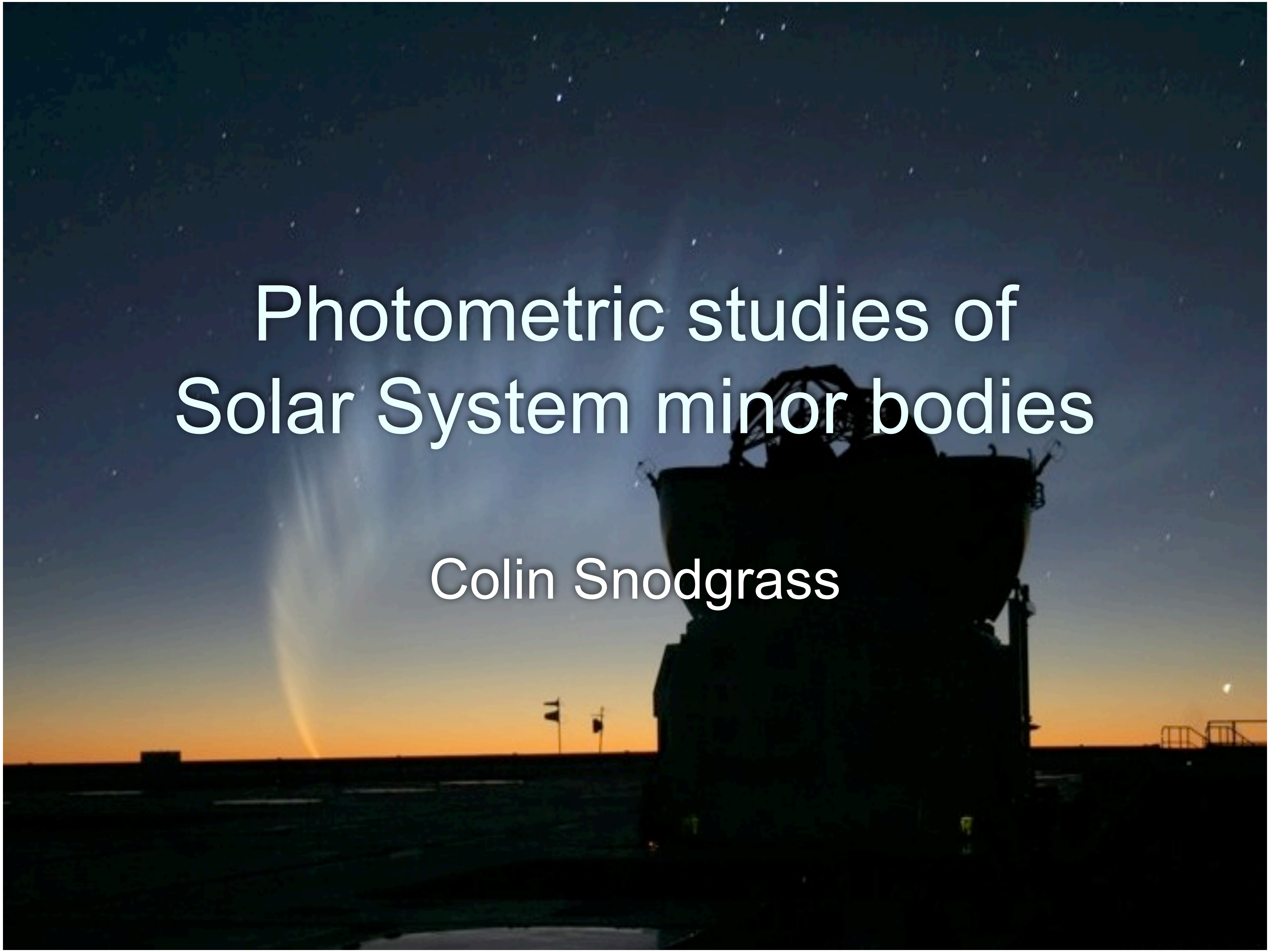

Photometric studies of
Solar System minor bodies
Colin Snodgrass

Outline

- Introduction
  - Who I am
  - Solar System, minor bodies
  - Comets
- Distant JFC work
  - Thesis work: Sizes, shapes, densities, colours
  - New projects: Phase functions, SEPPCoN, 67P
- Active comets
  - McNaught
  - Holmes

