GROWTH – India

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Global Relay of Observatories Watching Transients Happen

Indian participation

- Key science interests:
  - EMGW, Young Supernovae, [Novae]
- ToO time on optical telescopes (HCT, IGO)
  - Monitoring time on HCT for late phases
- DDT time on GMRT
- New 0.7m telescope
- Potential Astrosat DDT requests
  - 2 day response time, "ToO only in exceptional circumstances"

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Indian Astronomical Observatory
Digpa-ratsa Ri (Mt. Saraswati), Hanle

- Location: 32d46m46s N; 78d57m51s E
- Altitude: 4500m (15000ft)
- ~260 clear nights/yr (~190 photometric); Median seeing ~1 arcsec

- 2m Optical/NIR telescope – The Himalayan Chandra Telescope (HCT)
- High altitude Gamma Ray Array Telescope (HAGAR)

- Aluminizing facility, LN_2 plant
- Observatory powered by solar power – A GREEN OBSERVATORY
  (with backup diesel generators)

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Himalayan Chandra Telescope

- 2m aperture f/1.75 primary; f/9 Cassegrain
- Telescope first light in August 2000, remote operation in January 2001
- Telescope and instruments testing and commissioning – 2001 September – 2003 April
- In regular use since May 2003
- **Telescope, Dome and Instruments Controlled remotely using a dedicated satellite link from IIA's CREST campus at Hoskote, Bengaluru**

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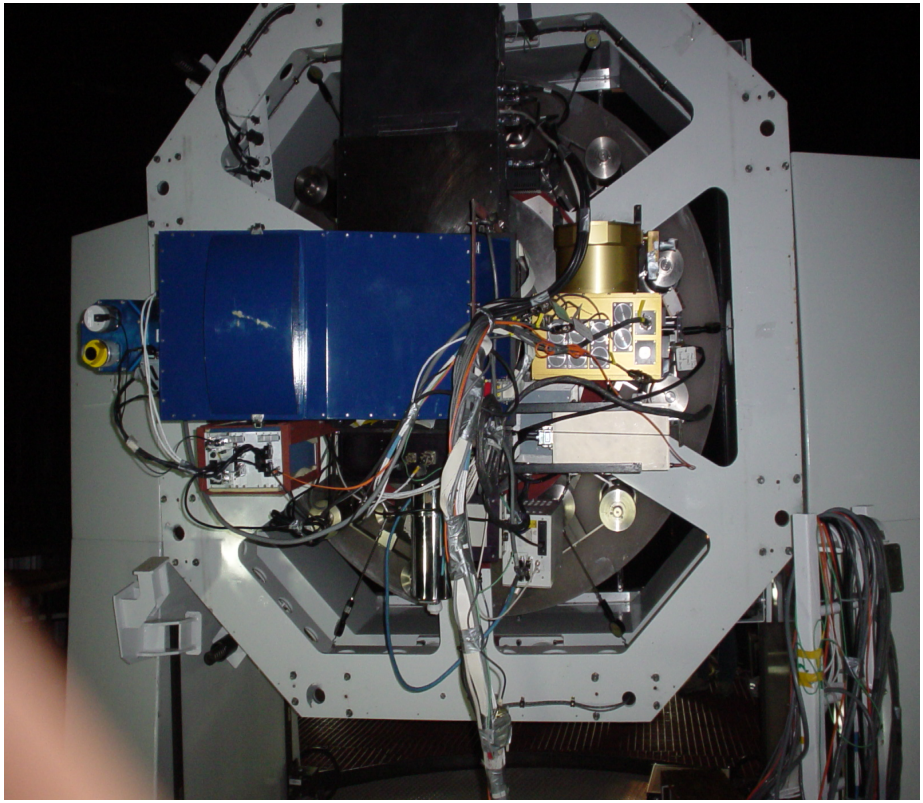
HCT Instruments

