



MAGIC LANTERN

# Magic Lantern

Canon EOS Camera Tool

[www.magiclantern.fm](http://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

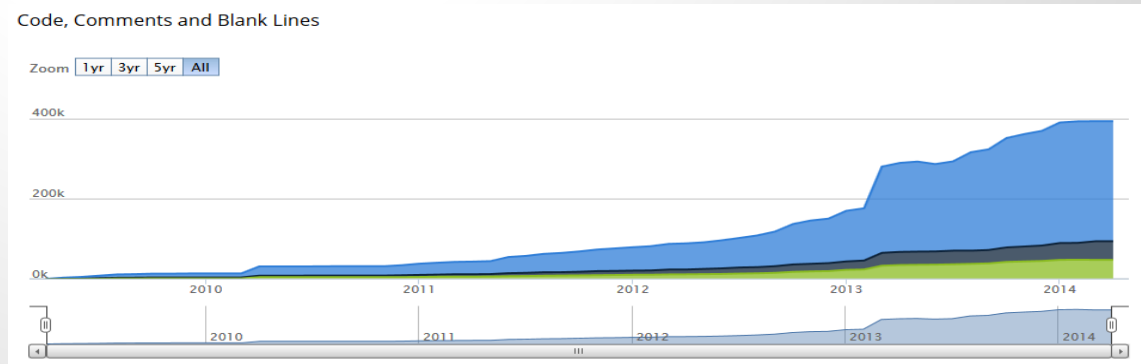
## Community:

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  - We do not publish crypto keys neither algorithms.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

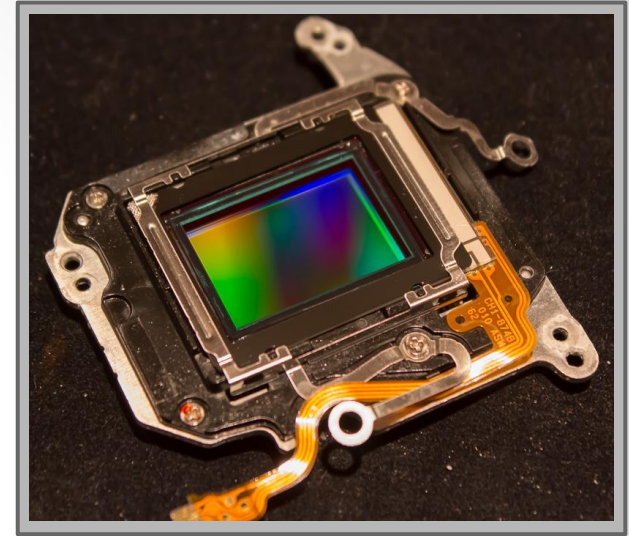
- **2009-2010:** mostly one-man show (Trammell Hudson)
  - Inspired by CHDK (boot method), but new code
  - First camera: EOS 5D Mark II
  - First code on Bitbucket: April 2009
  - Community mainly collaborated on mailing list, wiki and Vimeo group
- Since **2010:** Alex is the main dev and coordinator
- Xmas **2011:** HDR video
- **2012:** new website: [www.magiclantern.fm](http://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:**

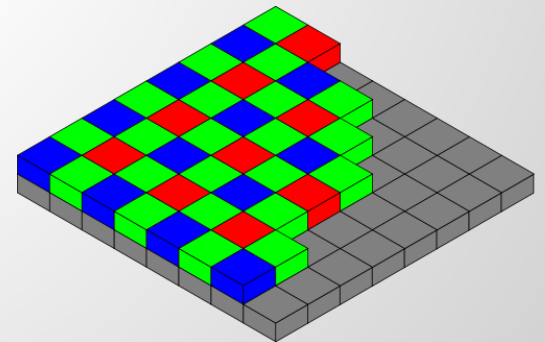
*"I have no other words to describe it – this is huge news (...) The world just exploded."*

**Cinema5D:**

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

**Neumann Films:**

*"We are impressed, to say the least!"*



source: Wikipedia



# Standard H.264

Source: [www.eoshd.com](http://www.eoshd.com)



**RAW Video**

Source: [www.eoshd.com](http://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