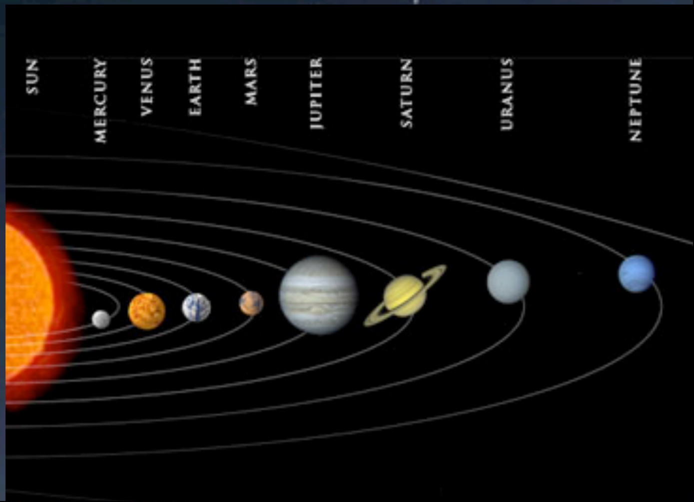
Photo: E. Jehin

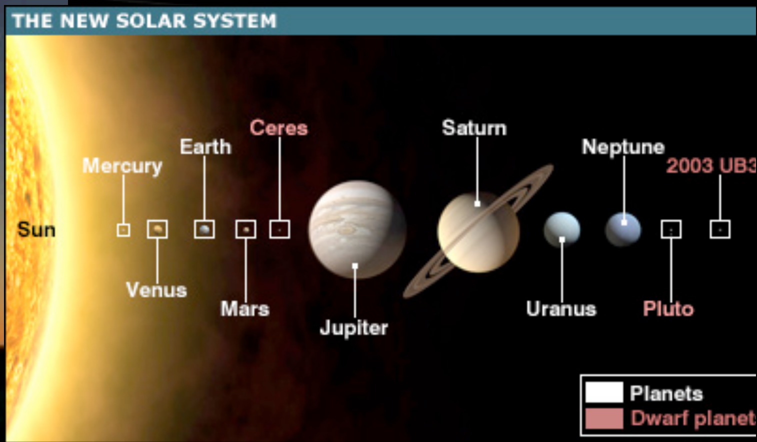
Who am I?

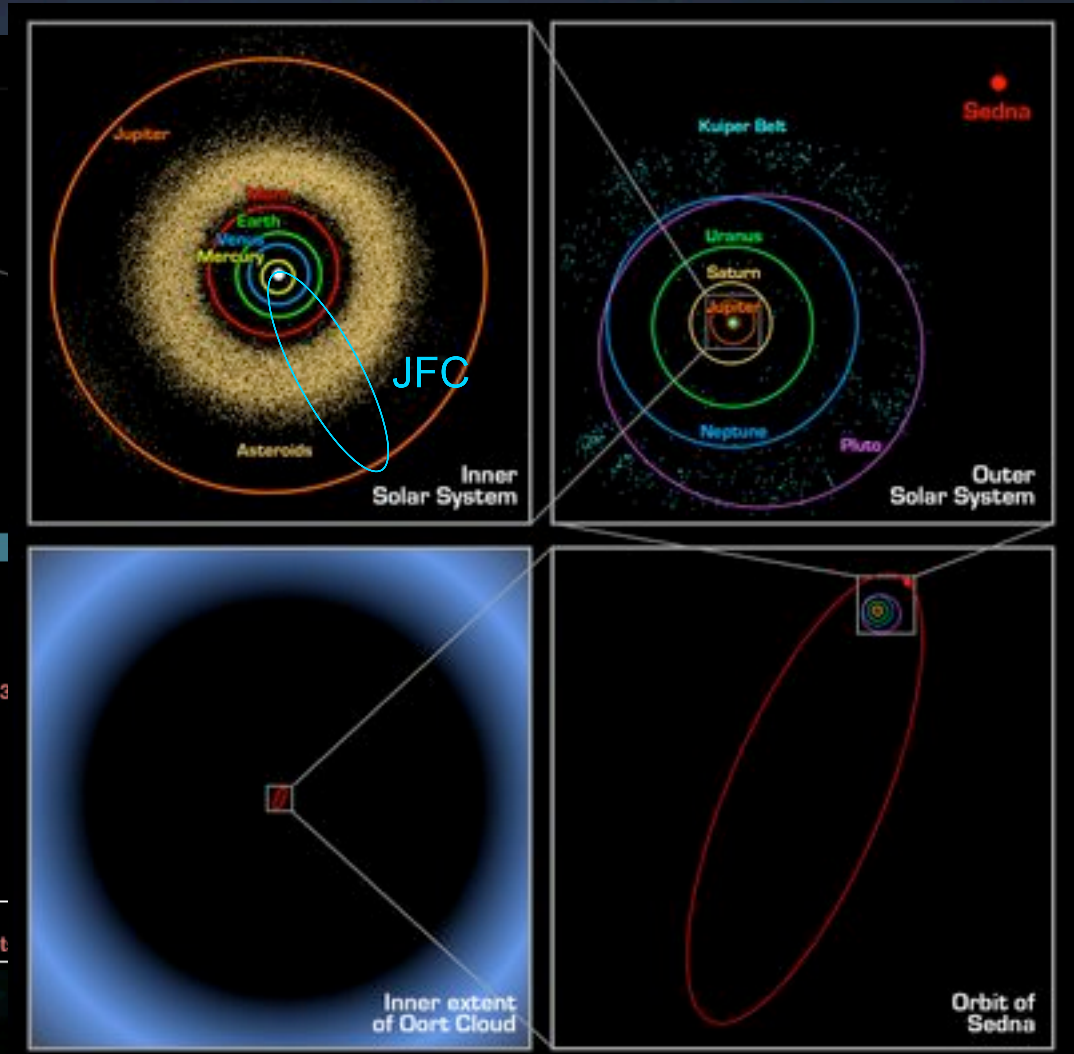
- I'm from Scotland.
- I studied at St Andrews in Scotland and at Queen's University Belfast in Northern Ireland.
- I've been an ESO fellow since October 2006.
- I'm based in Chile, with duty station at La Silla.
- I work on planetary science in general, with a focus on Solar System minor bodies.