- Instruments mounted on a cube with 4 side ports and one on-axis port
- Hanle Faint Object Spectrograph Camera (HFOSC) – 300-920nm range Imaging and low-medium resolution spectroscopy
- TIFR Near-Infrared Spectrometer Camera (TIRSPEC) – 0.9-1micron range. Imaging and low-medium resolution spectrosocopy
- Hanle Echelle Spectrometer (HESP) – 350-920nm range. High resolution spectroscopy (R~30000; 60000)



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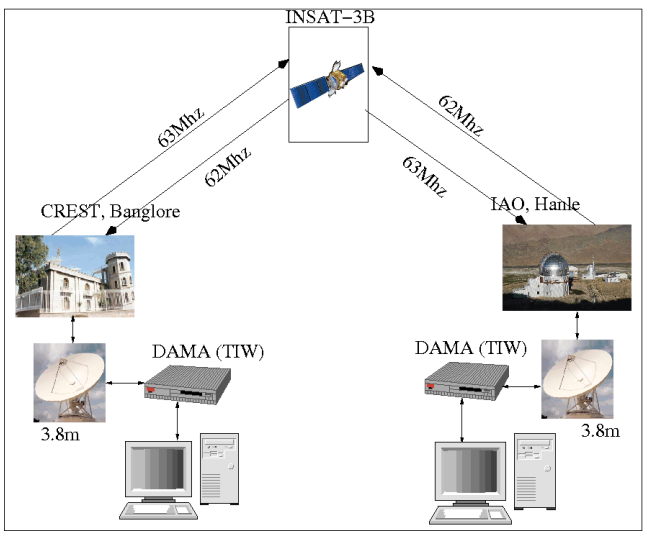
Indian Astronomical Observatory, Hanle, Ladakh

Observatory

Gamma-ray Array Telescope (HAGAR)



Remote Operation from Bangalore

Base Camp of IAO

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Examples of HCT Follow up

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Transients with IGO and HCT

- Successful existing collaboration

Discovery
- iPTF, California

→

Monitoring
- Varun Bhalerao, IUCAA

→

Follow-up
- Anupama & Sahu, IIA/ Hanle

- Publications

- Kasliwal, M.M., Sahu, D.K., Anupama, G.C. 2009, CBET 1874, 2
- Kasliwal, M.M., Sahu, D.K., Anupama, G.C. 2009, CBET 2117, 1
- Singer, L et al, 2015, ApJ, 806, 52
- Bhalerao, V., & Sahu, D. K. 2014, GCN, 16244
- Bhalerao, V., Singer, L. P., Kasliwal, M. M., et al. 2014, GCN, 16442
- Singer, L. P., Kasliwal, M. M., Bhalerao, V. B., et al. 2014b, GCN, 16668
- Hsiao, E.Y. et al. 2015, A&A, 578, A9