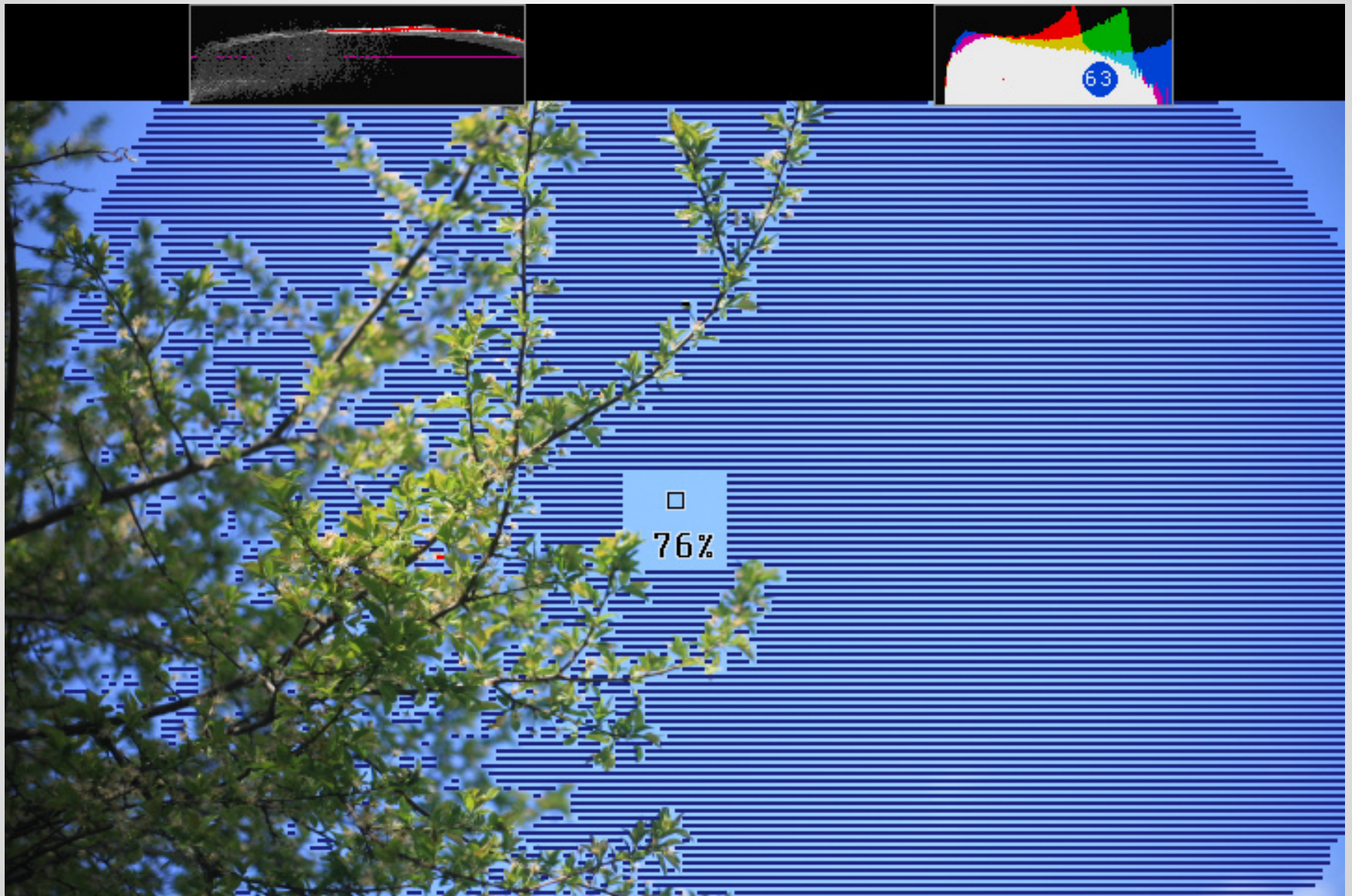
- 1000x cards fast enough for RAW video (1920x1080 24fps)
- **RAW video madness begins**

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  $\Rightarrow$  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