Photo: E. Jehin

Solar System minor bodies







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Comets

- Small bodies of ice and rock.
- Remnants of Solar System formation.
- Activity due to sublimating ices when near the Sun.

http://antwrp.gsfc.nasa.gov/apod/ap071105.html
Credit & Copyright: Vicent Peris and José Luis Lamadrid (astrofoto.es)

Photo: E. Jehin

Cometary nuclei

- Nuclei are small (radii a few kilometres) & dark (albedos typically only 4%)
- When active, the nucleus is obscured by coma unless imaged at very high spatial resolution.

Photo: E. Jehin

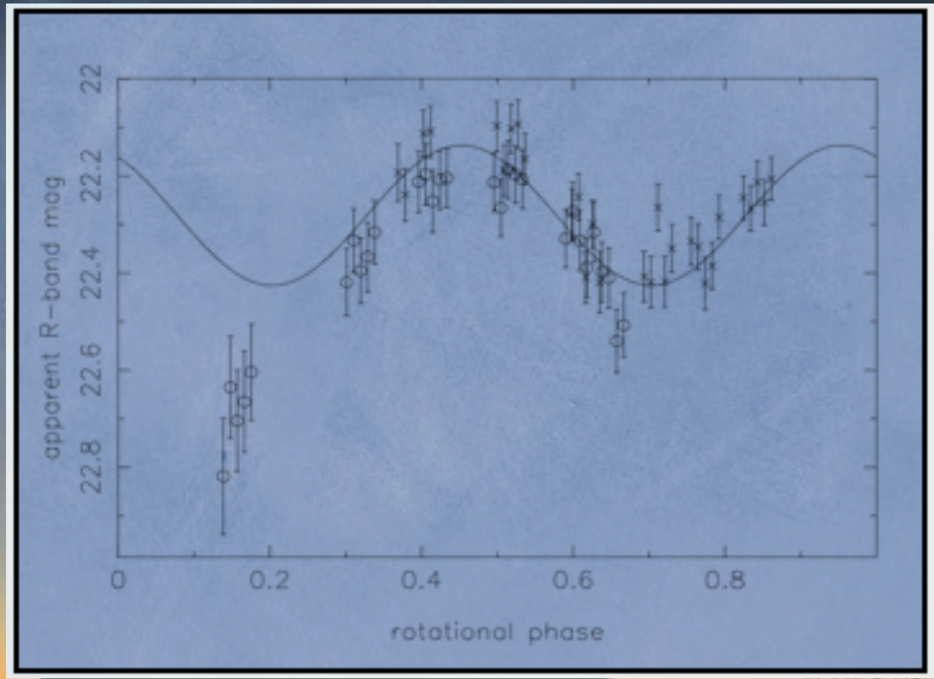
Observing the nucleus

- Canonical cut off for activity is R_h = 3 AU.
- We perform multi-filter, time-series photometry (CCD imaging). Requires 2-4m class telescope.
- From this we can measure surface properties (colours) and the bulk physical parameters of size, shape, rotation period and density.
- By studying a large number of comets in this way, we can constrain the general properties of the population.

Photo: E. Jehin

Time-series photometry

- Rotation of non-spherical nucleus causes variation in brightness.
- Searching for periodicity gives rotation rate.
- Mean brightness gives size.



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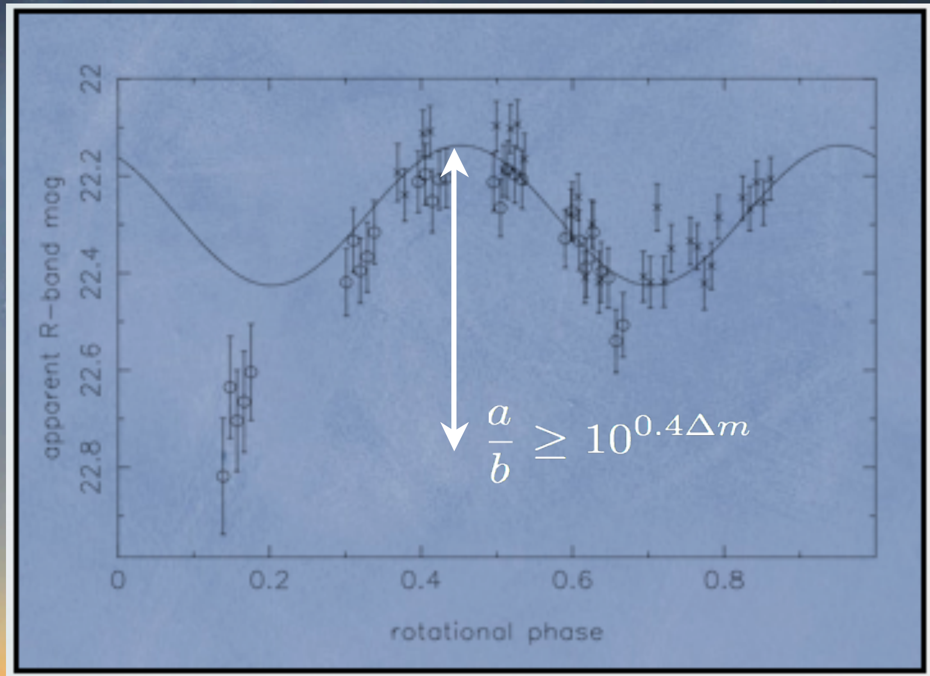
Time-series photometry

- Amplitude of light-curve gives elongation of nucleus, a/b.
- P_{rot} and a/b give minimum bulk density, by balancing self gravitation and centrifugal forces.