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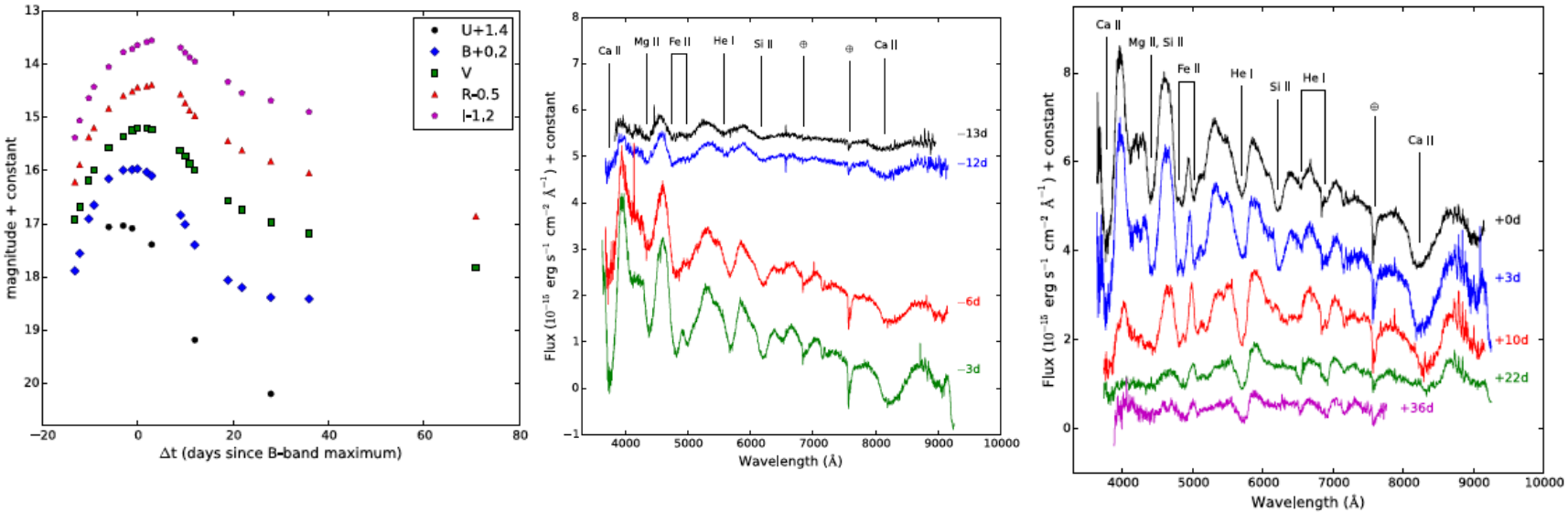
Supernova Monitoring - HCT



- iPTF13bvn – type Ib [Srivastav et al. 2014, MNRAS, 443, 1663]
- First spectrum -13 days
- Photometry ~80 days
- Spectroscopy ~40 days
- Fast declining, low luminosity type Ib
- Binary progenitor [Bersten et al. 2014, Srivastav et al. 2014]

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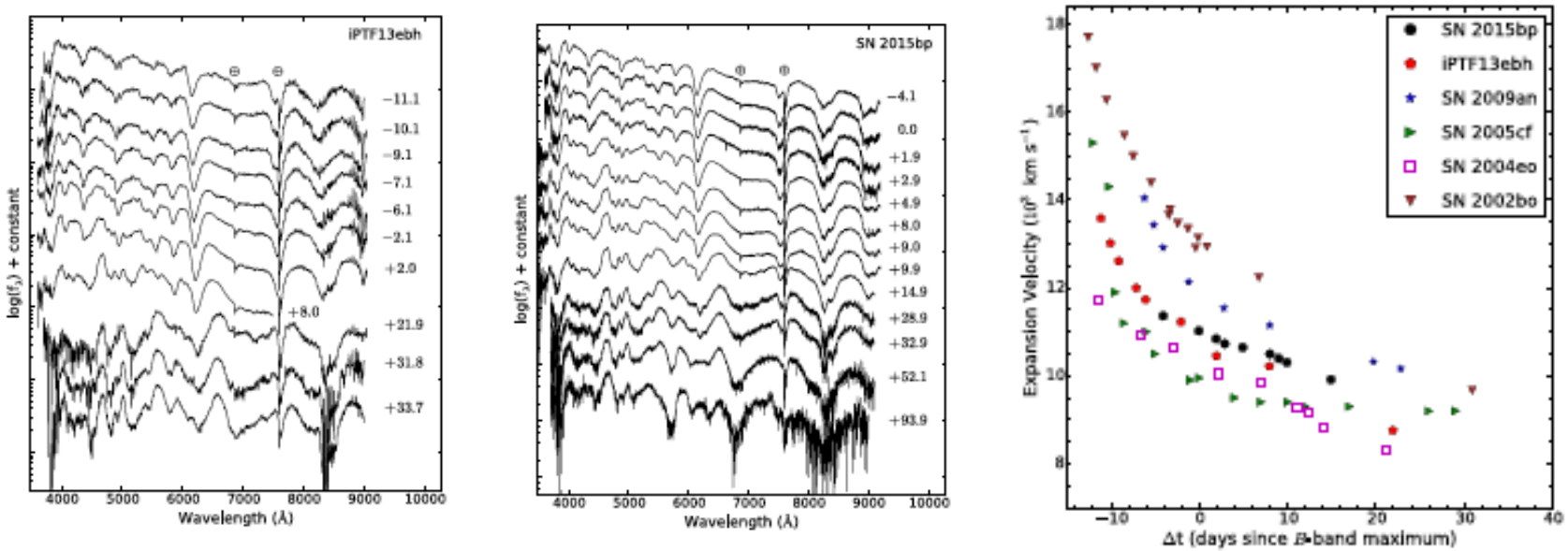
Supernova Monitoring - HCT