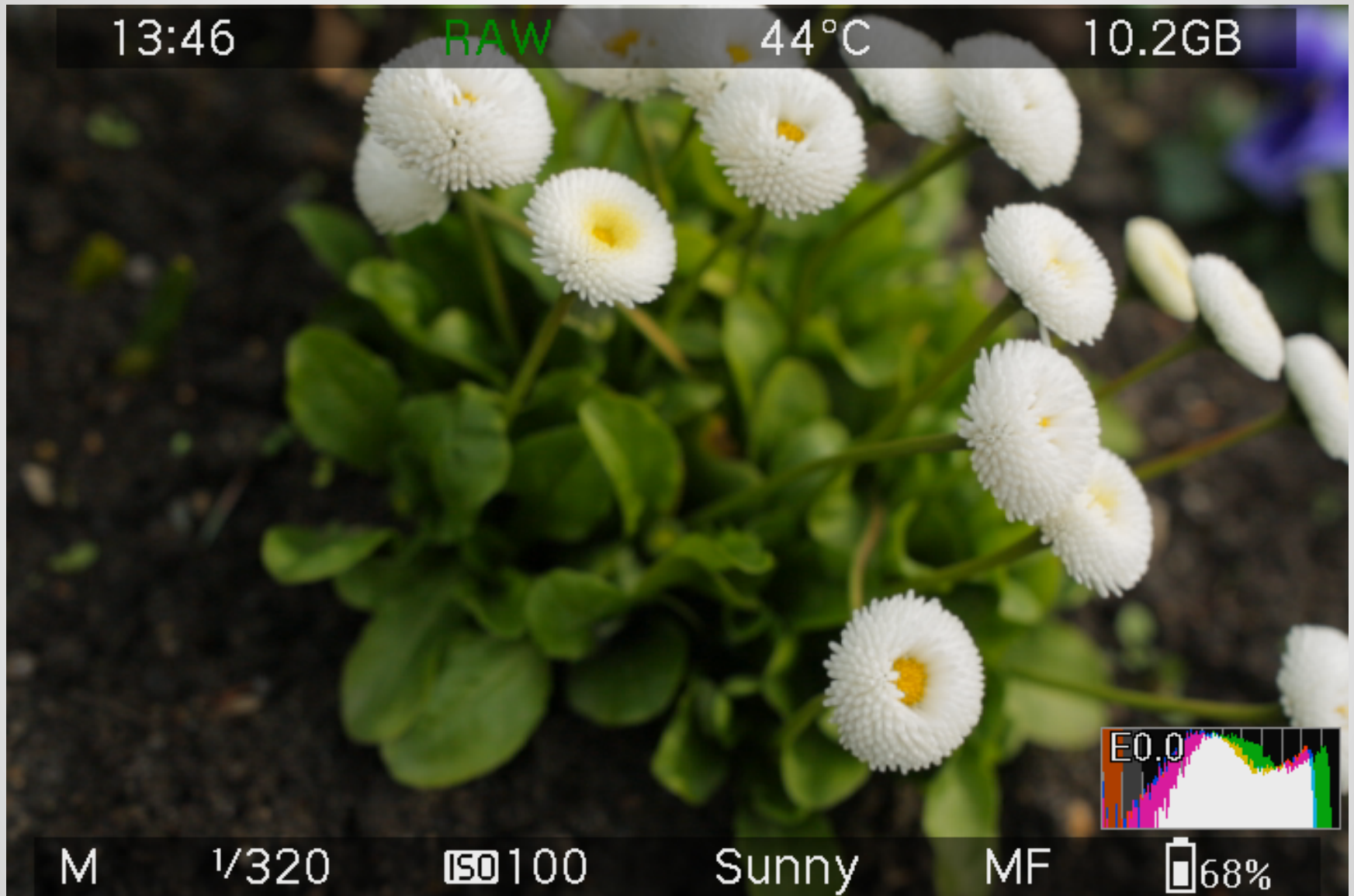
# Auto ETTR



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!



+1.5 EV in post (ufraw soft-film)