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Rotational statistics

- Spin frequencies should have a Maxwellian distribution for a collisionally relaxed population.
- Comets appear to have a more flat distribution: torques from jets of cometary activity dominate the spin state of nuclei.

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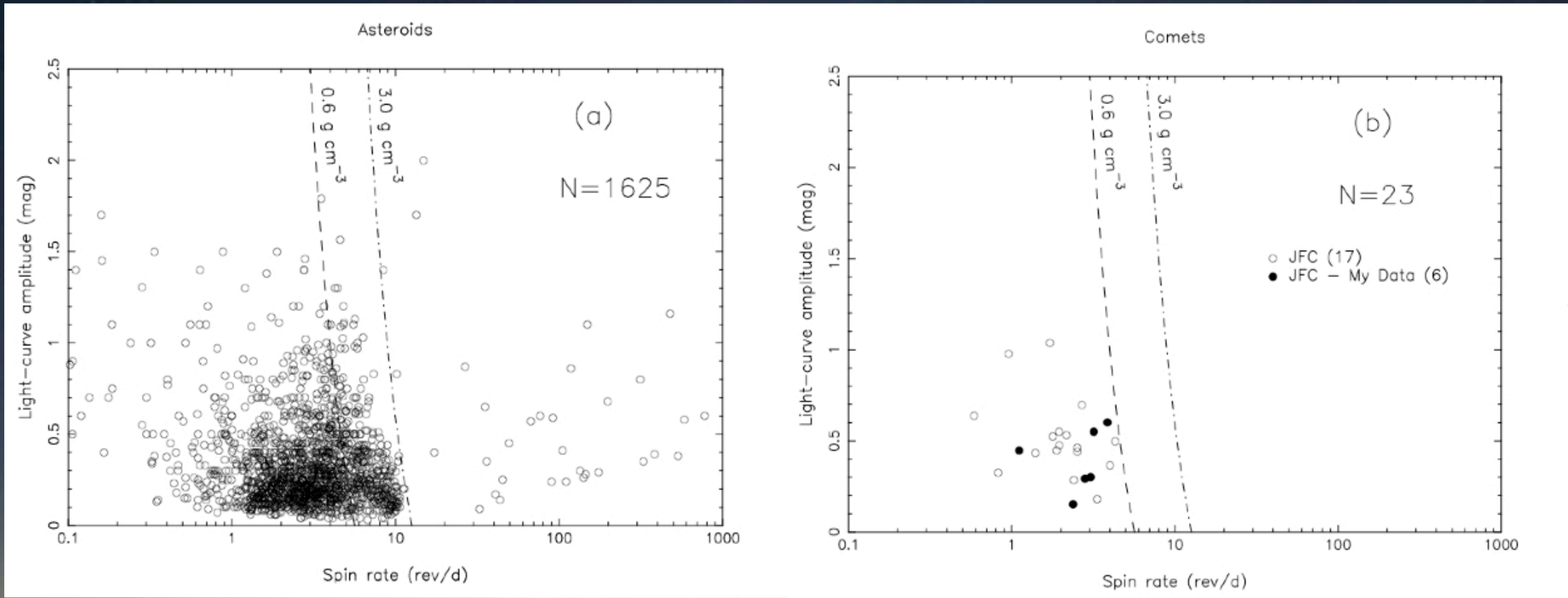
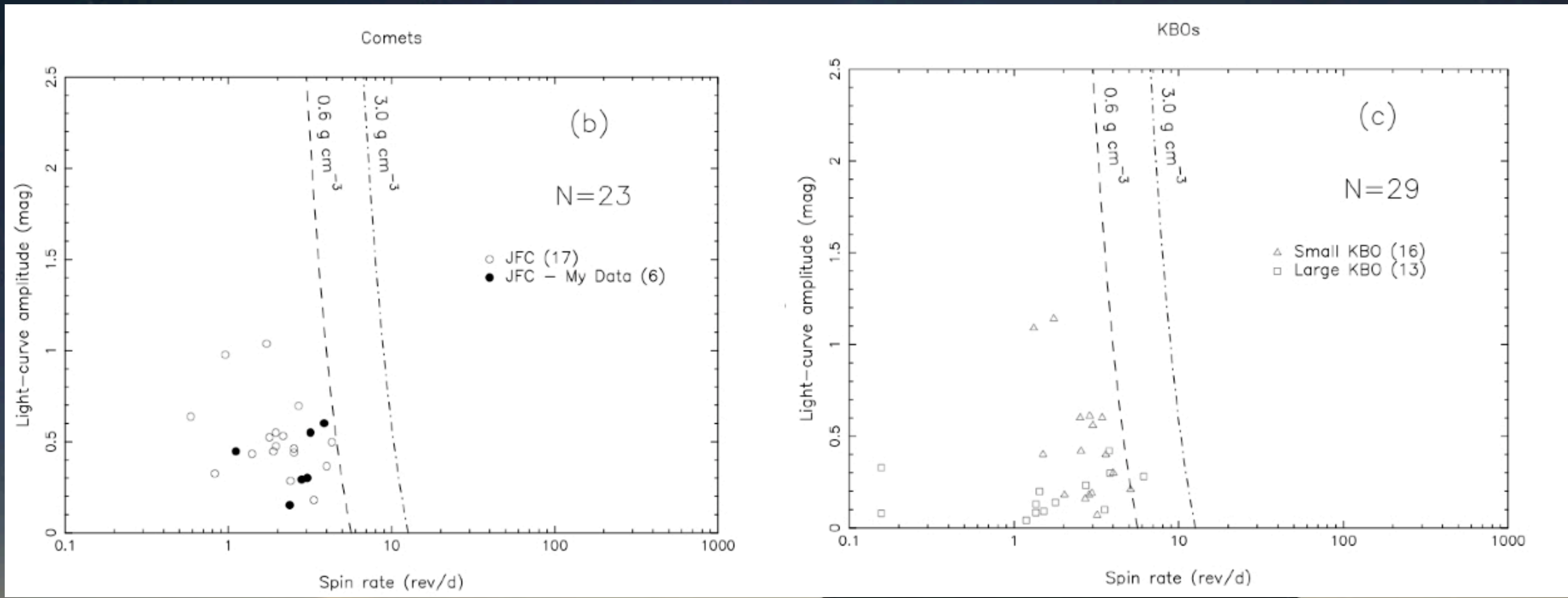
Bulk Densities