- iPTF13ebh and SN 2015bp – transitional type Ia [Hsiao, E.Y. et al. 2015, A&A, 578, A9; Srivastav et al. submitted]
- First spectrum - iPTF13ebh: -11 days; SN 2015bp: -4 days
- Both SNe are low luminosity events, with lower than normal velocities that have a rapid velocity evolution along with fast declining light curves (designated as FAINT class by Benetti et al. 2005)

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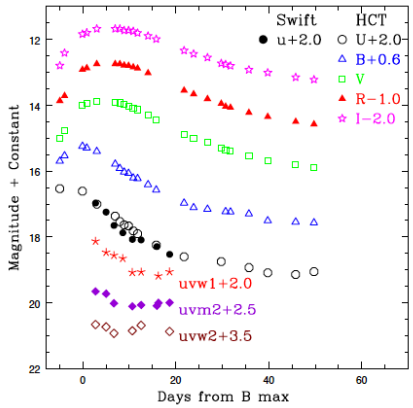
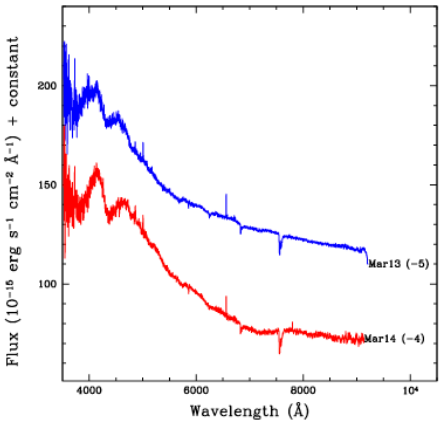
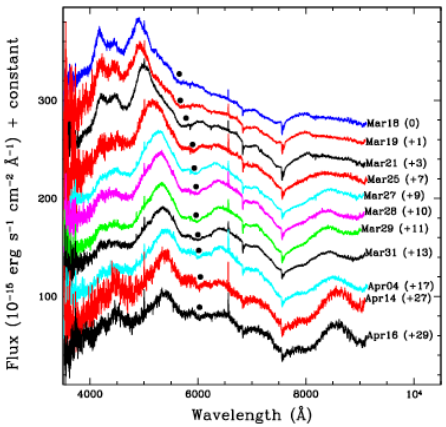
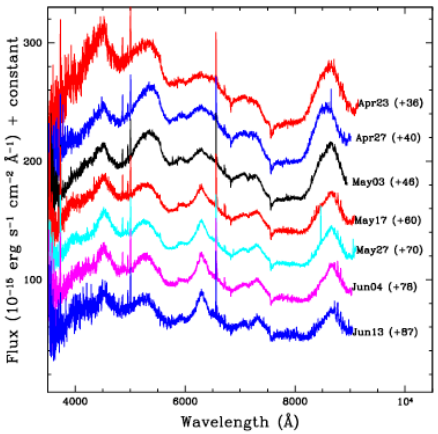
Supernova Monitoring - HCT