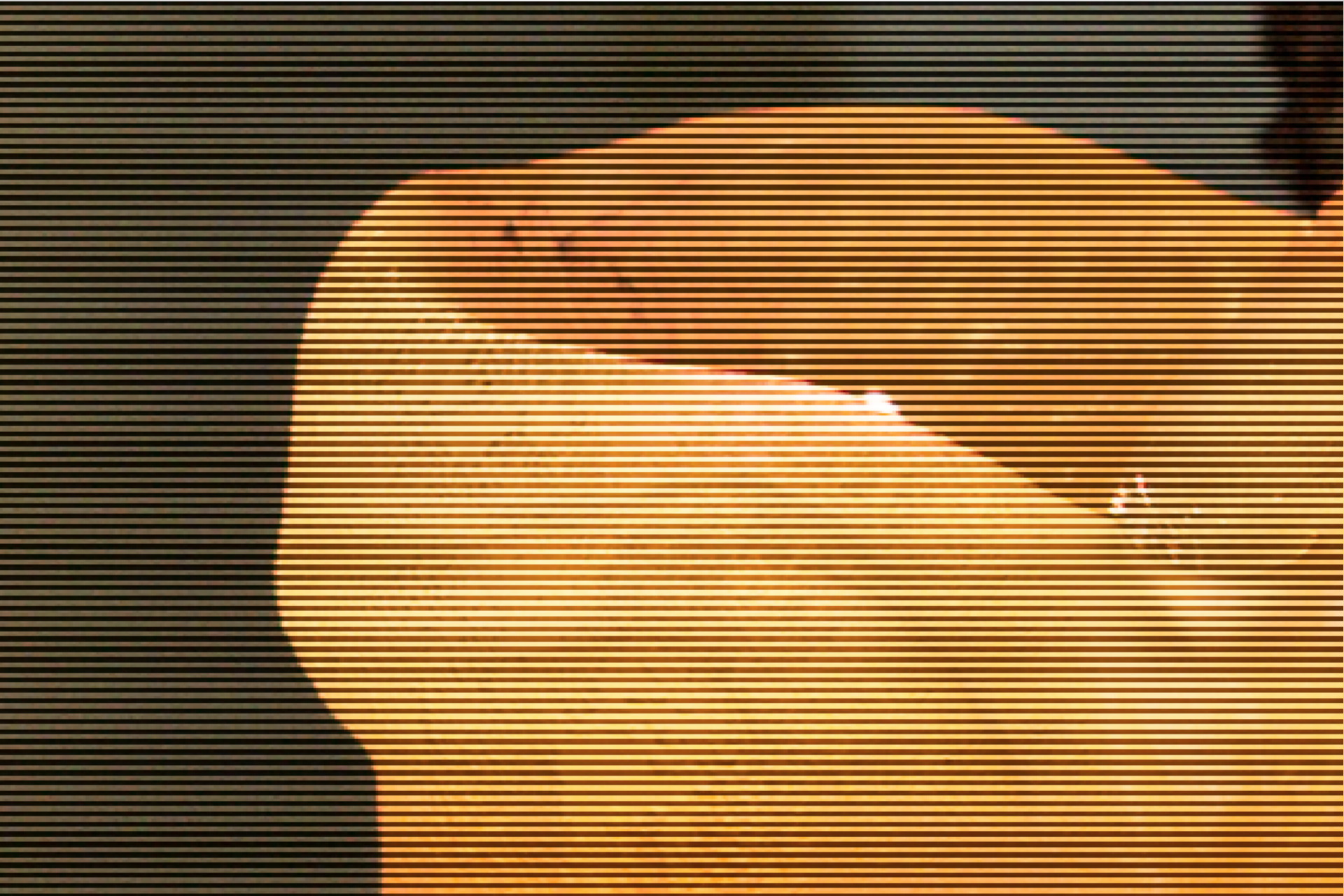
# Back to ISO 100, +7.5 EV in post

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!

... without the noise !





# Try doing this with a stock Canon!

No problems with Nikon D800.