- Light-curve amplitude against spin-rate.
- Minimum bulk density for each minor body (rubble pile).
- Cut off gives average bulk density for population.

Photo: E. Jehin

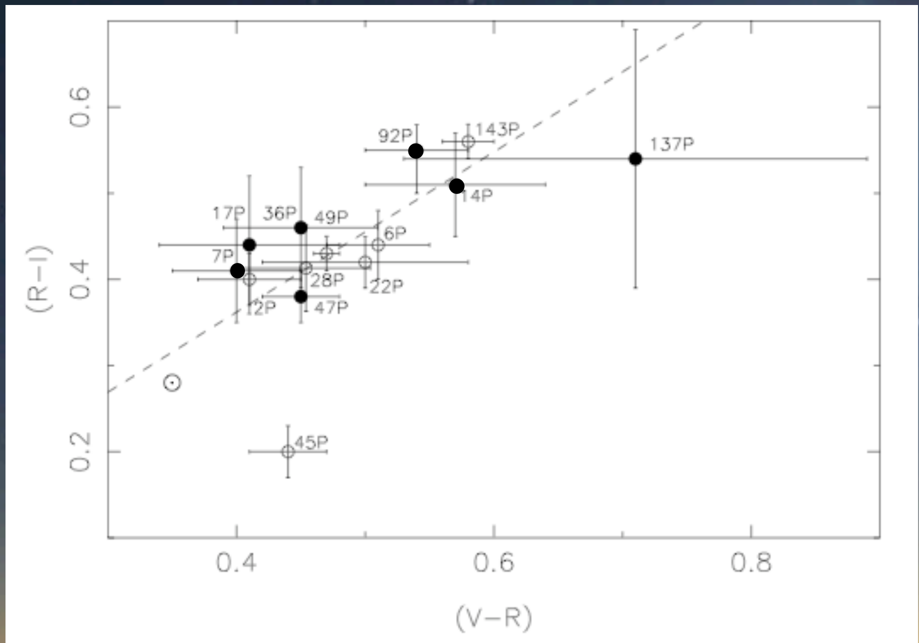
Bulk Densities (2)



- Same plot for KBOs - split into small (r<200km) and large.
- KBOs appear to have a similar cut off to JFCs, despite different sizes of observed bodies.

Photo: E. Jehin

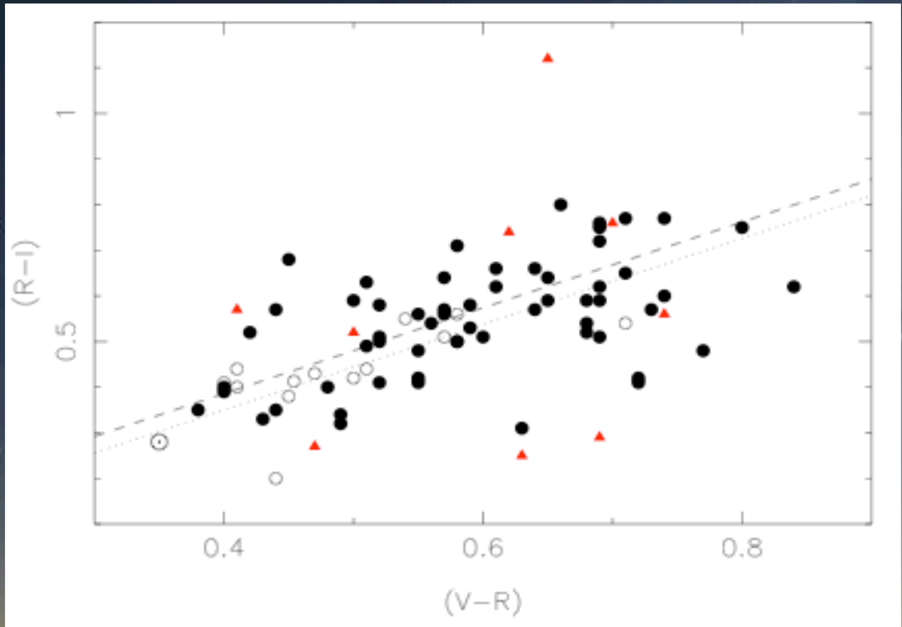
Surface Colours



- There is a linear relationship between the measured colour indices (V-R) and (R-I).
- This implies increasing albedo through V, R & I bands, i.e. greater reflectance at greater wavelength.