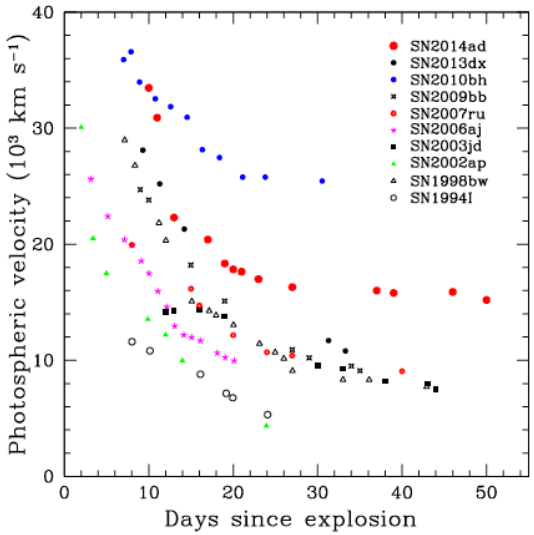








- SN 2014ad – Broad lined Type Ic
- Follow up - -5d to +87d (photometry and spectroscopy)
- Early velocity ~33,000 km/s
- Luminosity higher than non-GRB BL Ic
- Detection of Helium – responsible for absence of GRB [prevents emergence of jets?]



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Sahu et al. ApJ, submitted

IIA Supernova Team

Devendra Sahu
Assoc. Prof.
[SNe, GRB]

Shubham Srivastav
PhD Student – final year
[Hydrogen deficient SNe Ia, Ib/c]

Avinash Singh
PhD Student
[Core collapse SNe]

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GROWTH India - Funding

- Project approved by the Science and Engineering Research Board of the Department of Science and Technology, Government of India (DST-SERB)

- Rs. 38 million (about 560k USD)
- Covers:
  - New telescope and camera
  - PI visits (eg – GCA)
  -
  - Extended graduate student visits (Javed Rana)

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0.7m Telescope

- Sited at IAO, Hanle – existing dome
- 1 deg FOV; Photometry
- Will be *India's first fully robotic telescope*
- 30% time available for other activites
  - Astrosat, LIGO-India, LSST (IUCAA partner)
  - Non-ToO: Blazar and AGN monitoring
  - Frees up time on other telescopes
- Useful for other projects after GROWTH

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0.7m - Current status

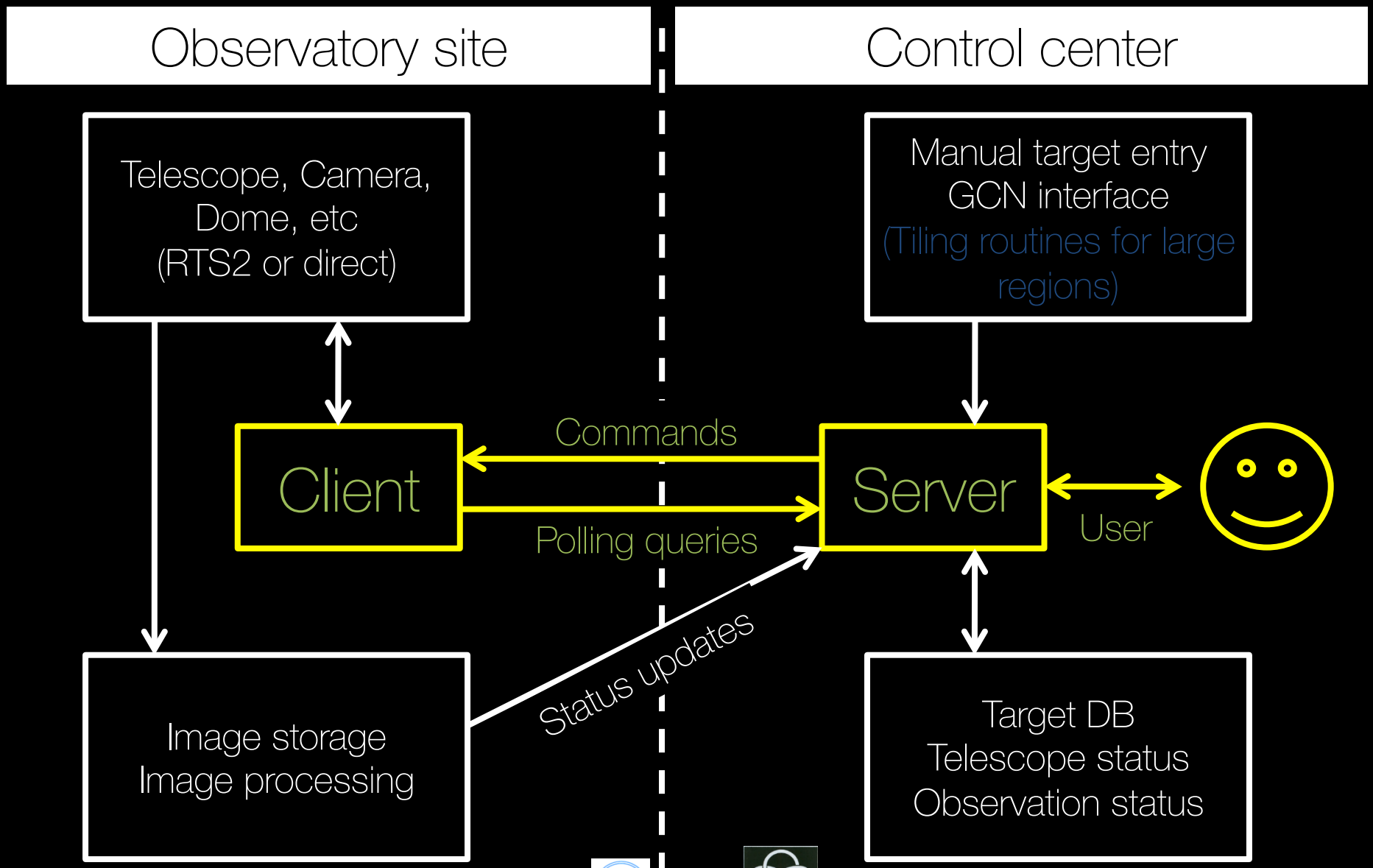
- Telescope and camera tender call
  - Final bid date – 25 July, finalize by mid August
- Remote control and autonomous software
  - Development by IUCAA and IISER Pune students
  - At mature development stage
- Image processing expertise at IIA

