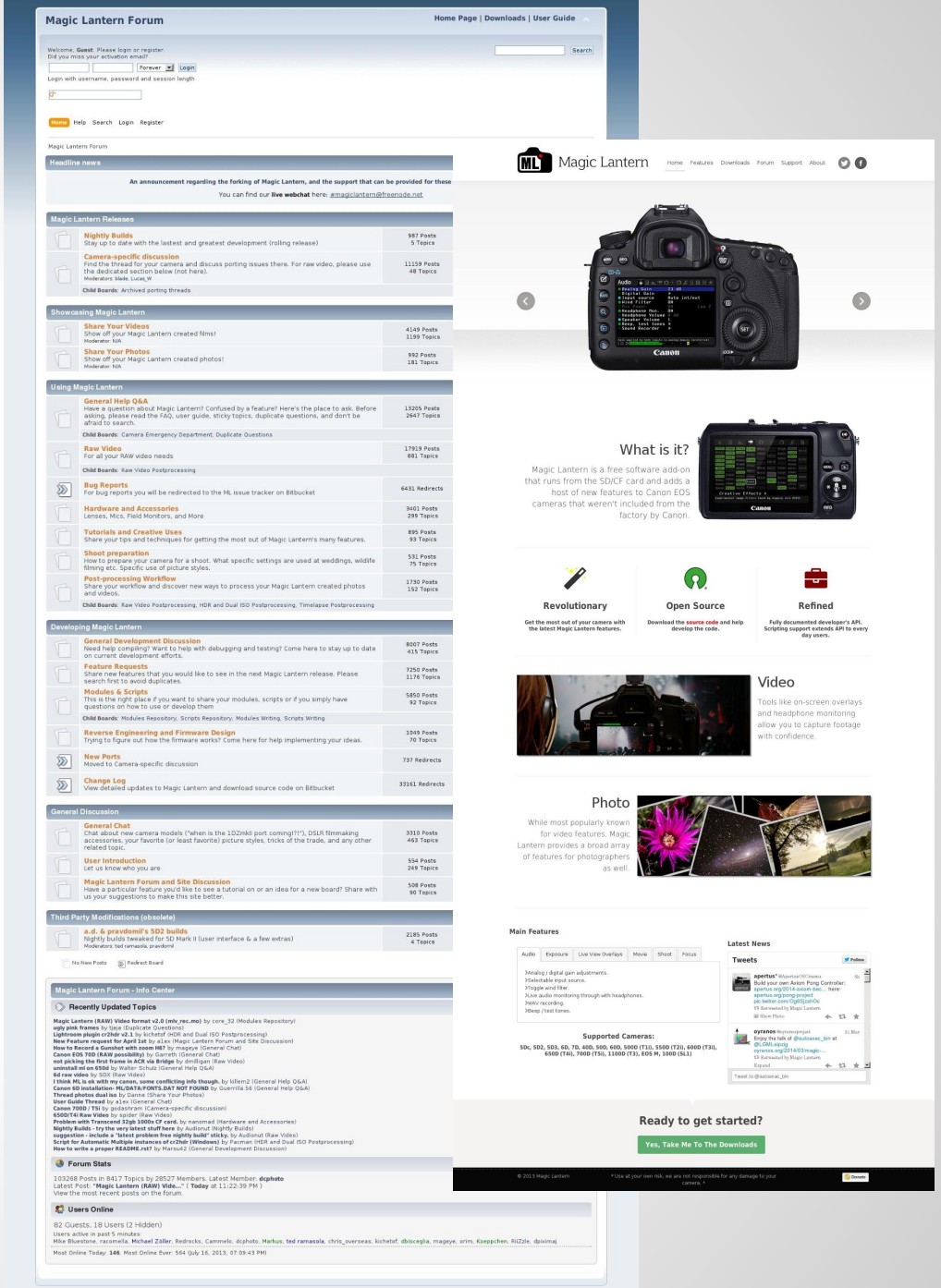
Steady growth of community (both users and developers) will present both new challenges and opportunities.

We'd love to see magic lantern features/file formats supported in open source software… anyone? :)

... just keep the project rolling!

Thanks!

Please join us on friday
for the live workshop.
Bring your cameras!

Please visit:
www.magiclantern.fm

We are always looking
for more developers
and reverse engineers!