Sample from Jonathan Zdziarski, <http://www.zdziarski.com/blog/?p=2792>

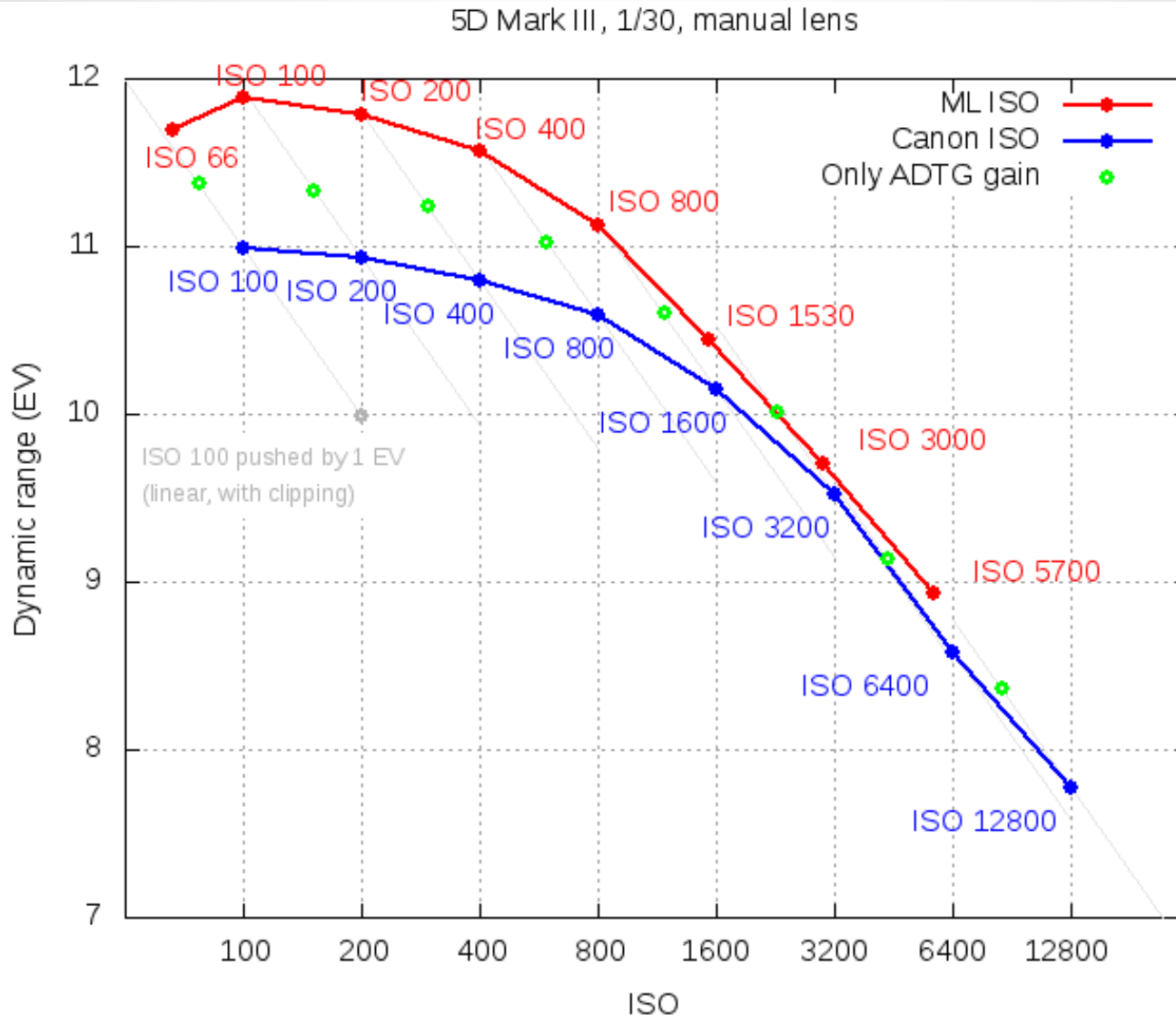
Open Source Brings High-End Canon 5D MK III Dynamic Range Closer to Nikon D800