Photo: E. Jehin

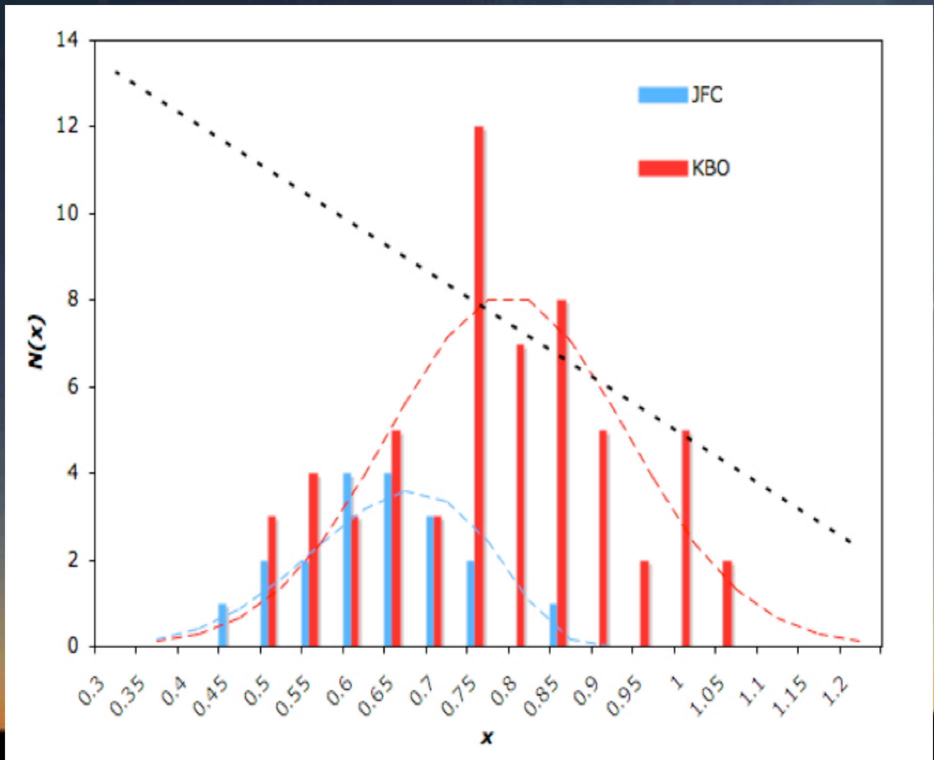
Surface Colours (2)



- The same relationship between (V-R) and (R-I) holds for KBOs.
- Nuclei are found to be red, but not as red as KBOs.
- This is attributed to removal or covering of the ‘ultra-red matter’ seen in KBOs by cometary activity.