Telescope Automation

Remote Telescope Control

- We have developed a client-server model for sending triggers to telescopes
- Built in python, relies on open source "RTS2" package
- Client sits at telescope, makes only outgoing http connections to server
  - No firewall / VPN issues
- Server coordinates targets, gives status reports etc

GROWTH Telescope Architecture



System advantages

- Highly modular, easy to adapt to any other telescope
- Adapted as test case to DOFT, a 1.3m telescope in Devasthal, India
- Atharva Patil (GROWTH undergraduate intern) is using the same software for automating the Lulin 1-m telescope (LOT) with Chow-Choong Ngeow

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SCOT: Telescope status page

Server for Coordinating Observations of Transients

Telescope status | Single trigger | GW trigger | status | User settings

You are logged in as XYZ. Current IST: YYYY-MM-DD HH:MM:SS. Current UT: YYYY-MM-DD HH:MM:SS. Last refresh:X min ago (or at XYZ **UT**)

Create New Trigger

Target Name (optional) :

Trigger RA in decimal degrees :

Trigger Dec in decimal degrees :

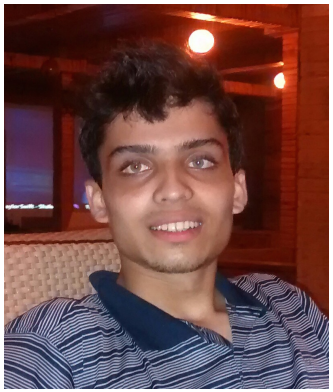
Filter (R,V,B,U) :

Exposure Time (sec) :

No. of Exposures :

Create Trigger

Server:
Current basic interface



Sujay Mate

Sumeet Kulkarni

Atharva Patil

Siddharth Maharana

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Optimal Scheduling

- If ToO requires imaging large areas, how best to select and sequence the images?
- Work by Javed Rana, Varun Bhalerao et al
- Adapted to iPTF scheduler (with help from Leo Singer)

- For more details, see Javed Rana's talk

ACKNOWLEDGEMENTS

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