Canon 5D MK III  
ISO 100 f/5.6 1/10  
+4 EV Added in POST

Nikon D800  
ISO 100 f/5.6 1/10  
+4 EV Added in POST

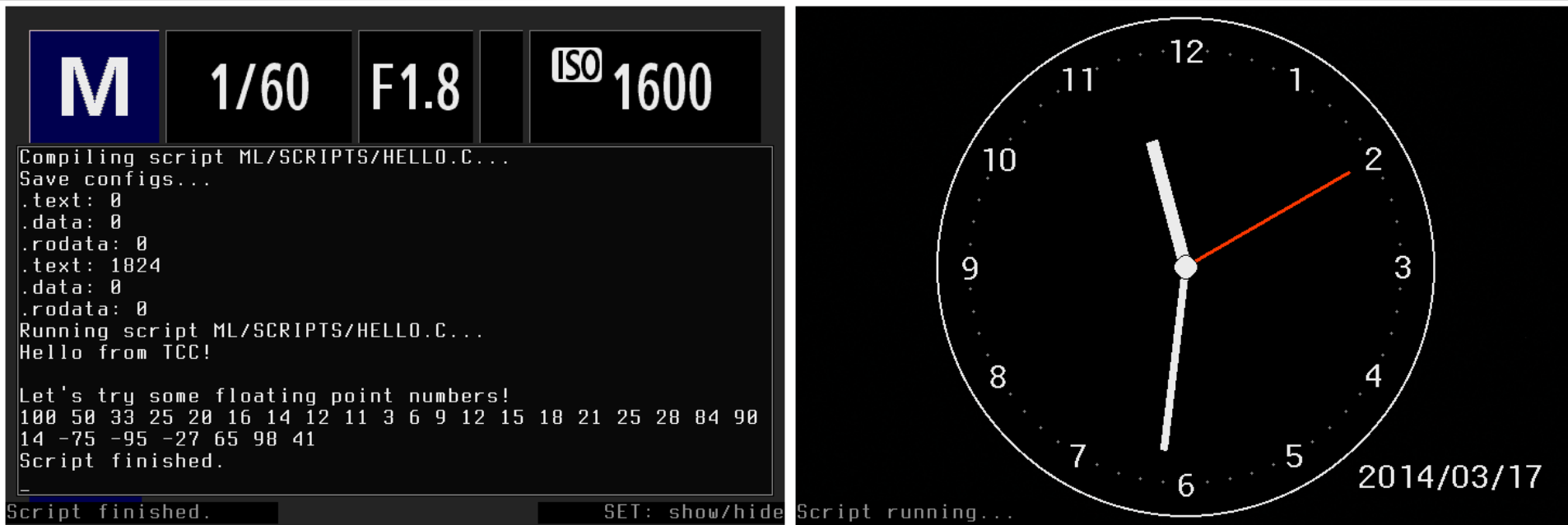
# Work in progress: “sensor upgrade”

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](http://www.magiclantern.fm)

## We are always looking for more developers and reverse engineers!

The screenshot shows the Magic Lantern Forum homepage. At the top, there's a navigation bar with 'Home Page', 'Downloads', and 'User Guide'. Below that is a search bar and a login/register section. The main content area is divided into several sections:

- Headline news:** An announcement regarding the forking of Magic Lantern and support for Canon EOS R.
- Magic Lantern Releases:** A table listing releases like 'Nightly Builds', 'Camera-specific discussion', and 'Share Your Photos'.
- Showing Magic Lantern:** A section for sharing content like 'Share Your Videos' and 'Share Your Photos'.
- Using Magic Lantern:** A large section with sub-categories like 'General Help Q&A', 'Raw Video', 'Bug Reports', 'Hardware and Accessories', 'Tutorials and Creative Uses', 'Shoot preparation', 'Post-processing Workflow', and 'Developing Magic Lantern'.
- General Discussion:** A section for general chat and user introductions.
- Third Party Modifications (obsolete):** A section for user-made modifications.
- Forum Stats:** Shows 103268 posts in 8417 topics by 28527 members.
- Users Online:** Shows 82 guests and 19 users.

The screenshot shows the Magic Lantern website's main page. At the top, there's a navigation bar with 'Home', 'Features', 'Downloads', 'Forum', 'Support', and 'About'. Below that is a large image of a Canon camera with the Magic Lantern interface overlaid. The main content area features three columns of text and icons:

- Revolutionary:** 'Get the most out of your camera with the latest Magic Lantern features.'
- Open Source:** 'Download the source code and help develop the code.'
- Refined:** 'Fully documented developer's API. Scripting support extends API to every day user.'

Below these are three sections:

- Video:** 'Tools like on-screen overlays and headphone monitoring allow you to capture footage with confidence.'
- Photo:** 'While most popularly known for video features, Magic Lantern provides a broad array of features for photographers as well.'
- Supported Cameras:** A list of camera models including Canon EOS 70D, 80D, 90D, 5D Mark III, 5D Mark IV, 6D, 6D Mark II, 70D, 700D (T5), 100D (T4), 100S (T5), 100D (T3), 1500D (T6), 600D (T3i), 650D (T4i), 700D (T5i), 1000D (T3i), 1050N (T5i), 100D (T3i).

At the bottom, there's a 'Ready to get started?' section with a 'Yes, Take Me To The Downloads' button.