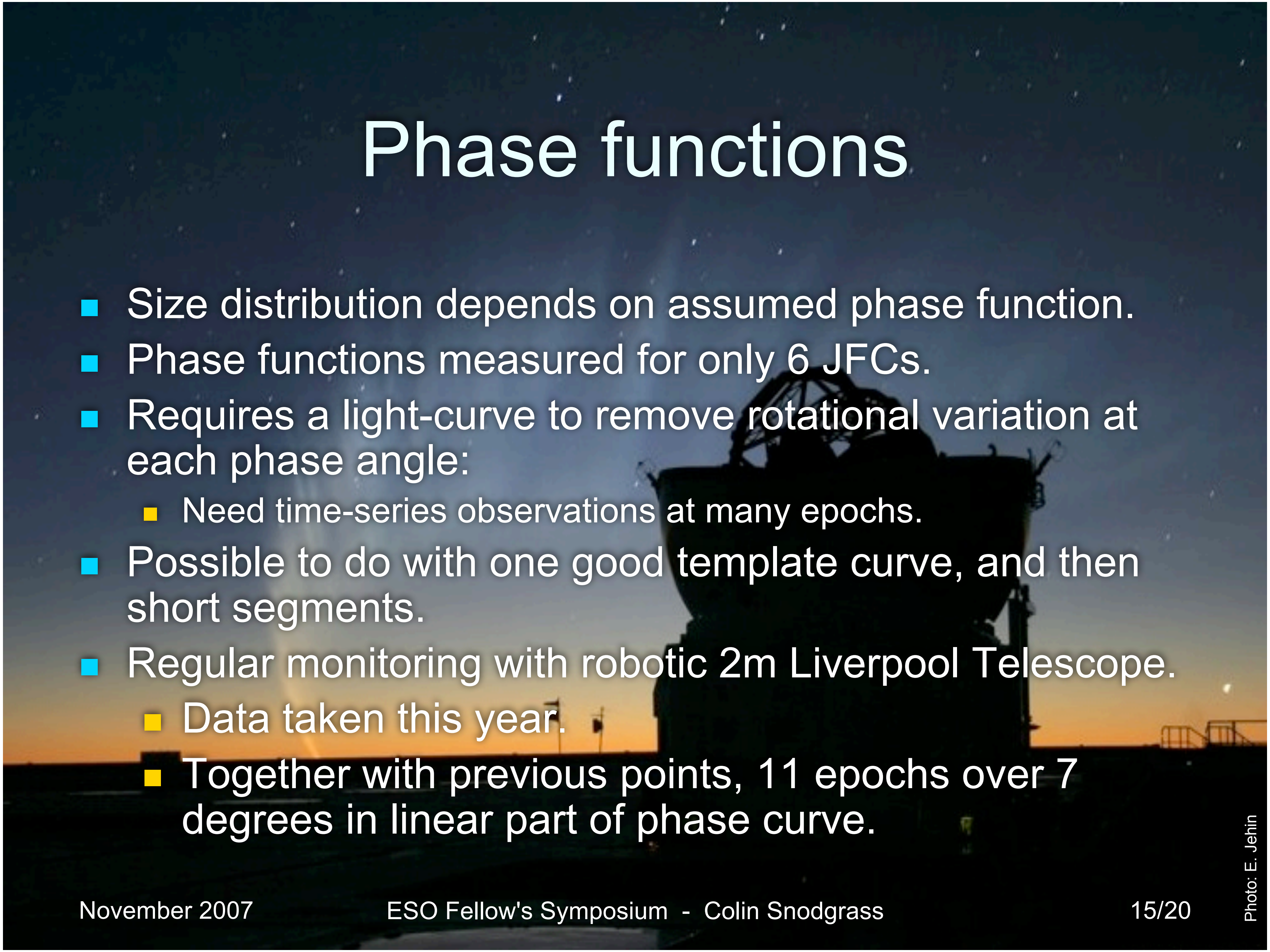
Photo: E. Jehin

Surface Colours (3)



- Reducing the colours to a single parameter gives approximately normal distributions for both JFCs and KBOs.
- The JFC distribution can be reproduced by applying a linear ‘de-reddening’ function to the KBO one: i.e. the reddest surfaces are the most depleted.

Photo: E. Jehin



Phase functions

- Size distribution depends on assumed phase function.
- Phase functions measured for only 6 JFCs.
- Requires a light-curve to remove rotational variation at each phase angle:
  - Need time-series observations at many epochs.
- Possible to do with one good template curve, and then short segments.
- Regular monitoring with robotic 2m Liverpool Telescope.
  - Data taken this year.
  - Together with previous points, 11 epochs over 7 degrees in linear part of phase curve.

Photo: E. Jehin

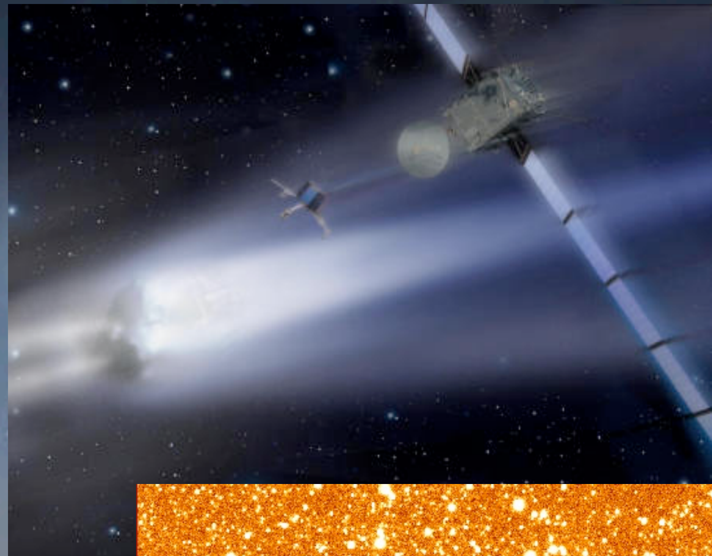
Albedos

- Size distribution also critically depends on assumed albedo.
- Spitzer program to get observations of 100 JFC nuclei - SEPPCoN, P.I. Y. Fernandez.
- Ground based semi-simultaneous optical at many facilities worldwide (inc 6 nights NTT so far).
- Combination of thermal IR + Optical gives albedo and size distributions.
- Also colours, light-curves, phase functions for a large subset of the comets.

Photo: E. Jehin

67P/Churyumov-Gerasimenko

- Target of the Rosetta mission, due to arrive at the comet in 2014.
- Observations of the comet this year at the same orbital position it will be in 2014.
- Light-curves, colours, phase function etc.
- Tricky as comet is in front of galactic centre at the moment - crowded field.
- Activity may start this year.



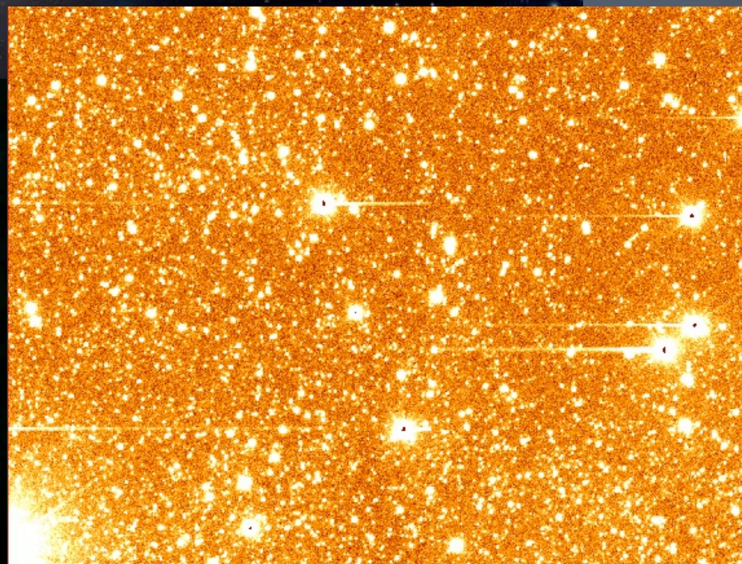


Photo: E. Jehin

Active comets

- Two unexpected events this year produced fantastic comet displays visible to the naked eye.
  - Comet C/2006 P1 (McNaught) is a dynamically new Oort cloud comet which passed close to the Sun in January and became the brightest comet in 40 years.
  - Comet 17P/Holmes is a JFC which underwent a spectacular outburst and brightened by 14 magnitudes in late October.
- We got data on both comets…

Photo: E. Jehin

Comet McNaught

- Perihelion on 12th January.
- Observed with the NTT starting on the 27th, at airmass 5 in twilight...
- Strong CN gas jets seen, and exotic species identified in gas coma (Sodium and other metals).

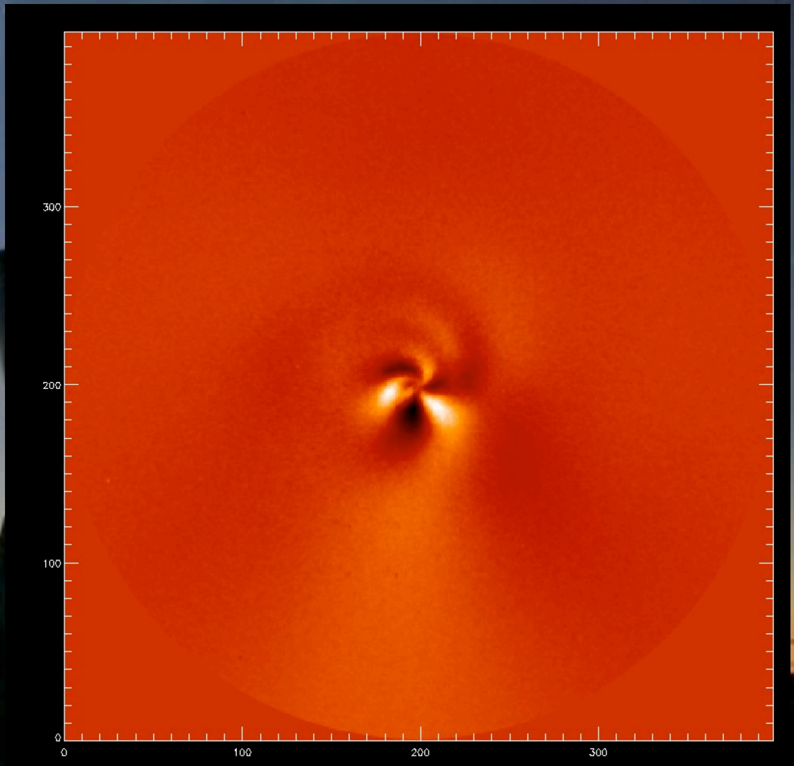


Photo: E. Jehin

Comet Holmes

- 17P/Holmes was out bound at ~2.5 AU and fading normally at V~17 in late October.
- At around Oct 24.0 UT a sudden outburst occurred, and the comet reached V~3.
- Reported by amateurs - quick reaction meant that we have data starting at Oct 24.9.
- Data from numerous Northern sites. Unusually circular coma.
- We see an expanding shell of material, now being swept into a tail.

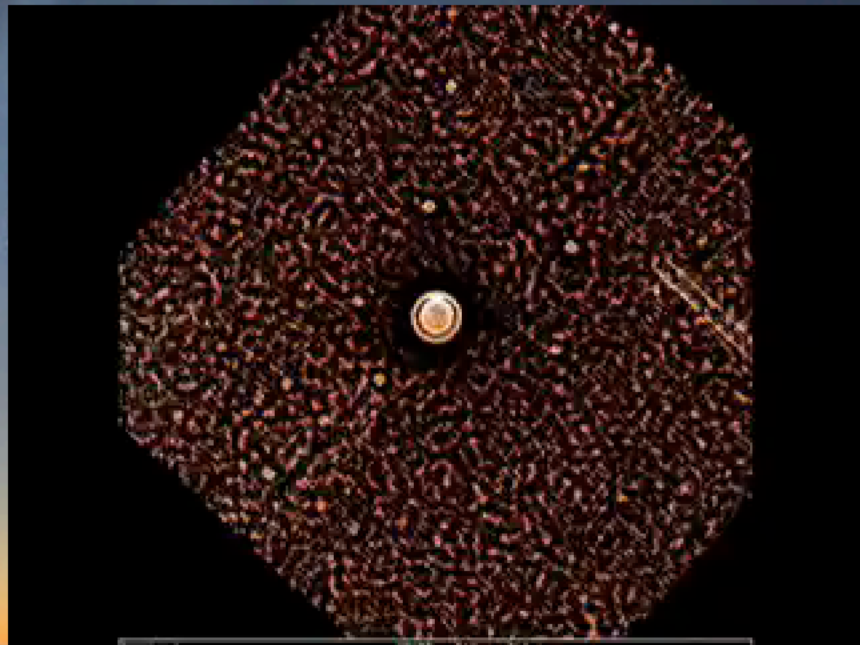


Photo: E. Jehin